CHANGES IN THE UPPER LIMBS AT THE SITTING POSTURE: EARLY AWARENESS OF TRUNK AWKWARD POSITION

A. Alizadeh[1], S.H. Mosaddad[2], H. Sadeghi Naeini[3], M. Khorram[4]
[1] Iran Univ. of Science & Tech.,Tehran, Iran, azadeh.alizadeh@gmail.com
[2] Iran Univ. of Science & Tech.,Tehran, Iran, h_mosaddad@iust.ac.ir
[3] Iran Univ. of Science & Tech.,Tehran, Iran, naeini@iust.ac.ir
[4] Iran Univ. of Science & Tech., Tehran, Iran, khorram@iust.ac.ir

Abstract

The main objective of this article was to evaluate ergonomic changes in the upper limb to protect the body's unpleasant situations at the station. One of the main causes of musculoskeletal disorders is the bending and twisting of the trunk. These damaging situations often occur among office workers, car drivers, blue-and-white collar workers. To check the ergonomic changes in the body, a flickering camera was used. In addition, a surgical necklace was used to examine people with back and skeletal musculoskeletal problems in the neck and back. This study was performed through Likert scale and SPSS software was used to measure the effectiveness of this cervical vertebrate. In observing the behaviors of 86 statistical samples, it was determined that the body has a descending sinusoidal movement within 30 minutes. In the second phase, 38 subjects with musculoskeletal problems, the effect of using neck remedies using a Likert questionnaire were investigated and analyzed using SPSS software. The effect of this method was 50%. Depending on the needs of the body during the work time to maintain an ergonomic state of health, fatigue inhibitors are recommended. To prevent the body from damaging forms, it is necessary to take effective measures in the design of a device so that it would be more durable and allow the freedom function.

Keywords: *ergonomic design, ergonomic research, industrial design, harmful behaviors, musculoskeletal disorders*

1. INTRODUCTION

In today's world, due to the variety of jobs, the diversity of workstations and the subsequent placement of the body in these conditions, the pain caused by it, is an issue. The structure of the skeletal system is such that it suffers the greatest pressure. These stresses, due to the fact that the body is not placed in a proper position, over time, causes irreversible erosion of the vertebral column and the medial skeletal body [1]. The highest rates of skeletal-musculoskeletal disorders are due to the inadequate position of the body at work stations [2].

One of the main causes of tiredness and musculoskeletal problems among those who sit behind the table is the long and incorrect sitting of them behind the desk [3]. Failure to sit and to get used to an unhealthy physical condition during sitting or long-term work in a constant physical condition can cause fatigue and musculoskeletal problems in the staff [4]. The sitting office station has the highest number of musculoskeletal problems in the neck, spine and back [5].

At work stations sitting behind the desk, the collision of the neck, shoulders, and upper spine is the most important cause of certain diseases in these areas [6]. The neck, shoulders, and spine are not aligned with the back of the desk, which usually lasts for hours, causing frequent and permanent compression damage to the muscles and bony structure of the neck that affects the cervical vertebrae to the back of the neck [7]. The most common parts of musculoskeletal pain are among the administrative staff in the neck and shoulders [8, 9]. To get rid of pain, the back of the chair should be restored to their sitting position, that is, to sit on the table when their elbows are placed on the table, this causes the spine to stay flat and the body does not bend too much forward, and as a result, pain do not go back to anyone [10]. Sleepiness is the most effective reason for muscle weakness [11]. The pressure on the intermediate seals in the sitting position is 35% higher than the standing position [12]. Researchers at the National Institute of Neurological Disorders and Stroke have come to the conclusion that regular body movements stimulate fresh blood flow and feed nutrients into intervertebral discs. But long-term sit-ups lead to disruption of the alignment of discs and the formation of hard collagen between tendons and ligaments [13]. Annual prevalence of neck-shoulder pain in office workers has been found to be from 27% to 48% [14]. It is important to sit correctly in order to prevent these complications from knowing how to sit [15]. Spending work hours and doing routine tasks behind the desk in many businesses (such as employees, office sectors, organizations) is natural. But after a few months, these people suffer from short-term complications in the neck and spine and after several years, these complications become chronic musculoskeletal disorders in the upper extremities. Therefore, this study examines the status of the body during work hours, back office work and upper limb responses to posture.

The purpose of this study is to identify body movements during work in sitting position, these movements are in fact the response of the body to the conditions of the work station. By knowing the exact answers, a device that is compatible with the body can be designed. In this study, the first stage of the body's behavior during direct observation is investigated. In the next step, there are solutions to the complications posed by the seat sitting behind the desk that are currently being used by the users, one of which is the use of a medical necklace and medical aid that has been investigated. The effectiveness of this relief tool is very affordable in providing further solutions and product design.

2. METHOD

2.1 Participants

In the first stage, the participants were 86 employees in three randomly selected designing companies. They were asked to participate in the study. They were observed while they were working at their desks by means of a camera. In the second phase, 38 people from Akhtar Medical Center (Tehran Specialized School of Musculoskeletal Disorders) were asked to wear a brace and finally respond to a researcher's made questionnaire. The reason was to figure out whether the use of brace was effective or not.

2.2 Design

This was a descriptive-analytic study and was carried out in two steps.

2.3 Instruments

2.3.1 Observation

Through observation of the behavior, the condition of the upper limb of the user's body was examined during work. The two components of time and body posture were examined in this test. 30 minutes were allocated to observe all the participants' body posture while doing an office job.

2.3.2 A researcher's made questionnaire

In the second stage, a questionnaire was distributed among 38 participants, of whom, only 33 responded. The questionnaire was based on a Likert scale, including 11 questions, and was used to find answer to the question of "Is the use of cervical and spinal cord care therapy effective in the body's inappropriate condition?". Needless to mention that prior to the main study, the validity and reliability of the questionnaire were investigated.

2.4 Procedure

First, 86 people were observed while they were at their desks doing their jobs. All their body postures during 30 minutes were video-recorded. Their body postures were put in a diagram with different states of tensile, very stretched, normal, curved, and semi-curved. Second, 38 participants from Akhtar Medical Center was asked to wear a brace and respond to the questionnaire. Once the data the questionnaire were gathered, they were all put into SPSS 20 software and a thorough analysis was made.

3. RESULTS

The results of the first step are shown in Figures 1 and 2. The condition of sitting on the chair over a period of 30 minutes, due to the immobilization of the upper extremity of the body in the long run, becomes uncomfortable for users. According to the results of the test, the fatigue tolerance threshold is defined to be 10 to 12 minutes. After this time, fatigue gradually increases and the tensile and torsional movements of the upper limb begin. The results of upper limb movements are shown in Figure 1. Of the 86 people, 74 were converted to curvature after 30 minutes, which includes 86% of the statistical sample (Figure 2).

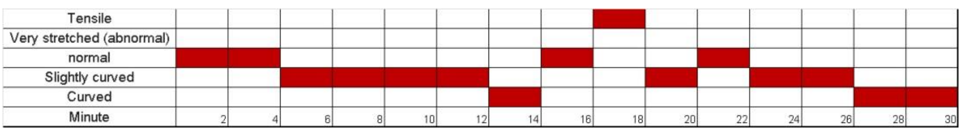

Figure 1: Average changes in sitting position during 30 minutes of behavior observation of 74 participants

The analysis of graphs (1) and (2) shows that the statistical sample of 86 people, observing the 30-minute behavior of each person, represents the upward movement of fatigue and the lack of focus on sitting conditions in accordance with health standards. Antidote analysis means that the 4-minute intervals of people go from a state of conscious, focused, conscious, and conscious to the body and state of the body to a state of anxious, half-conscious, tired, and half-conscious. From 4 to 12 minutes, the body is slightly curved. The minutes from 12 to 16 are completely tired and the shoulders have fallen. After 16 minutes, the upper limb, due to body fatigue, has a return to normal position, and then returns to the curvature after tensile fixation in the faces and hands and upper trunk at minutes 20-22 . In this study, according to observing the behavior of individuals, starting the injuries from the 10th minute should be considered.

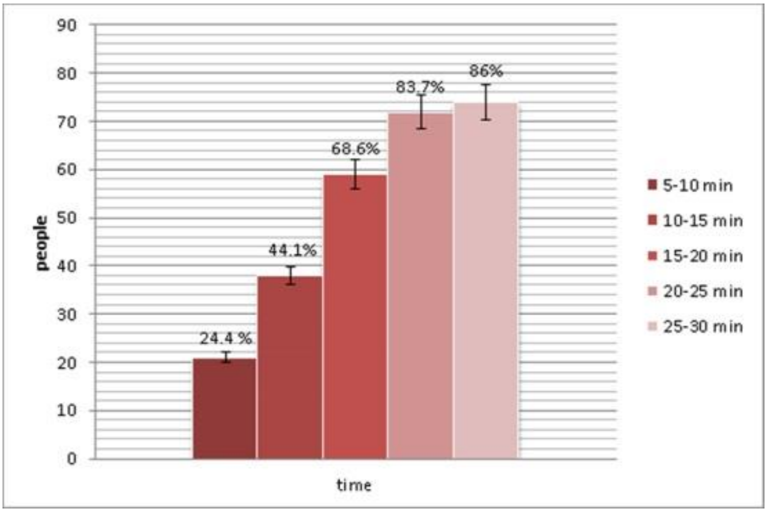

Figure 2: The percentage of people who have changed position of the upper limbs

The outcome of the Likert scale in the second phase regarding the efficiency of cervical and spinal cord care is shown in Table 1:

Table 1: Directional Measures (ETA Correlation Coefficients in the Evaluation of Medical Aid)

			Value
Nominal by Interval	Eta	pain Dependent	.505
		mean Dependent	.384

Table (1), which indicates the correlation coefficient of ETA, is used for cases where one of the variables is nominal and the other is the distance -bound. Regarding the amount of eaten, the correlation between the pain and the mean of the product used (medical neckline), if the pain is taken by the device, is 50%, and if the product is dependent, the correlation is 38%. This means that therapeutic and therapeutic tools are effective in treating neck pain, spinal cord, or prevention, but not completely, almost 50% of users (statistical sample) did not obtain the desired result from this equipment.

4. CONCLUSION

The results of this study show that, in the first stage, 86% of the population, after 22 minutes in sitting position, suffer from complete upper limb fatigue, which leads to damaging behaviors over time. These behaviors and resulting fatigue end in irreparable complications in accordance with previous studies. The user in the first 4 minutes, is in good spirits, focused, and aware of his body. After 10 minutes, in the same steady state of work, the body becomes semi-conscious, sleepy, and tired. To get back to one's body, one needs an informant. Neck and spinal cord injury preventive measures are defined including sitting position modification, neck control, stress relief, use of neck and auxiliary neck, and special stiffness for the head, neck and shoulders. As a result of the answer to the research question "Is the use of cervical and spinal cord care therapy effective in the body's inappropriate condition?"

It was found that 50% of the medical aids are effective in controlling the body of the user in the position discussed. They also restrict the scope of the user's movement, which leads to an intensification of upper limb injuries. Eventually, their role in informing the person about his body position at the station is 50%. The conditions and also the need for a device to help maintain the normal state of the body and prevent the deviation of the middle skeleton were described so that its use for all working hours is comfortable and a distressing feeling (in terms of form, thickness, sex). It is also necessary to design a device for informing about the position of the affected organs, which will be possible in the industrial design and ergonomically designed approach to solve the problem of one's lack of awareness of the harmful behaviors.

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RESEARCH MODEL IN ERGONOMIC FOR PRODUCT DESIGN PROCESS IN BEHAVIOURAL MANIPULATION

E. Armayuda[1], O. Kurniawan[1], R. Lin[2]
[1] Visual Communication Design, Faculty of Creative Industries and Telematics, Trilogi University, South Jakarta, Indonesia,
armayuda@trilogi.ac.id， oki-k@universitas-trilogi.ac.id
[2] Graduate School of Creative Industry Design, National Taiwan University of Arts, New Taipei City, Taiwan, rtlin@mail.ntua.edu.tw

Abstract

Product design as an object is able to give command how to use through its interface form. Such interfaces sometimes give no choice but to obey the way to use the product, especially those who has different segmentation background, the product design could force someone to do something according to how it works. Most of the design process already engage the evaluation process from user experience and refine it into better and suitable design. A good design could not only focus on economic purpose especially for user satisfaction, because not all of the customer has the awareness of the other aspect that may effect their behaviour in daily life. A good design product could be a way to manipulate user behaviour to maintain a good behaviour according to the particular group or community norms and value as a segmentation. This paper aims to offer a model to consider some aspect in design process by adapting from SAD to CHEER model.

Keywords: *Behavioural Design, Product design, Good design, from SAD to CHEER*

1. INTRODUCTION

Product design has been a part of human life. Since the last few decades there is various motive behind the product design itself, and the most basic motive is to fulfil human needs. While the product use to create for its function, recently changes into something related to its own century. It evolve from the product for function, changes into design for the user friendly, fun and so on. Lin explains the evolution of design products known as 5F,"These five F's are: (1) 1930's -design for 'Function', (2) 1950's -design for 'Friendly', (3) 1970's -design for 'Fun', (4) 1990's -design for 'Fancy', and (5) 2000's -design for 'Feeling' [9].

When the design tend to chase the trend of the user feeling, the awareness of designer responsibility is challenged, it's because not all of the user has the awareness of the effect of their own satisfaction. Sometimes the tend of industrial product focus on the user satisfactory which is lead to the reckless behaviour of the user.

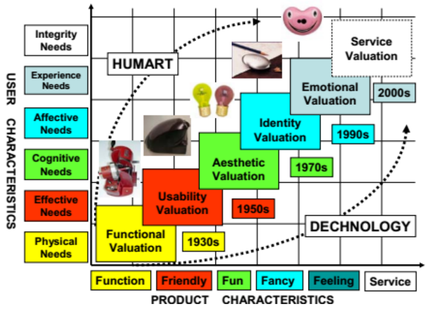

Figure 1: The evolution of product design
Source: Lin 2007

Design should not always be done solely for the sake of the industry oriented which aims for users satisfaction to gain economic benefits. This studies argue that product design should not only focus on commercial purpose only, but also trough product design, designer could participate in the process of creating better society, by manipulating user interface of particular product design to affect user behaviour. Papirous also said the similar thing in the field of graphic design, in an interview about visual communication design said "Science of visual communication design is not just design to fulfil the needs of the industry. But able to make a lonely city into a shining city."[15].
Designers always seek to expand their roles. Theories like human - centred design focus on physical needs and the tasks they perform with products, another human focused design approach emerged out of an interest in how products were formed in the first place - the cultural implications and meaning of product and their form.
In the field of design for sustainability, as in all fields of design, ergonomics represents an innovation factor of the design culture that provides by designer with the necessary knowledge about human characteristics and capabilities, and the methodological tools for evaluating different people-needs during use and interaction with the products at work and in everyday life. [17]
Beside cognitive aspects of product design the emotional aspects is also to be considered, as suggested by Norman, Emotion result from three different levels of the brain: visceral; behavioural; reflective. Each plays a different role in the total functioning of people. Visceral design accommodates Appearance, Behavioural design accommodates The pleasure and effectiveness of use, and Reflective design accommodates Self-image, personal satisfaction, memories [4]
To get a better understanding of the studies, the research will adapt the existence model, so the new model would be a model based on previous model with specific context. To break down the research model for product design motive, the method should distinguish by its motive. One of the method of cross cultural communication is conduct by Rt Lin, model "from SAD to CHEER" as shown in figure 2. The figure attempt to bridge cross cultural communication, basic principle of SAD (Science, Art, and Design) divide into 3 part of inspiration, ideation, and implementation with attributes for evaluation CHEER (Collaboration, Humanity, Empathy, Ecology, and Renaissance) with 3 level of communication. The studies will begin by apply "From SAD to CHEER" method to find research model for product design process.

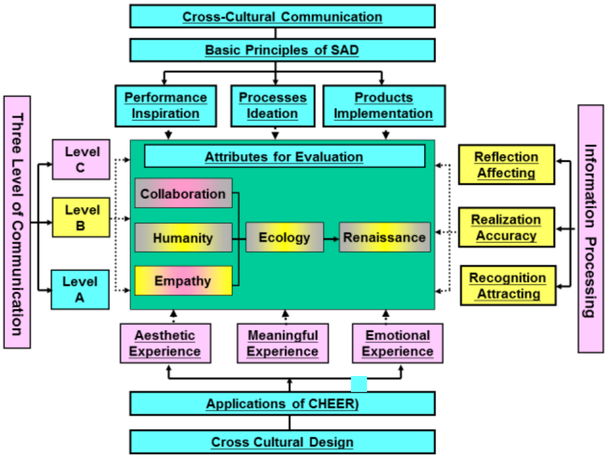

Figure 2: Cross-cultural Communication in Design Collaboration: From SAD to CHEER. In International Conference on Cross-Cultural Design. Springer, Cham.
Source: Lin (to be publish in 2018)

Figure 2 above, explain that basic principle of SAD include 3 part of performing inspiration, processing the idea, and implement it in product design, while the application of CHEER as the attribute of evaluation in cross cultural design should consider 3 stage of experience of tangible/aesthetic, intangible/meaning, and also the emotion. All of the process explain in vertical ways is relevant to the design process, and the horizontal ways (three level of communication and information processing) will be an assessment for the audience/user of the product which related to the three level of responses, reflecting affecting, realization accuracy, and recognition attracting.

2. RESEARCH FRAMEWORK

The model "from SAD to CHEER" explain about 3 level of communication, design process, audience response, and also product impact. The attempt to adapt this method to distinguish product design process, the model will be adjust in the context of product design. The process always affect by the cultural background of particular segmentation. "Culture" plays an important role in the design field, "and cross cultural design" will be a key design evaluation point in the future. Designing "culture" into modern product will be a design trend in the global market [11]. There is various motive behind the product design, the motive can be distinguish into two kind, for economical purpose such as commercial product and social purpose as a form of design for society.
The Breakdown of design process of SAD; 1.Performance Inspiration (related to the design purpose as the inspiration), 2.Process Ideation (bridging the design purpose and implementation), 3.Product Implementation (implement the idea into daily product design) and product implementation as application of CHEER; 1.Aesthetic Experience (the product attract for business purpose), 2.Meaningful Experience (the product affect the efficiency of workplace), 3.Emotional Experience (elaborate norms and value for advance purpose of product design).

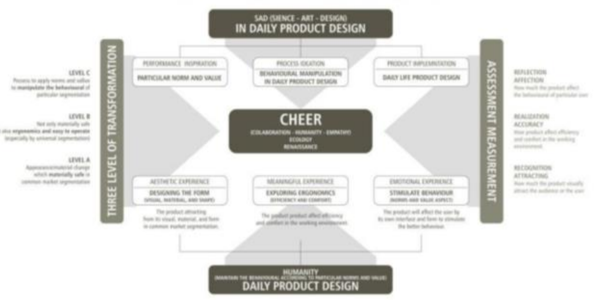

Figure 3: model "From SAD to CHEER" applied in product design process
Source: author research (2018)

The other part of the model which originally discuss about three level of communication and processing information would be use as the level of product design process which is distinguish by the design purpose. The information process part would be the way to assess each level.

3. METHODOLOGY

The research based on SAD to CHEER model to break down the product design motive into three level. The method to applying from SAD to CHEER model for product design motive from the basic motive into advance motive. There is stage of product design process and all of the process start from Performance/ inspiration as a motive of product design start to the first level of design process which is; 1. Aesthetic experience, which is focus on designing form for basic/ business purpose. 2. Meaningful Experience, which is exploring the ergonomics and efficiency in workplace. 3. Emotional Experience, which is focus the user interface manipulation to stimulate particular user behaviour.

The level of research method for product design studies using SAD to CHEER will be done in 3 level of research (design process); 1) Transforming the form. In this level, design process will focus on how product attract the market, because besides its basic purpose of design which is fulfil the particular needs of market, the product orientation is focus in exploring tangible aspect of product design to attract audience with the pure business purpose. The method to achieve this design level is by using basic theory of product design focus on visual attraction. 2.) Exploring the Ergonomics. In this level, the research focus on Exploring ergonomics to adjust product design for the needs in working place. The studies to achieve this level is by combining the basic theory of product design and explore its function regarding safety, efficiency, and productivity in workplace. The focus of this level is to create a product which is not only attracting but, helpful for efficiency in workplace. 3) Affecting Behaviour. In this level the design process involve a scenario setting for product design to manipulate the product interface that will affect the user. By manipulating the interface, user will use the product as an attempt to stimulate new behaviour for user. The goals of this level is manipulate interface that will manipulate user experience, so the user indirectly will have a new way of using product as starting point for behaviour stimulation. The process will conduct by applying empathy which relevant to particular market segmentation.

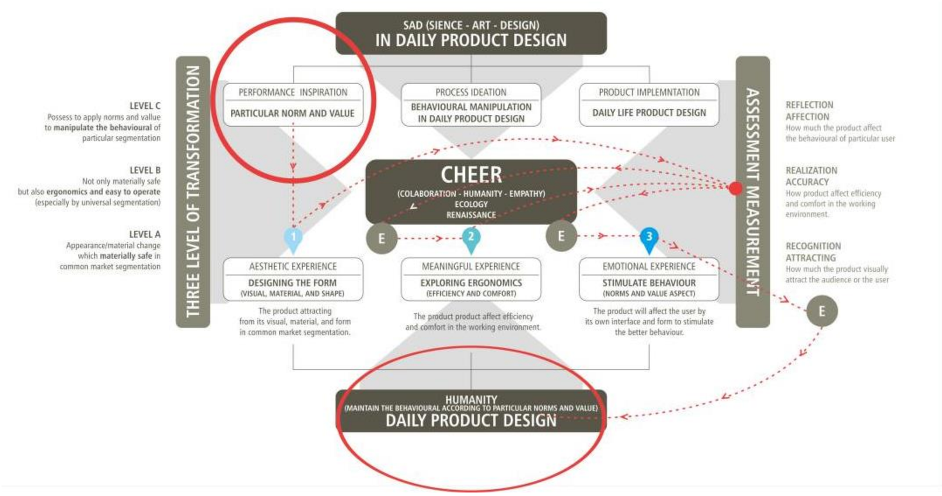

Figure 4: Research work flow for product design to manipulate behaviour
Source: author adaptation from Lin (2018)

Design strategy is considered to be one of the pivotal component in cultural and creative design industries, and this will have a significant impact on consumer perception of innovation [12]. By involving norms and value as basic idea to design product, the result of product design process will affect the user. So the idea is creating product with purpose to change/manipulate user behaviour using interface manipulation.
The assessment measurement will be needed to assess the impact of the product. Apply the perfect method of SAD to CHEER, all of three level should be done in the design process by passing the evaluation in every design process level.

4. CASE STUDY OF DAILY PRODUCT DESIGN

One of many product design use in daily activity is chair separate seat for one person, typically with a back and four legs. [14] The first chair Rybczynski was able to identify in the historical record was not a physical chair but a sculpture of one from the Cycladic islands in the Aegean Sea, dated to the period 2,800 - 2,700 B.C. The figurine depicts a musician playing a harp while sitting in what looks like a typical kitchen chair, with a straight back and four legs. By the time of the ancient Egyptians, sitting was a matter of status: Everyone sat on stools or on the ground, but chairs with backs or armrests were reserved for the elite. [5] in today use, chair is an integral part of human activity. In our modern industrial society most people spend a good deal of their lives sitting down. From a heritage of fishermen, hunters and farmers, humanity has developed into a predominantly sedentary race. Our evolution can be a summarized: Homo erectus (upright man) to Homo sapiens (thinking man) to Homo sedens (sitting man). [1]
To get a better understanding about how to distinguish the product design research to reach the studies about 'Research model in Ergonomic for Product design process in

Behavioural Manipulation'. The model that distinguish the studies will help designer to focus on what matter in design process for manipulate behaviour.

Figure 5: traditional chair (dingklik)
Source: taken from www.indonesian-teak.com (2018)

The stage of research will be distinguish into three level and each level will use the case study of chair to give an example for design process. Each level of design process will use the level of assessment measurement from recognition of attraction, realization of accuracy and reflection affection. The stage of the research will be apply in chair by following the figure bellow.

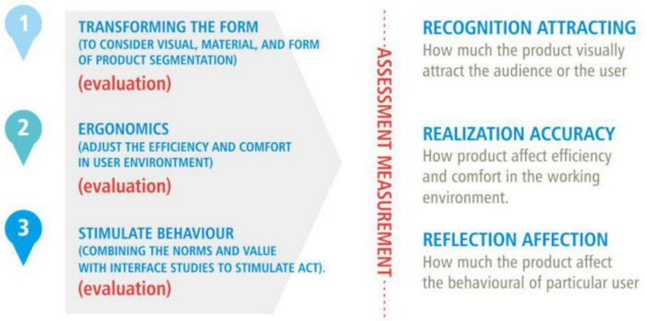

Figure 6: stage of manipulating behaviour in design process
Source: author (2018)

The chair has its original function to help a person as individual or group to rest their feet or reduce the energy to stand, but the execution process of designing chair is depend on the motive. By dividing the stage of design process by following the idea of 'From SAD to CHEER' model, the research will be group into 3 motives, 1) Design for tangible aspect, by transforming the form, 2) Design for the environment in work place, and 3) Design for a behaviour in the society, by designing product which can stimulate a particular behaviour for the user.

4.1. Transforming the form

The first level of design process motive is focus on tangible aspect such as physical stuff by transforming the form of traditional chair into a product design chair which is attracting by its shape and appearance. The design process of this stage using design rules of how to create an attractive product design.

Figure 7: transforming form in aesthetic (Jens chair by Jens Risom and Bloom by Kenneth Cobonpue)
Source: taken from http://www.dwr.com (2018)

Relating to the adaptation model from SAD to CHEER to pass this stage there is assessment measurement that state, how much the product result by this process visually attract the audience or the user. The key factor of this stage is "visually attract" which is define by tangible aspect which can catch by visual factor. The aspect of visual factor in product design related to tangible aspect which projecting the desired attributes through the use of shape, material, texture and Colour. [3]

4.2 Exploring the ergonomics

The second stage of the research is not only focus on tangible aspect. The exploration in the research process should be focus to another aspect of the user. In this context the case will be apply in the workplace. The studies of designing product which suitable in workplace to get the efficiency is mention in ergonomics design studies. Ergonomics focuses on human beings and their interaction with machines, materials, information, procedures and environments used in work and everyday living [1] Ergonomics is the science of fitting the job to the worker. In a phrase, the task/job must 'fit the person' in all respects, and the work situation and environment should not compromise with human capabilities and limitations. [6]

Figure 8: design into ergonomics aspect (Herman Miller Executive Aeron Task Chair & La-Z-Boy Delano Big & Tall Executive Chair)

Source: taken from www.thespruce.com (2018)

At this stage of research designer already include the studies of ergonomics, so the research not only focus on how to create an attractive product design, but also consider the function and user, related to the workplace. From the figure 8 above can be seen, the transformation from the traditional chair into office chair which already consider the high, the size, shape, and the other aspect which could support the comfort of the work process in the office.

Product design process in this stage will be assessment by measure how the product increase the efficiency and comfort in the working environment. The studies of ergonomics involve not only studies in design field, but could involve engineering, medical, and event psychological field. The product which is produce by this studies almost touch the matter of behavioural manipulation in purpose of creating a good environment in workplace, but the impact of this design still in particular segmentation (company or factory), and the studies about manipulate culture behaviour is focus on creating better society which is will be discuss in the next stage.

4.3 Stimulate behaviour

This stage of research is the goal of this studies which is focus in design process that can create a product (daily product design) that can manipulate the user behaviour into particular behaviour based on particular norms or value. The result of the design process could be applied as a public facility product. The final product usually a product with an interface that manipulate to stimulate particular action, in some case the interface designed to prevent user doing particular behaviour. This studies also argue that the design could manipulate the user behaviour by manipulating product interface which can cause particular action expected from user.

Figure 9: product design to stimulate particular behaviour (central armrest bench & leaning bench)
Source: taken from www.wishboneltd.com (2018)

The figure above shown a public chair to prevent particular action that represent by anti homeless chair with central armrest. The chair usually installed in public area such park. The purpose of giving central armrest is not to give a border for each seat, but its design to prevent people using bench inefficiently but to prevent the homeless sleep there so the other people couldn't sit on the bench. The other figure called leaning bench, ignoring its controversy, leaning bench indeed efficient for the limited public space. This bench usually installed in high mobile activity area. The purpose of this chair is to design uncomfortable to prevent people sit in those particular area.

Over all this kind of product already stimulate an action to its user because the design of the interface. This product is the real example that in design process, designer could refer to particular goals (could be some purpose to manage user behaviour or achieving particular behaviour from the norms and value).
The assessment of this stage is by measuring how much the product affect the behaviour of particular user. In this case the design process following particular norms and value to manipulate user behaviour which is in line with the norms and value that follow by those particular society. The studies of this stage could be run by applying behaviour planned theory.

5. RESUME

The process in designing product is depend on its motive. Design should not always be done solely for the sake of the industry solely oriented to the satisfaction of users to gain economic benefits. This studies argue that product design should not only focus on commercial purpose only, but also trough product design, designer could participate in the process of creating better society. In the context of designing product which can manipulate user behaviour, there is three stage, the stage adapt from the model of 'from SAD to CHEER' to get a better understanding of three stage of design with each measurement assessment:

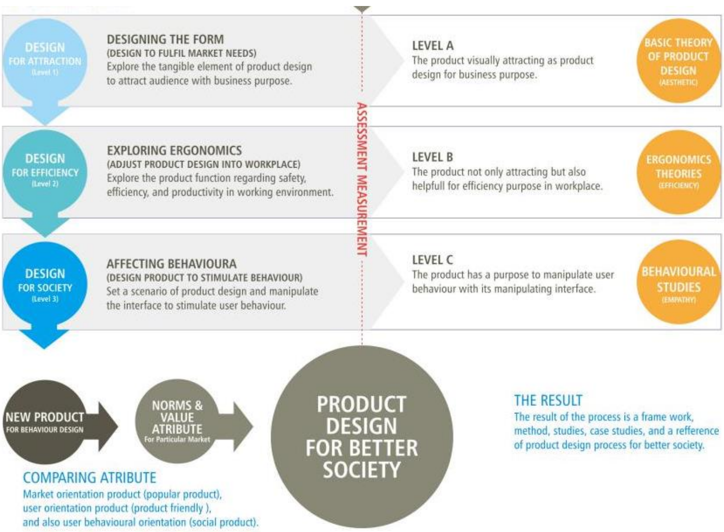

Figure 10: stage of design process in behavioural manipulation
Source: author (2018)

The three stage of this research could be a way to distinguish the motive in product design process. The third level of the studies could be focus on how to create better society, because not all of the product will bring comfort to the user, but by these kind of product the user could get a better behaviour which is relevant to their particular norms on social value.

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MOBILE EYE-TRACKING -BASED USABILITY EVALUATION METHOD IN PRODUCT ERGONOMICS: PRESENTED VIA VARIOUS CASE STUDIES

M. Babicsné Horváth[1], K. Hercegfi[2], A. Hidas[3]
[1] Budapest University of Technology and Economics, Department of Ergonomics and Psychology, Budapest, HUNGARY, bhorvathmaria@erg.bme.hu
[2] Budapest University of Technology and Economics, Department of Ergonomics and Psychology, Budapest, HUNGARY, hercegfi@erg.bme.hu
[3] Budapest University of Technology and Economics, Department of Aeronautics, Naval Architecture and Railway Vehicles, Budapest, HUNGARY, ahidas@vrht.bme.hu

Abstract

Nowadays, many researchers use eye trackers, however research on usability testing tangible, three dimensional products cannot be found in the literature. To demonstrate this new methodology, this paper presents various case studies. During the series of experiments, not only the products were evaluated but the eye-tracking technique itself, in terms of its suitability for testing similar products. The first product was a kitchen machine which was tested without a user manual. The second product was a tent; in this case, the participants could use the user manual, which was also analysed. The third product was a foldable dish set. Based on the knowledge gained during the three tests, some suggestions for the product development was made and some recommendations for the methodology of eye-tracking -based usability testing was formulated. The goal of this study is to contribute to the subsequent researches and give a basis for similar experiments.

Keywords: *eye-tracking, empirical usability evaluation, product ergonomics, case studies*

1. INTRODUCTION

Nowadays, eye trackers are quite popular devices amongst ergonomists and marketing researchers, and eye-tracking has become a widely used test method. With the help of this perception-based technology, the movements of the eye (saccades, fixations) can be captured and analysed. The method has various applications. It is used by marketing researchers, e.g. to study behaviour and cognition during shopping [1]; by ergonomists and user experience (UX) researchers [2], e.g. to test mobile devices and websites. It can help the development of assistive technologies supporting disabled people [3], or can be used for behavioural research [4] and for research on cognitive science (e.g. studying reading [5], cognitive load [6], neuroscience issues of general information processing [7]), too.
Though, the method has not yet applied widely among designers or ergonomists in product design. There are some examples of application in related areas, such as

packaging design [8] [9] or aesthetics (e.g. examining the impact of the appearance of certain objects on users [10] [11] [12] [13]). These results show a tendency for integrating eye tracking systems into product development processes. However, no publication that deals with the methodology of testing a spatial, tangible product exists in the literature, so it is likely that no substantive research has been carried out on the subject.
In the mentioned researches that are in connection with product design two dimensional pictures of objects were shown to the participants. It means the subject couldn't touch the product, which can be a critical limitation of the test method. In these researches, no product-user interactions were created, consequently usability testing of the product was impossible with that picture-based methodology.
Recognizing the lack of researches in the field, three empirical studies were designed and fulfilled to provide a base of methodology development for usability testing of three dimensional products with eye-tracking.

2. METHODS AND RESULTS OF THE THREE EMPIRICAL TESTS

In all of the three researches, Tobii Glasses were used as the eye-tracker tool and Tobii Studio as the software for analysis. The examinations had multiple goals: Usability testing of the products and assessment of the suitability of Tobii Glasses for the usability testing of similar products. In this paper, the three case studies will be shown. Each of the tests were structured similarly, but they have highlighted different advantages of the used method. Altogether 21 person participated in the studies as subjects. The common structure of the sessions of the tests was the following: After briefing the participant, first, the device was calibrated. Then, the participant executed the given tasks that was explained to them in advance. At the end of the sessions, the participant answered a few questions about their experiences in form of a short interview.

2.1. The first study: eye-tracking based usability evaluation of a kitchen machine

2.1.1 Methods

The first tested product was a kitchen machine, which, besides the basic function, can be converted to a shredder or to a hand blender, too. By choosing the product, it was important that the product is a three dimensional object and is complicate enough to assemble. At this time the product was tested without user manual.
In this experiment six people took part as subjects and a team of five people helped to carry out the tests. The task consisted of four subtasks: (1) first to assemble the product to a traditional kitchen machine with whisks, (2) after that to swap to kneaders, (3) then to reassembly it to shredder, (4) and finally to a hand blender.

2.1.2 Results

The revealed problems were analysed separately. In the next pictures snapshots from the videos which contain eye movements are shown.
For instance, finding the button for sliding and folding the stand was one of the identified problems. From the video data the place where the participants search foremost for the

button, namely where it would be logical to place it, can be located. (Fig. 1 a) The red signs shown the eye movement (saccades, fixations). In the right picture (Fig. 1 b), the actual location of the button can be seen. With the help of these video recordings conclusions can be deducted and after thorough evaluation suggestions can be made to re-design the product.

a. b.

Figure 1: Finding the button for sliding and folding the stand: a: The place where it was first searched, b: Finding the right place of the button

To be able to perform statistical analysis on the results we would need a data series of 10 or more element, however testing with 4-6 person is currently being used in industrial practice of software usability testing, and it can also provide notable results. In this 4-6-person testing, the qualitative examination will come to the fore, the numerical data are only for informational purposes and support the so far reported.
Two metrics were chosen: error-free rate and time on task. The error-free rate is the percentage of test participants who complete the task without any errors i.e. they carry out the given task independently and correctly without any assistance. Time On Task is the amount of time it takes the participant to complete the task, measured in seconds. The deviation from the average performance and the peak data was analyzed, in case of high peak values, the root-cause was detected and an explanation was given. With these data the importance of the different problems during the task execution was seen.

2.1.3 Further observations regarding the method

The following conclusions drawn from the videos and interviews evaluated in the first experiment relate to eye movement-based usability tests.

- Parts too close to the eye do not appear at all or are barely visible in the video, though these would be very important. Therefore selecting a specified workspace is recommended.
- The difficulty of setting the distance while post-processing the eye-trackers footage is related to the previous point. As the user is in continuous motion, it is difficult to detect when and how far away the viewed object is; therefore it is also a problematic to set in the Tobii Studio software, and could give us inaccurate results.

2.2. The second study: eye-tracking based usability evaluation of packing up tents

2.2.1 Methods

As a step further, we chose a bigger object for the second test: a tent, which can be set up in two seconds. Nine people participated in this research. Setting up these kinds of tents is very easy, however packing them up (folding) could be very tricky. Therefore, the task was to pack up two tents, in which bigger movements were needed. In this case, the subjects could use the user manual, which, in this way, could also be tested.

2.2.2 Results

Thus in this experiment, thanks to the simple flat surface of the user manual, we could apply heat maps [14] in addition to the video recordings and defining the problems. In mobile eye-tracking, the heat map is a visualization technique, a two-dimensional figure where the low-high rarity of points recorded from the directions of glazes is marked with cold-warm colours.
For instance, in the following picture, the heat map of a user manual can be seen (Fig. 2). It can be noticed that the participants looked at the smaller images of the manual most often, which suggests that they tried to figure out how to assemble the tent on the basis of these. The explanations on the smaller pictures, however, were not as important as those on the main picture.

Figure 2: The heat map of a user manual of a tent. Surrounding the A3 sized paper, eight infrared marker of the Tobii Glasses can be seen: they are for identifying the plane to be analysed.

Similarly to the previous experiment, the quantitative data are only for informational purposes, but in this experiment, the number of test subjects is almost 10, so these data are more accurate and therefore offer a quantified comparison of the two tents. The two tents were compared based on the task time. The order of the two tents were random (Table 1).

Table 1: Task time, compared the two tents (red and green)

	1	2	3	4	5	6	7	8	9	AVG	D	OV
First folded	R	G	R	G	R	G	R	G	R			
1st tent	7.17	4.00	13.00	17.67	4.50	9.67	4.00	2.33	4.00	6.26	3.42	13.00
2nd tent	8.33	5.25	2.50	1.83	3.00	6.00	2.67	10.50	3.67	4.86	2.95	10.50
Green	8.33	4.00	2.50	17.67	3.00	9.67	2.67	2.33	3.67	4.87		-
Red	7.17	5.25	13.00	1.83	4.50	6.00	4.00	10.50	4.00	6.25	3.50	13.00

Key: R: Red, G: Green, AVG: Average, D: Dispersion, OV: Outstanding values

The table shows that the average packing time is around 5 minutes. We observed, that this time depended on whether the given tent was first or second to the test participants. The average folding time for the second tent is less than the first one because the impact of exercise. However, folding the green tent was faster in average than the red tent. This has proved the hypothesis that folding the tent named "easy" is really easier.

2.2.3 Further observations regarding the method

The following conclusions drawn from the videos, heat maps and interviews evaluated in the second experiment relate to eye movement-based usability tests.
During the task, participants often moved their upper body rapidly and heavily, so the recording unit was not only clipped on the participants' belt, but placed in a belt bag. This has proven to be a good solution, and it is recommended to use for other similar experiments.
Due to the high amount of movements, the quality of the recordings was not perfect. From these, we conclude that this technique is not suitable for examining such tasks on its own, it must be supplemented by external observations, interviews, etc.
The heat maps were useful for the research. During the experiment, we examined the manuals with infrared (IR) markers in order to find out which step is understandable for the user. To this purpose, the applied device is feasible.
Several participants mentioned that they were strained during the session by the great silence of the lab environment: the users felt the situation unnatural, not necessarily responding as in everyday life. To solve this problem, playing a simple music is recommended, which will help to create the comfortable atmosphere.

2.3. The third study: eye-tracking based usability evaluation of a foldable dish set

2.3.1 Methods

The third product was a foldable dish set. The package consists of three plastic containers, a deep plate, a flat plate and a cup, all of them are given in a flat shape. To eat or drink from them, you should fold them with a few moves. In this experiment, six persons were participated.

This product line creates a bridge between the tent and the kitchen machine. Smaller in size, but the participants have not yet encountered such a product before the experiment, and the folding part is similar to the tent principle. In this case, first, the participants were asked to try to fold the dish without the user manual, and if they didn't succeed, they were allowed to use it.
Based on the conclusions of the previous experiments, few changes in the lab environment was made. During the experiment, music was played, which was not disturbing (according to the later claims of the participants). The workspace was marked by lines on the table. A flexible plastic device was placed on the eye tracker that prevents the participants from looking under the glasses. The table, where the participants can work was tilted.
The task was the same for every participant. First, they have to fold the deep plate, then the flat plate and finally the cup. This order was invented because based on our hypothesis, the cup was the most difficult to fold. The learning process also played an important role in the experiment, as the participants gained experience at some level by folding the two plates.

2.3.2 Further observations regarding the method

The following conclusions drawn from the videos, heat maps and interviews evaluated in the second experiment relate to eye movement-based usability tests.
Based on the experience gained from the previous studies, many problems have been eliminated, but other problems have arisen.
The heat maps slip in the images with the IR markers, probably due to the fact that, in vain of the table was tilted, the participants looked at the surface at a small angle, resulting in an upward slope (Fig. 3). The tilt of the flat surfaces at a higher angle is recommended.

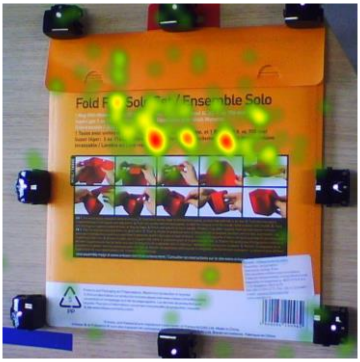

Figure 3: The slipped heat map with constant error.

Similar mistakes may occur despite all precautions. If, as in the present case, a constant error can be assumed on the basis of certain parts of the figure (eg. sure they did not look for a blank part of the user manual, if it was an important figure below it), it can be corrected by a constant in the evaluation.

For the more visible eye movements, a blue line indicated the border of the workspace. Even so, there were a few participants with no apparent eye movement. They pulled the manual closer…
Visibility of the eye movement also depends on the physical properties of the person, e.g. bigger eyebrows, smaller eyes, eyelid sagging. Or, when looking down, the eyelid closes halfway, thus preventing infrared light from entering the eye and reflecting on it. More precise instructions are recommended.

3. CONCLUSION

Based on the first experiment, it can be stated that, apart from a few minor issues, the tool was useful in usability testing of a product. In future, it could be used to support similar projects as eye tracking can help ergonomists or designers to identify easier which parts of the product should be developed further.
Based on the second experiment, it can be stated that the device can also be useful for usability testing of similar products, however, for such large-scale products or dynamic tasks, supplementation with external observation is indispensable. Additionally, applying the heat maps is useful for analysing user manuals, as the users do not always remember where they looked at and what visual information helped to correct the problem.
Based on the third experiment, it can be stated that the conclusions of the first two tests were useful and by correcting them, more accurate results are available in case of similar usability researches.
Summarizing our experiences, it is difficult to trace eye movements to three-dimensional objects, however, the method gives a lot of plus to conventional usability tests.
This research is a starting point, which can help in further experimentation and the spread of the methodology.

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ANTHROPOMETRIC STUDY OF BRICK KILN WORKERS FROM THE PERSPECTIVE OF EQUIPMENT DESIGN

L. R. Bachwal[1], A. Kundu[2], P. Rawal[3], G. G. Ray[4]

[1]Indian Institute of Technology Bombay, Mumbai, India, lavanya86@yahoo.com
[2]Indian Institute of Technology Bombay, Mumbai, India, kundu.amar2010@gmail.com
[3]Indian Institute of Technology Bombay, Mumbai, India, priyanka24rawal@gmail.com
[4]Indian Institute of Technology Bombay, Mumbai, India, gaurgray@gmail.com

Abstract

In India, more than 23 million people are employed in the Brick making industry for the brick making process. There is immense drudgery and work related musculoskeletal disorders reported by workers, so it is important that strategic ergonomic intervention is made that considers the anthropometric data of the workers engaged in the job. Present study reports 25 different anthropometric dimensions of 66 male brick kiln workers from the western and eastern states of India. From the collected data, the value of Mean, Standard deviation, 5th, 50th and 95th percentile were calculated. Comparison of collected data among the workers of the two states presented in this paper suggests non-significant difference among various body dimensions except for nine dimensions. The results from this paper can be used to develop and design tools that are worker-friendly and safe and may allow improved productivity for the brick kiln industry.

Keywords: *Anthropometry, Ergonomics, Brick kiln, Indian men*

1. INTRODUCTION

Brick making industry in India is one of the largest in the world, following the second position to China. It is one of the most widely spread unorganized small scale industry in India. The brick kiln industry usually works on a seasonal basis and hence it attracts migratory workers from surrounding rural areas [1]. A large section migratory labour work force has also been reported which is not only inter-state but inter-district as well to work in the brick industry In the year 2009-2010, The National Sample Survey Organization (NSSO) in India estimated that brick kilns employed more than 5 per cent of India's 460 million workers, which would be approximately equal to or more than 23 million brick kiln workers [2]. The traditional brick making process in India involves activities like soil preparation, mud making, moulding of bricks (Thapera), stacking unbaked bricks in kiln (Bharai), Stacking bricks for firing in kiln (Khadkan), Maintaining Kiln temperature (Jalaai) and Removal of fired bricks (Nikashi).

For doing most of these activities the workers have to adopt postures such as bending forward, lifting heavy weight, twisting of truck repeatedly, carrying heavy weight and sitting in squatted posture for long hours. Thus the workers are more prone to developing Musculo-Skeletal Disorders (MSD). Previous studies on ergonomic analysis of the different operations involved in the traditional brick making operations have also highlighted the high physiological stress [3], immense drudgery, and work related MSD among the workers [4-6], absence of appropriate equipments [7], deteriorating health conditions [8, 9]. Thus, implying immediate ergonomics intervention in the different activities involved in the brick making industry. Presently the equipments and moulds used for brick making are manufactured and procured from the local artisan and small scale manufacturers in the respective regions. These equipments are made without the application of ergonomic considerations.

MSD and concentration deficit are commonly observed when there is clear disparity between anthropometric dimensions and products used by the consumer [10]. Thus in order to decrease the MSD, due to adopting awkward postures, anthropometric data of the workers will allow better ergonomic interventions for improvement of existing equipment, development of new equipment and better work posture, which will result into improved quality of life and better productivity from workers [11-13].

There is a strong variation among the body dimensions while considering the range of workers population towards improvising their work posture, work station design and equipment design. This necessitates a large cross sectional study of the population engaged in similar type of work [14]. An important factor to consider while designing a product is that the user of the product may come in many sizes and shapes. Anthropometric data varies considerably between populations across different regions. Environmental variations namely biological, nutritional, economic and cultural factors also influence anthropometry of populations.

Few of the factors influencing the Anthropometry of the population are region, race and age. Researchers reported that diet, environmental conditions and living style of different regions can influence the anthropometry and body composition [18]. Over the decades anthropometric data have been generated for different purposes. Previous studies done in the area of agriculture workers for tool design have highlighted that there are high level of differences in alike anthropometric dimensions of the workers across different regions in India. [16-21]. Dewangan reported that most of the body dimensions for the male subjects of the north eastern region are lower than those of other regions of India except southern region [22]. Chakarvarthy collected and recorded data of the Indian population in order to strengthen the design practice in India through use of relevant human dimensional data collected from Indian population groups for the specific needs of Indian users [23].

In context to brick making industry, there is an absolute dearth of data on the anthropometric dimensions of the brick kiln workers in India. With an estimate of about 23 million workers reported to be working in the brick kilns in over 1,00,000 brick kilns spread across India [2, 24], it is, therefore, essential to generate the anthropometric data of the workers engaged in the brick making operations. India is a vast country and due to various constraints it is difficult to conduct a wide spread survey in our personal capacity. Thus, the present study was undertaken to conduct a survey to collect and record the anthropometric dimensions of brick kiln workers in western region (Gujarat) and eastern region (Bihar) of India based on the availability and accessibility to the kiln in accordance with the kiln management, from the view point of work posture improvement, new concept equipment/redesigning existing equipment, work station design and designing of personal protective equipment.

2. MATERIALS AND METHOD

The study was conducted on a total number of 66 male brick kiln workers of age range of 18-45 years engaged in different operations in brick making. Out of 66 workers, 36 workers from Gujarat region and 30 workers from Bihar region of India were randomly selected from a total number of 200 of Gujarat and 150 of Bihar region for the present study. In general, the workers were free from any kind of physical deformity and illness.

2.1. Physical Parameters and Dimensions measured

The Physical parameters such as stature and body weight were measured with the help of a Martin type anthropometric rod (Seiber & Heigner, Switzerland) and a calibrated portable weighing machine respectively. The Body Mass Index (BMI) was also determined on the basis of weight and height measurements. Body types were further classified according to the International Classification of adult with reference to their BMI, as recommended by WHO [25]. 25 different body dimensions were selected for measurements which are highlighted in Table 2. These dimensions are selected from the view point of equipment design, nutritional assessment and work station design [26, 27]. Small measurements like Hand measurements and nose measurements were recorded using a small sliding caliper, curved sliding caliper was used to measure the head length and head breadth dimensions. A measuring tape was used to measure maximum calf circumference (relaxed) and Upper arm circumference (relaxed). The subjects were explained about the survey in detail by demonstrating the measurement procedure. The subjects were asked to stand erect on a flat surface and all the measurements were taken from the right side of the body. Means, standard deviation, coefficient of Variance and key percentiles (5th, 50th and 95th) of the data collected from the subjects in Gujarat and Bihar region were calculated.

3. RESULTS

Table 1 highlights the general physical characteristics of the participants of the study, which shows that 50% participants for both the Gujarat and Bihar groups belonged to the age group of 25-34 years.

Table 1: Physical characteristic of the Subjects

States	Age (years)	Mean Body Weight (±S.D) (kg)	Mean Stature (±S.D) (cm)	Mean BMI (±S.D)	BMI classification (WHO recommendation)
Gujarat	18-24 (n=10)	48.2 (6.6)	159.5 (4.2)	18.9 (2.2)	Normal
	25-34 (n=18)	49.1 (5.0)	161.8 (6.7)	18.8 (2.2)	Normal
	35-45 (n=08)	51.7 (5.9)	162.3 (6.2)	19.8 (3.0)	Normal
Bihar	18-24 (n=05)	53.8 (11)	160.6 (9.2)	20.7 (2.0)	Normal
	25-34 (n=15)	54.3 (7.6)	162.5 (7.1)	20.6 (2.8)	Normal
	35-45 (n=10)	56.9 (8.6)	160.6 (5.5)	22.1 (3.9)	Normal
S.D. – Standard deviation, BMI – Body Mass Index					

The highest mean body weight of the Bihar participants was 56.9(±8.6) kg that belonged to the age group of 35-45 years, while the highest mean body weight for the Gujarat participants was observed to be 51.7 (±5.9) kg for the same age group. Overall it was observed that the Gujarat participants had a comparatively lower mean weight across all age groups when compared with the Bihar participants. The Mean BMI of the participants across both regions was found to be normal based on the WHO BMI classification across all age groups. Though the mean BMI was found to be normal across all age groups, 50% of the total participants in Gujarat region were underweight as per the WHO BMI classification while on the other hand in Bihar, 17% of the total participants were found to be underweight.
The estimates of the range, mean, standard deviation (SD) and percentile values (5th, 50th and 95th) of anthropometric dimensions of the workers from Bihar region and Gujarat region are highlighted in Table 2. A relatively low standard deviation was observed in across all the body dimensions of the subjects from the Bihar region. The percent Coefficient of variation (%CV) results for Bihar region were observed to be higher for a few dimensions like Left grip strength (21.8%), Right grip strength (23.4%) and body weight (15.1%) which was exceedingly high compared to the other dimensions. The higher the coefficient of variation, the greater the level of dispersion around the mean of the anthropometric dimension measured. The %CV indicated that a higher sample is necessary before going to finalize the design dimensions.
Not many variations were observed between mean value and 50th percentile value for both the regions respectively. Both the Data of Gujarat (north-western region) and Bihar (south-eastern region) were further compared to identify if there is a difference in the anthropometric dimensions measured of both the regions. It was observed that Age, Body weight, Bi-condylar femur, Maximum calf circumference, Biacromial diameter,
Antero-posterior chest, Bi-iliocristal diameter, Maximum Hand Breadth Fist Height among the anthropometric parameters were found to be significantly different at $P < 0.05$ while other parameters were not found to be significantly different at $P < 0.05$. The table 2 shows the 5th or the 95th percentile values of body dimensions of the respective regions which can be used by designers for any design purpose. In terms of India context brick making industry is a very conservative which doesn't allow any such kind of studies. Considering the difficulty towards the accessibility in the brick making industry the present data can be used by the designers for any design purpose till further studies are conducted.

4. APPLICATION OF DATA:

It is highly essential that the equipments and tools are designed to match the physical requirements and capacities of workers engaged in the field. Mismatch in the tools used by the workers and anthropometric dimensions of the workers may make them prone to musculoskeletal injuries. If the workers have right tools and equipments for working in the brick kilns it shall result in improved work efficiency and better health status of the workers. An example of the use of the anthropometric design in the brick kiln is designing of a helmet for the *Jalaai* worker [28]. The main discomfort reported by the *Jalaai* workers was that of heat stress. The environment that the *Jalaai* workers work in is hot and they do not use any equipment to protect themselves against the heat. The idea was to design equipment to protect the workers from heat.

Table 2: Anthropometric dimensions of brick workers of Bihar and Gujarat region

Sr.no	Measurement	Bihar (n=30)						Gujarat (n=36)					
		Range	Mean	S.D	Percentile			Range	Mean	S.D	Percentile		
					5th	50th	95th				5th	50th	95th
1	Age (yrs.)*	20-48	31.6	7.1	21.0	30.0	45.0	18-45	27.6	6.8	18.8	28.0	39.3
2	Body weight (kg)*	38-73	55.1	8.3	43.4	54.0	70.2	37.20-61	49.4	5.7	39.8	51.0	56.9
3	Stature (cm)	149-174	161.5	6.8	151.0	161.4	173.1	149.2-178.7	161.2	6.0	153.5	160.8	169.3
4	Height of anterior superior iliac spine (cm)	85.5-98.5	92.9	3.8	86.4	93.5	97.9	80.6-108.4	94.3	5.8	83.7	94.6	103.6
5	Sitting height (cm)	66.7-93.1	81.8	4.6	76.9	82.2	88.2	75.2-92.1	83.0	3.3	78.0	83.0	88.3
6	Bicondylar femur (cm)*	8-10.4	9.1	0.5	8.3	9.1	9.7	7.4-10	8.7	0.6	7.7	8.7	9.7
7	Wrist breadth (cm)	4.9-6.6	5.5	0.4	5.0	5.4	6.3	4.9-5.9	5.4	0.2	5.0	5.4	5.8
8	Maximum calf circumference (relaxed) (cm)*	25-36.5	31.1	2.7	27.5	31.0	36.3	21-35	29.6	2.5	25.9	29.8	33.0
9	Upper arm circumference (relaxed) (cm)	13.5-32	24.6	3.2	21.2	24.3	29.0	17-29.5	23.6	2.5	19.8	23.5	27.1
10	Total arm length (cm)	75.1-89.3	82.3	3.7	77.0	82.5	89.2	74-91	81.5	4.1	76.0	81.3	88.0
11	Biacromial diameter (cm)*	38.7-41	34.1	2.7	30.6	33.7	38.4	25.6-35.4	32.2	1.9	29.2	32.5	35.1
12	Transverse chest (cm)	21.7-31.3	27.4	2.4	23.9	27.5	30.7	22.1-33.4	26.4	2.0	23.2	26.2	29.0
13	Antero-posterior chest (cm)*	17.8-23.5	20.5	1.5	18.4	20.2	23.0	17.5-21.8	19.8	1.3	17.7	19.8	21.7
14	Biiliocristal diameter (cm)*	23.6-30.5	26.8	1.9	24.1	26.7	29.7	23.1-31.8	25.8	1.9	23.7	25.2	29.4
15	Head length (cm)	16.7-19.9	18.5	0.9	17.1	18.3	19.8	16.9-20.1	18.4	0.8	17.2	18.5	19.7
16	Head breadth (cm)	13.4-16	14.4	0.7	13.4	14.5	15.5	13.2-16	14.1	0.6	13.4	14.0	15.3
17	Bizygomatic diameter (cm)	10.4-13.2	11.8	0.6	10.7	11.9	12.8	10.5-18.8	11.7	1.4	10.5	11.5	12.8
18	Nose height (cm)	1.5-3	2.0	0.4	1.50	1.95	2.61	1.6-2.8	2.1	0.3	1.6	2.1	2.5
19	Nose breadth (cm)	3-3.9	3.5	0.2	3.1	3.5	3.9	2.8-4.1	3.5	0.3	3.1	3.5	4.0
20	Hand Breadth (cm)	7.2-8.8	7.7	1.3	7.2	8.0	8.6	7.3-9.6	8.1	0.4	7.6	8.1	8.7
21	Maximum Hand Breadth (cm)*	9.3-11.6	10.3	0.6	9.5	10.3	11.4	8.2-11.5	10.0	0.7	8.9	10.1	11.1
22	Fist Height (cm)*	7.4-8.9	8.1	0.4	7.5	8.1	8.8	5.9-7.4	6.3	0.3	6.0	6.3	6.7
23	Maximum grip circumference (cm)	4.6-5.7	5.1	0.3	4.7	5.0	5.6	4.4-5.7	5.0	0.4	4.5	5.0	5.4
24	Maximum grip strength Left Hand) (kg)	16-49	31.4	6.8	24.0	30.5	42.2	24-52	34.5	6.5	25.5	33.8	46.1
25	Maximum grip strength Right Hand (kg)	16-52	33.1	7.7	21.8	32.0	47.1	22 -48	34.6	6.1	25.3	35.0	43.0

S.D – Standard Deviation, CV – coefficient of variation * Significant at $p < 0.05$ when Bihar and Gujarat data were compared

The main principle behind designing the equipment was that of insulation against heat from the environment. So, design intervention was required to insulate the worker without interfering or disturbing his natural work process. Human face is the most heat sensitive area among whole body. Head gear was essential to keep the workers safe from heat stress. Head Gear was designed as per anthropometric design of the actual brick kiln workers which is represented in Figure 1(a, b). As the same dimension based headgear is not suitable for the entire group, 3 different sized headgears was designed and the *Jalaai* workers were free to choose headgear as per their requirement and comfort. This above given example highlights how the use of anthropometric data can be very helpful in the new concept tools/redesigning existing tools, work station design and designing of personal protective equipment for the brick kiln workers.

a. b.

Figure 1: a. Proposed design of head gear for brick kiln (jalaai) worker (Front view)
b. Proposed design of head gear for brick kiln (jalaai) worker (Side view)
Source: Taken from Dhara et. al. 2016 [28]

5. CONCLUSION

The paper presented anthropometric data from 66 male workers with age range of 18-45 years from western region and eastern region of India. Twenty five different anthropometric dimensions have been recorded of workers engaged in the different operations by following standard anthropometric procedure with reference to its functional use; for recommendation in tool modification and development of new products for the brick kiln worker. It was found that apart from a few dimensions, anthropometric data of brick kiln workers of Gujarat (western region) was not significantly different than their counterparts from Bihar (eastern region) from the present study. Thus, it can be concluded that interventions and tools designed for one state can effectively be used in the other state as well. The present anthropometric data could thus be useful from the view point of work posture improvement; new concept tools/redesigning existing tools, work station design and designing of personal protective equipment for the workers, that is both user friendly and safe, in both the areas under study.

Future Scope: Identifying more brick kilns in the same regions i.e. Gujarat region and Bihar region and collecting anthropometric data of the workers for further analysis with a larger sample size. Identification of Brick kilns across India (northern, central, southern, eastern, western and north eastern) followed by collecting and recording anthropometric data for regional specific use for designing of equipments Considering the importance of the anthropometric data from the view point of workers uplift and sustainability in their job, further in dept study in the related area must be conducted for better design intervention and new generation tool development.

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PHYSICAL WORKLOAD WHILE WORKING WITH HEDGING BILL AND BATTERY CUTTER IN TENDING OF PEDUNCULATE OAK

M. Bačić[1], M. Šušnjar[2], Z. Pandur[3], M. Šporčić[4], M. Landekić[5]
[1] Faculty of Forestry, University of Zagreb, Zagreb, CROATIA, mbacic1@sumfak.hr
[2] msusnjar@sumfak.hr, [3] zpandur@sumfak.hr, [4] msporcic@sumfak.hr,
[5] mlandekic@sumfak.hr

Abstract

The main tool used in forest tending work is a hedging bill, a hand tool consisting of a hold and a blade sharpened on both sides. Working with the hedging bill is physically very tiring and takes place under difficult working conditions (high temperature, dense vegetation, insects). For purpose of humanizing the forest tending work, a tool that has not been yet used in Croatian forestry - the battery cutter in this case Stihl ASA 85 - has been tested. In this paper a comparison of hedging bill and battery cutter was made from an ergonomic aspect. Average and maximum heart rate of a worker when working with the two mentioned tools was taken as a relevant comparison factor. Measuring the heart rate during effective work time the physical workload of the worker was determined. Garmin Fenix 3HR has been used to measure heart rate in the conducted research. The results obtained show less physical workload of workers when working with battery cutter.

Keywords*:* *physical workload, hedging bill, battery cutter, forest tending, Croatia*

1. INTRODUCTION

In Croatian forestry forest tending is mostly done manually. The most frequently used tool is hedging bill. Due to delicacy of tending work (worker must pay attention on the present young trees of significant species) a semi-mechanized mowing can't be applied. Working procedure is that worker holds a hedging bill in one hand, and with the other hand he bends a tree for easier cutting. After cutting, the worker is pulling the tree from the crown zone and placing it at least one meter below the crowns of the pedunculate oak. If tending takes place in stands with slightly larger diameters, the worker must hold the hedging bill firmly with both hands to perform the cutting. Working with the hedging bill is physically very tiring and takes place under difficult working conditions (high temperature, dense vegetation, insects). Hedging bill as a tool certainly finds its application in stands where the diameters are small, and the presence of oak is poor. In such stands, the worker doesn't have to pay much attention to the existing young oak trees and does what the hedging bill is made for – mowing and trimming. Furthermore, when working with hedging bill in stands where undesired wooden species are of somewhat larger diameter, i.e. where more swings are needed to cut one tree, the worker receives strong strokes that are felt from the wrist to the shoulder joint. The frequent use of hedging bill in such works leads to injury to worker and a decrease in the quality of his life. In terms of quality of work and productivity, it is also possible to notice the negative sides of the use of the hedging bill in the mentioned working conditions. From long-term perspective, replacing hedging bill in works of oak tending and partial mechanization of these works, the number of disabled workers resulting from the use of an inappropriate tool would be reduced. In Croatian forestry, most of the works are mechanized and the tendency is that manual works are also mechanized. Mechanization of works in forestry has a multiple positive effect on the physical workload of worker, its productivity and preservation of its health, the quality of the work done, and the satisfaction and motivation for work. Ergonomic research in forestry in Croatia is more intensely carried out in the 90s of the 20th century, where for estimating the physical workload in a dozen types of forestry works (Tomanić et al. 1990; Vondra et al. 1990; Martinić 1993; Martinić 1994; Vondra 1995) from practical reasons, methods based on pulse measurement were applied. Several authors state that cardiovascular load in pre-harvesting operations when using semi-mechanized tools rather than manual tools is significantly reduced (de Oliveira et al. 2014; Nutto et al. 2013). For purpose of humanizing the work of tending of the oak stands, a tool that has not been used in Croatian forestry, battery cutter, has been tested and compared to hedging bill by using average working heart rate to define physical workload. In orcharding battery cutter has been used for pruning trees for many years, and due to similar nature of the work in the tending of oak stands, the possibility of their application in forestry has been observed.

2. MATERIALS AND METHODS

2.1 Research area

The research was conducted in 10 years old state forest managed by Forest Administration Vinkovci, Forest Office Vinkovci. Main commercial tree species in this part of Croatia is pedunculate oak (*Quercus robur* L.). In early life of pedunculate oak it is necessary to perform tending work to assure, among many other features, high quality wood product in future. Young forests in Forest Administration Vinkovci are divided by geometrical network of breeding paths. Segments of divided forest have 5 m x 35 m dimensions, and area of approximately 175 m^2. These segments were main unit of conducted measurements and all measuring is made on the segment level. Terrain was horizontal. Observed forest segments were all next to each other to avoid major variability. Air temperature during conducted measurements was between 15 ºC and 25 ºC.

2.2 Research objects

Worker was a 41 years old male with body mass of 105 kg, and height of 180 cm. At the time of research worker had 16 years of working experience in forestry. For conventional tending method worker was using standard issued hedging bill (figure 1 - left) with a mass of 1,5 kg and a length of 1,15 m. For new method Stihl ASA 85 battery cutter with a mass of 0,98 kg and AP 300 backpack battery with a mass of 1,7 kg (figure 1 – right) was used.

Figure 1: Hedging bill (left), battery cutter (right)

2.3 Research instruments and methods

Data was collected during tending of four segments using conventional tool (hedging bill) and four segments using new tool (battery cutter). During tending of specific forest segment with either of mentioned tools, worker was recorded with action camera type SJ4000. Video recording was performed to obtain effective worktime, and also to count number of swings with hedging bill per one forest segment. The number of swings was obtained by viewing recorded video files. Number of cuts with battery cutter was obtained via built-in counter on the control unit. Number of swings/cuts is relevant factor of forest segment variability. More swings/cuts mean that more unwanted tree species are present on the observed forest segment, and consequently more tending work is necessary. Swings and cuts are not to be mixed, as it takes significantly more swings with hedging bill than cuts with battery cutter to tend one forest segment. Obtained data is sorted out in MS Excel 2016. To evaluate and compare physical workload of worker while working with hedging bill and battery cutter, a heart rate method was used. Worker was equipped with Garmin Fenix 3HR heart rate monitor, and his heart rate was recorded during effective worktime. After tending one forest segment worker would take one longer pause to lower his heart rate to levels before any work. In practice, during tending work, it is common that worker is working until he finishes one forest segment before resting. Average and maximum heart rate during effective work in addition to heart rate dynamics were taken as relevant parameters. Heart rate monitor is designed in form of a wristwatch and it didn´t interfere with worker's movements during tending. The physical workload assessment was based on the methodology proposed by Apud (1999). Before measuring heart rate, it is necessary to inscribe worker's age, sex, body mass and height, and wrist where heart rate meter is placed (left or right). Recorded heart rate data is downloaded via Garmin Connect user's interface and sorted out in MS Excel 2016.

Table 1: Classification of physical workload according to the average working heart rate

Physical workload	Average working heart rate [bpm]
Very light	< 75
Light	75 - 100
Moderately heavy	100 – 125
Heavy	125 – 150
Very heavy	150 – 175
Extremely heavy	> 175

Source: Taken from Apud E., 1999 [1]

3. RESULTS AND DISSCUSION

Research results are displayed in table 3 where physical workload in every forest segment (Seg) is determined by using average working heart rate. Although all forest segments were next to each other, some of them had more oak trees, and some of them more trees of unwanted species. Effective work time, number of cuts/swings and cuts/swings per minute represent factors of forest segments variability. However, because neither cut with battery cutter nor swing with hedging bill represent one cut down tree, variability of forest segments tended with different tools can't be compared. With mentioned factors, only variability of forest segments tended with the same tool can be compared.

Table 2: Research results

Battery cutter						
Seg	Effective work time [hh:mm:ss]	N cuts	Cuts/min	Avg HR [bpm]	Max HR [bpm]	Physical workload
1	00:40:49	762	18,7	120	157	Moderately heavy
2	00:36:08	748	20,7	116	147	Moderately heavy
3	00:30:00	576	19,2	121	143	Moderately heavy
4	00:42:06	830	19,7	126	145	Heavy
Avg	00:41:15	729	19,6	**121**	**148**	Moderately heavy
Hedging bill						
Seg	Effective work time [hh:mm:ss]	N swings	Swings/min	Avg HR [bpm]	Max HR [bpm]	Physical workload
1	1:11:21	1803	25,3	131	169	Heavy
2	1:04:23	1650	25,6	127	162	Heavy
3	1:02:50	1632	26	114	166	Moderately heavy
4	00:48:33	989	20,4	122	148	Moderately heavy
Avg	1:01:44	1518,5	24,3	**124**	**161**	Moderately heavy

Working with hedging bill lasted on average 20 minutes and 29 seconds longer than working with battery cutter, and it takes more than twice as many swings with hedging bill to tend one forest segment in comparison to cuts with battery cutter. Results also show that worker is doing more swings than cuts per minute. Swinging the hedging bill is physically exhausting and requires more workers energy than cutting with battery cutter. Consequently, higher average and maximum heart rate was recorded when worker was working with hedging bill.

Figure 2: Heart rate dynamics (battery cutter – 3 segments)

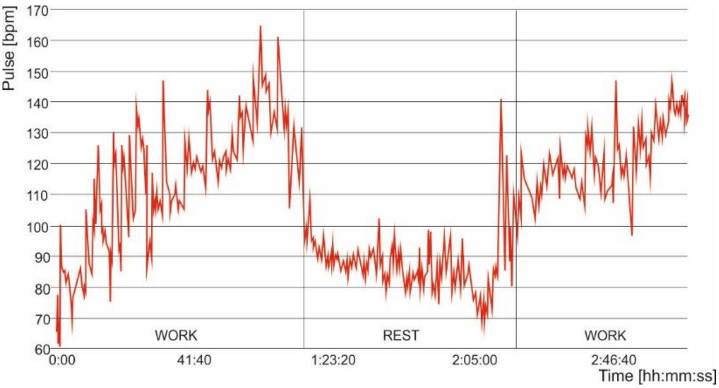

Figure 3: Heart rate dynamics (hedging bill - 2 segments)

The biggest difference is in the maximum heart rate, while the average heart rates are quite similar. Similarity of average heart rates can be explained with worker's working pace. While working with battery cutter the working pace was even throughout one forest segment. However, while working with hedging bill, worker was reaching higher heart rate faster, and had to intentionally slow down to lower his heart rate and make work more comfortable (Figure 3, second segment). This can also be seen in figure 2 and figure 3 where is evidently that the highest peaks are reached while working with hedging bill, rather than battery cutter. Regarding physical workload, on average working with both tools was classified as moderately heavy. Although, work in half of segments tended with hedging bill is classified as heavy and average value is just below the heavy class. Influence of effective work time duration is also notable. In both cases (hedging bill and battery cutter) the highest average pulses were recorded in forest segments with the longest effective work time.

4. CONCLUSION

Recorded heart rates point to higher physical workload when working with hedging bill. Worker is working longer and at the quicker pace when working with hedging bill. In addition to lower heart rate when working with a battery cutter, worker is also more productive compared to working with hedging bill. While the average heart rate is similar when using both tools, there is a significant difference in maximum heart rate and effective work time between two observed tools. Results confirm that semi-mechanized tools can reduce physical workload and improve productivity in pre-harvesting operations. In this example humanization of work is mostly reflected in lower time exposures to physical workload.

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A PROPOSED APPROACH FOR SYSTEMS ERGONOMIC ASSESSMENT

M. E. Boatca[1], A. Draghici[2], S. Irimie[3]
[1] Politehnica University of Timisoara, Timisoara, ROMANIA, boatcaelena_2009@yahoo.com
[2] Politehnica University of Timisoara, Timisoara, ROMANIA, anca.draghici@upt.ro
[3]University of Petrosani, Petrosani, ROMANIA, sabina.irimie@gmail.com

Abstract

Ergonomics remains a high interest area across businesses and industries, as it provides key solutions to workplace optimization. An important aspect is that theoreticians generally provide solutions that are tested by other theoreticians, without actually addressing real problems encountered by practitioners in their current activity. A major concern for applying ergonomics in organizations is finding the proper answer for the following question: "How to assess a work situation and provide the best solution for ergonomic optimization?" In an attempt to respond to this interesting question, the authors studied various assessment methods and benchmarked them. Further, they developed a questionnaire to determine applicability of a new assessment method. The main area of applicability for the assessment method is musculo-skeletal disorders.

Keywords: *assessment methods, ergonomics, research instrument, workplace optimization*

1. INTRODUCTION

Nowadays, organizations are heavily investing in occupational health and safety (OHS) programs, especially with the aim of risk prevention and legal compliance. Typology of work situations has dramatically changed in the past years, as the number of office workers is rapidly increasing worldwide. In this context, risk assessment itself must be realigned with the current status quo in order to cover the whole risk palette – including higher incidence of musculoskeletal disorders (MSDs). However, MSDs are not new to ergonomists and their assessment has been studied from various perspectives in the past decades. Researchers proposed various assessment methods aimed at understanding key causes of MSDs and identifying optimal solutions for decreasing incidence of MSDs and improving life of workers already suffering of such disorders.

It is important to mention that ergonomists are continuously seeking for improved ergonomic assessment methods, with the purpose of answering to main concerns of practitioners, rather than creating methods that might not be useful in day-to-day activity of organizations - despite their innovative character.

This paper focuses on providing an overview of key ergonomic assessment tools as a preamble for setting up a new assessment method that combines usability and

questionnaire-based MSD evaluation. One key observation is that such an assessment method is just a part of a toolkit for ergonomic assessment.
What makes MSDs assessment difficult is the fact that there is no optimal position, as humans are designed to move and not to stand/sit solely. Therefore, ergonomic assessment must address major aspects of work-related situations - such as complexity of moves and positions during work, OHS risks and organizational initiatives toward mitigation of MSDs incidence - and it must correlate them with other factors, including individual perception on work tasks, health status, personal lifestyle and work-life balance.

2. ERGONOMIC ASSESSMENT METHODS – BRIEF ANALYSIS

Depending on researchers' areas of expertise, ergonomic assessment methods reflect various perspectives and approaches to OHS and MSDs. Further, legal entities and NGOs developed assessment tools applicable across all industries and types of organizations, pursuing dynamic analyses of country- or region-wise OHS data.

2.1. International standards and surveys

Currently, many organizations focus on implementing OHS systems rather than using government regulations as guidelines [1]. This resulted from the need of building a comprehensive framework for OHS preventive measures, as well as for assessing current OHS situation in the organization and for developing ergonomic solutions to identified flaws and risks. As a consequence of this preference for OHS systems, International Organization for Standardization (ISO) is planning to launch ISO 45001, a standard for OHS management systems. The initiative was launched in 2013, after ISO initiated harmonization of all its standards in terms of language and structure. ISO postponed multiple times the launch of ISO 45001, aiming for March 2018 as the timeline for final standard publication [2].
The importance of this standard for the present paper consists in the possibility of auditing organizational activities based on systemic approach, retrieving an objective, independent and realistic overview of the current status. Additionally, auditing enables identification of key improvement areas and tracks implementation of proposed solutions.
The main drawback of ergonomic assessment based on ISO 45001 auditing relies in the general character of the analysis, without offering a deep understanding of major factors that generate increased incidence of MSDs in a specific workplace or for a specific task.
Regarding region-wise assessments, the European Agency for Occupational Safety and Health at Work (EU-OSHA) developed the European Survey of Enterprises on New and Emerging Risks (ESENER) [3]. In 2014, 50,000 companies operating in 36 countries across Europe participated in ESENER. The results of this detailed survey highlighted major risk factors and how they are managed, psychosocial risks and MSDs, and employee participation in OHS activities. The most important contribution of ESENER consists in enabling companies to understand importance and increased incidence of MSDs, as well as identifying improvement measures. Additionally, the EU-OSHA approach enables practitioners and researchers alike to develop a new perspective in developing impartial assessment methods that are easily applicable in day-to-day activity.

2.2. Ergonomic assessment methods for MSDs developed by scientists and researchers

According to G. Li and P. Buckle [4], work-related MSDs are often associated with occupational risk factors such as physical work load (force, posture, movement and/or vibration), psychosocial risks and individual factors. Most of the times, exposure to work load can be assessed based on parameters such as intensity, duration and repetitiveness. However, most of the assessment methods are focused on working postures, without properly quantifying other factors. Unfortunately, taking a comprehensive approach is very difficult, as there is limited knowledge on 'safe exposure level' [4] and its use for benchmarking risk levels.
As per Table 1, there are three main categories of assessment methods: observational methods, direct methods and self-report on physical load. Each category includes a variety of methods aimed at identifying MSDs.

Table 1: Overview of main ergonomic assessment methods – by type

Main category	Description	Examples
Observational methods	- Involve recording specific features of work and workers' positions without disrupting workers - Such methods are inexpensive, but they lack precision - Key categories are pen and paper-based methods and videotaping and computer-aided observational methods	- Posturegram - OWAS - Posture targeting - PLIBEL - REBA - QEC - ARBAN - VIRA - ROTA - HARBO
Direct methods	- Consist in evaluating the health status of workers using either manual devices or electrical equipment - Thanks to technological advances, direct MSDs assessment can be made using computer-aided technologies	- Posture assessment - Postural strain or local muscle fatigue assessment
Self-report on physical work load	- Involves detailed subjective and performance-based measurement, with the benefit of reflecting actual work load and high risk situations - The disadvantage of this method is subjectivity, as workers might report situations as being worse than they actually are	- Body mapping - Rating scales - Questionnaires - Interviews - Checklists

Source: Based on authors' findings

Manolescu [5] presents a few methods and techniques for ergonomic assessment and analysis from the systemic perspective (i.e., understanding work as a system comprising the worker, equipment and the work environment). Among the most frequently used

methods are RNUR, LEST, ERGOS, IEMRCM, ERGOMUN and the ergonomic control list. These methods provide an overview of the work system, but are difficult to quantify and may generate lack of inter-correlation between subjective and objective factors.
According to Araujo [6], pain is the fifth vital sign for identifying and assessing basic body functions and health quality. Therefore, assessing MSDs is directly linked to pain assessment.
Institute for Clinical Systems Improvement (ICSI) developed a guide for adult acute and sub-acute low back pain, offering an assessment method with two algorithms (one for diagnosis and one for treatment). This approach sheds light on a key aspect [7]: practitioners need to assess whether workers suffer of pain before proceeding to other initiatives. According to ICSI method, depending on pain intensity and frequency and on MSD diagnosis, there are two aspects to take care of:

1. Assess the health status of the respective workers and introduce them into a recovery and treatment program;
2. Perform a root-cause analysis to identify causes of MSDs in the workplace and mitigate the respective risks (i.e., perform workplace ergonomic assessment and propose ergonomic intervention).

These algorithms have the advantage of enabling practitioners to assess the current situation of MSD-related risks, but do not offer a comprehensive tool for identifying causes; the algorithms must be combined with other assessment methods to establish an effective ergonomic intervention.
Unfortunately, majority of assessment methods are developed by researchers, who do not have the same perspective and background on a specific work situation as practitioners do [4]. These methods provide interesting conclusions, but are very intricate and complex, and require high level of expertise and experience to be used. Also, these are hard to implement in real work situations. The reason behind this is related to the manner of testing feasibility and importance of each method: researchers use laboratory testing or samples to validate their methods.
Another limit refers to deciding whether a specific risk involves ergonomic intervention. Practitioners have an in-depth vision on work and tasks and are able to apply ergonomic assessment only for problematic jobs or tasks. The results should easily answer to their main questions: "is ergonomic intervention necessary?" and "is ergonomic intervention effective?" Current assessment methods offer a static overview of the situation, without necessarily answering these two questions.

3. PROPOSED NEW ERGONOMIC ASSESSMENT METHOD

Development of a new assessment method for MSDs is aimed at addressing key limitations of current methods and providing a useful tool for day-to-day use in organizational activities. Establishing a new assessment method implies understanding the concept of usability, as part of the larger systemic approach. Further, the Nordic Questionnaire sets the general framework for the method proposed in this paper.

3.1. Usability

The concept of usability is defined as "capability of being used"; in the 1980s and 1990s numerous papers highlighted that usability encompasses the attributes that make a product usable [8]. According to ISO 9241-11:1998, the concept of usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." [8] Usability, as an assessment method, comprises a questionnaire used for measuring product usability. Extending the concept of usability to systems, the usability questionnaire can be applied to workers, in order to assess their perceptions on working conditions and work environment (regarded as elements of the work system). This would enable assessment of subjective aspects, with relevance for a comprehensive overview on key areas that require ergonomic interventions.

3.2. Standardized Nordic Questionnaire

The Standardized Nordic Questionnaire [9] was developed in 1987 for the analysis of musculoskeletal symptoms. The questionnaire was developed by a group of researchers from Sweden, Denmark, Finland and the US, with the support of Nordic Council of Ministers.

In comprises forced choice binary or multiple answer variants for each question and can be used as self-assessment tool or as part of an interview. Questions refer to symptoms that are most often encountered during work. The main advantage of this tool is the possibility to identify activities that generate most work discomfort and pain and to assess the current health status of each employee. Additionally, used for dynamic analysis, the questionnaire can be applied over the long term and on a regular basis to assess if ergonomic interventions are effective.

There are two variants of the questionnaire: a general questionnaire and another one specific for low back pain and neck/shoulders pain. In the first part of the questionnaire, an image of the human body is presented from the back view, as shown in Figure 1. The image is divided into nine anatomical regions. The questionnaire is split in nine sections, each corresponding for one of the anatomical regions identified in the image. This helps the employee to easily identify the appropriate answer and the interviewer/researcher to establish main over-loaded body regions and the main causes for the respective. The nine body regions are those where pain is most commonly encountered.

According to [9], the main limitations of this questionnaire are the general limitations of the questionnaire technique. Also, there is space for subjectivity depending on the experience of the employee who fills in the questionnaire and the context where the interview is taken. The third limitation is linked to human tendency of remembering more recent and more serious pain and MSDs rather than less serious and older ones.

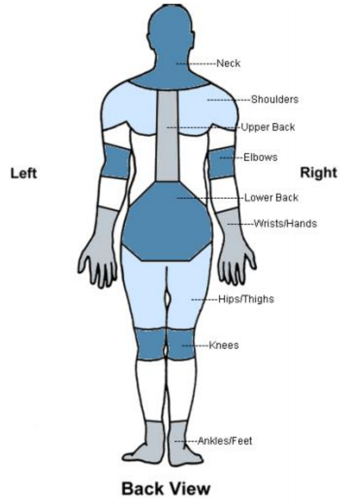

Figure 1: The Nine Body Regions Identified in Standardized Nordic Questionnaire
Source: Taken from Kuorinka, I. et al., 1987 [9]

3.3. Proposed Assessment Method for MSDs

The assessment method proposed in this paper should be regarded as a set of steps (as shown in Figure 2) to be taken in order to obtain a comprehensive overview of work means and environment as a complement to employee's situation at the work place, together with a profound understanding of the connection between employees' life at work and their life outside of work. This method targets both prevention and optimization activities in the case of identification of flaws and overloads during worker's activity.
The most important recommendation for successful application of the method is forming an interdisciplinary team of specialists.
The first step is initial evaluation of the organization to understand its main problems and strengths. Generally, such an evaluation can be made through a discussion with the management team.
The second step consists in applying 'MSD and overall wellbeing questionnaire', which is a more detailed version of the Standardized Nordic Questionnaire. This questionnaire is aimed at better understanding work environment, tasks, and relationship between these and employees' personal life and health status. The main hypothesis used when creating this questionnaire was that variety of MSDs and pain intensity level can be easier differentiated when understanding the bigger umbrella of potential causes (both at work and after working hours). This tool relied primarily on Nordic Questionnaire.
Besides the questions regarding frequency and intensity of work tasks and pain by body region, 'MSD and overall wellbeing questionnaire' involves assessment of the overall health status, work habits, lifestyle and a section with open questions referring to problems encountered during work and suggestions for improvement. Considering that this would involve a large set of questions, time necessary for completing the questionnaire might take more for employees who are not familiar with filling in a questionnaire. Therefore, it is recommended that a specialist fills in the questionnaire as

part of an interview where he explains all unknown details to the employee. However, if the assessment team considers that such a detailed questionnaire is not feasible / necessary, the short form of the Standardized Nordic Questionnaire can be used.
After analyzing the results and consolidating the information obtained, the assessment team should propose a set of improvement measures for an ergonomic intervention.
The fourth step consists in applying the 'work system usability questionnaire'- a personalized usability questionnaire, aimed at understanding employee's perception on the working environment, work tasks and work means. This is extremely useful for understanding the effectiveness of ergonomic intervention.

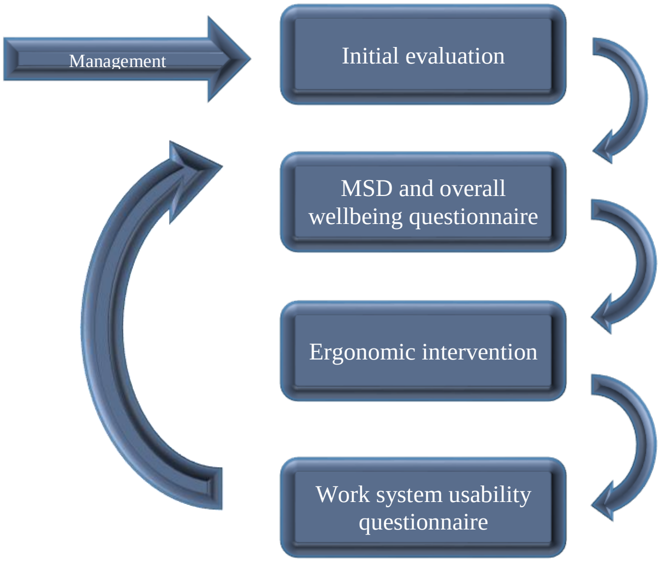

Figure 2: Major steps of proposed MSDs assessment method
Source: Based on authors' understanding

Complete usefulness of the method can be achieved if it is applied on a constant and repetitive basis (e.g., every year or every six months). This enables a dynamic analysis of the evolution of employees' health and organizational ergonomic achievements.
The main advantage of such an approach consists in obtaining a deep understanding of direct and indirect factors that generate MSDs and identifying key improvement areas. Also, organizations can track evolution and performance for proposed ergonomic interventions over long-term periods.

3. CONCLUSION

During the last decades, numerous researchers and OHS-related institutions made efforts for development of MSDs assessment methods with the aim of mitigating related risks and increasing organizational performance. However, these methods have the major disadvantage of not addressing current challenges faced by practitioners, but offering solutions to problems identified by researchers. Therefore, practitioners still lack instruments of assessment that enable them to identify appropriate solutions and implement ergonomic interventions.

Among the large range of methods, this paper benchmarked methods developed by EU-OSHA and ISO, the systemic approach and its methods, ICSI method and researchers' proposals.

From the variety of options available, Standardized Nordic Questionnaire was chosen as starting point for development of a new assessment method. Further, the concept of usability and the usability questionnaire were proposed for assessment of workers' perception on their tasks, work environment and work equipment.

What makes the proposed assessment method special is its complexity – it comprises several steps and involves a multi-disciplinary team of specialists. It enables practitioners to obtain a deep understanding of direct and indirect factors that generate MSDs and a comprehensive overview of the overall work system and its interdependence with workers' lifestyle.

There is still room for improvement, as practitioners may come with suggestions during use of the method and might identify flaws or aspects that are difficult to implement.

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ERGONOMICS AND OCCUPATIONAL HEALTH AND SAFETY FOR WELLBEING

M. E. Boatca[1], S. Irimie[2], A. Draghici[3]
[1] Politehnica University of Timisoara, Timisoara, ROMANIA,
boatcaelena_2009@yahoo.com
[2] University of Petrosani, Petrosani, ROMANIA, sabina.irimie@gmail.com
[3] Politehnica University of Timisoara, Timisoara, ROMANIA, anca.draghici@upt.ro

Abstract

Over time, wellbeing was and still is a preoccupation at individual, organizational and society levels on the back of human aspirations towards a better life. From singular trials, insulated at individual level, to national, sectorial or global attempts, efforts have been made to improve human life. Objectives such as safety, health and wellbeing animate various inter-connected domains and transform them in models – some unrealistic and others successful.
This paper highlights the comprehensive framework through which ergonomics contributes to improvement of health and safety in Romania, as a starting point of a well-consolidated relationship for occupational wellbeing.

Keywords*:* *ergonomics, occupational health and safety, wellbeing*

1. INTRODUCTION

Major challenges in today’s labor market (i.e., globalization, demographic boom, ageing population, rapid evolution of IT&C) generate significant changes in working systems. International Labor Organization and World Health Organization (WHO) consider the right to health and safety in the workplace as part of fundamental human rights, and, thus, every citizen of the world has a “right to healthy and safe work and to a work environment that enables him or her to live a socially and economically productive life” (WHO, 1995, p.6).
However, statistical data are disturbing: occupational accidents and work-related diseases are a main cause of death every day, resulting in ~2.78 million deaths per year. Additionally, ILO estimates that every year ~374 million non-fatal work-related injuries and illnesses are recorded, majority of them leading to extended absence from work. From the financial perspective, work-related illnesses and injuries cost ~4% of the global GDP per year; and this only adds up to the immense human cost (ILO, n.d.).
To facilitate the understanding of tight connections between the interdisciplinary and dynamic domains that make the object of this paper, in Table 1 there are presented brief definitions offered by professional associations and international organizations.

Table 1: Definitions of concepts in the area of ergonomics and wellbeing

Concept	Definition	Authors
Work	"Involves the application of physical or mental effort, skills, knowledge or other personal resources, usually involves commitment over time, and has connotations of effort and a need to labor or exert oneself. Work is not only 'a job' or paid employment, but includes unpaid or voluntary work, education and training, family responsibilities and caring."	Warr, 1987; OECD, 2003; Waddell & Burton, 2006
Health	"State of physical, mental and social well-being that provides the individual with an opportunity to conduct a socially and economically productive life (despite philosophical debate) is usually operationalized in terms of the absence of symptoms, illness and morbidity."	WHO, 1948; WHO, 1995; Danna & Griffin, 1999; Waddell & Burton, 2006
Well-being	"Subjective state of being healthy, happy, contented, comfortable and satisfied with one's quality of life. It includes physical, material, social, emotional ('happiness'), and development & activity dimensions."	Felce & Perry, 1995; Danna & Griffin, 1999; Diener, 2000; Waddell & Burton, 2006
Ergonomics	„Profession that applies theory, principles, data and design methods to optimize people's welfare and overall system performance", demonstrates a permanent concern for specialists in this field. The two objectives are clearly expressed covering the social objective of ergonomics (human well-being) and the economic objective of ergonomics (performance)."	IEA, 2010; Irimie, Manolescu, & Lupu, 2017
Safety and health	"All institutionalized activities aimed at ensuring the best conditions for carrying out the work process, life protection, physical and psychical integrity, health of workers and of other persons participating in the work process."	The Parliament of Romania, 2006
Quality of life	"Individuals' perception of their position in life in the context of the culture and value system in which they live and in relation to their own goals, expectations, standards and concerns."	The WHOQOL Group, 1995; Waddell & Burton, 2006

Source: Based on author's findings

Work and education are considered as the most efficient ways to improve individual wellbeing (associated with wellbeing of their families and of communities they live in) and, hence, improve quality of their life. Waddell & Burton, after laborious researches, stated that "Work is generally good for health and wellbeing." (2006, p.38)
Anttonen & Räsänen (2008) and Hämäläinen (2007), knowing that wellbeing is one of the common objectives of ergonomics and occupational health and safety (OHS), made a

European-level analysis to understand whether legislation mentions the concept of wellbeing and if it is implemented across enterprises. Results of their research are presented in Table 2.

Table 2: Legislation and implementation of W-BW strategy and models in partner countries

Country	Concept mentioned in legislation?	Idea implemented on country level	Implemented at enterprise level
Belgium	Yes	Yes	Yes
Finland	Yes	Yes	Yes
Germany	Yes	Yes	Yes
Ireland	No	Yes	Yes
Italy	No	No	Yes
Romania	No	No	Yes

Source: Anttonen & Räsänen, (Eds.), 2008, p.14.

Romania does not have a national legislative basis for development of wellbeing activities in the workplace or, at least, a model established among professional communities operating in the field of public health and OHS. The concept of wellbeing is known only by OHS and HR specialists. However, companies (enterprises) have various work models differentiated among them, such as collective training sessions on health education, fitness and nutrition consulting centers, etc. Ergonomics is underdeveloped in Romania: an indicator is introduction of ergonomist profession in Romanian legislation only in 2017 (Irimie, Manolescu, & Lupu, 2017).
This leads to the conclusion that Romania is not in line with the European trend regarding increasing interest for interconnections between ergonomics and wellbeing.
The next chapter is focused on understanding international interest for ergonomics and wellbeing from the research perspective.

2. QUANTITATIVE ANALYSIS OF RESEARCH PUBLICATIONS FROM THE FIELDS OF ERGONOMICS AND WELLBEING – METHODOLOGY, RESULTS AND DISCUSSION

Research methodology consists in a quantitative analysis based on statistical synthesizing of papers published in ScenceDirect available through SciVerse Hub platform (Irimie, Baleanu, Irimie, 2012). The analysis focuses on publications and research fields they refer to, with emphasis on ergonomics and wellbeing.
ScienceDirect is a platform owned by Elsevier and comprising peer-reviewed scholarly literature. Generally, universities and research institutions offer ScienceDirect access to their researchers' community. ScienceDirect contains articles from 3,800 journals and ~37,000 books from various domains; a very useful feature of the platform is multiple criteria and category searches.
Coming back to the current research approach, for comparability purposes, papers were analyzed for the 1995-2018 period for three fields: 'ergonomics', 'wellbeing' and 'ergonomics and wellbeing'. It is highly important to mention that 2018 refers to a two and a half months-period (January, February and first 15 days of March).

During 1993-1994 there have been published 34 papers in the area of 'ergonomics and wellbeing' and no papers in the other two fields, hence the starting year of this analysis was established as 1995, when there were papers published for all three fields (see Table 3).

Table 3: Statistical Distribution of Publications - by Research Field

Year	Field		
	Ergonomics	Wellbeing	Ergonomics and Wellbeing
1995	1,119	288	4
1996	821	292	4
1997	664	264	6
1998	608	223	1
1999	479	236	2
2000	457	352	1
2001	484	362	-
2002	420	313	3
2003	538	410	5
2004	635	473	7
2005	818	537	10
2006	711	622	7
2007	768	855	6
2008	739	1,011	8
2009	781	1,172	10
2010	814	1,313	12
2011	777	1,692	11
2012	922	2,328	21
2013	971	2,696	19
2014	1,129	3,416	32
2015	2,198	4,046	76
2016	1,387	4,637	49
2017	1,426	5,754	61
2018	592	2,553	22

Source: Based on data retrieved from ScienceDirect

From the total of 56,480 papers published in the three fields during 1995-2018, 35.9% refer to ergonomics and a prominent 63.5% are in the field of wellbeing. During 1995-2018, number of papers published in the field of wellbeing increased at a 12.9% CAGR, while the number of papers published in the field of ergonomics decreased at a 3.5% CAGR.

This reveals that interest for ergonomics has been reducing, while emphasis on wellbeing has been strongly promoted both in scientific research and as part of strategic initiatives in large companies.

Another conclusion revealed by analysis of data in Table 3 is that ergonomics and wellbeing are rarely approached together albeit the interconnection between the two fields. As per US-based National Institute of Occupational Health and Safety (NIOSH), complementing ergonomics with wellbeing programs is essential to successfully implementing a long-term health and wellbeing program across an organization. Among the major benefits of associating ergonomics with wellbeing are capability to address issues that are more important to workers, improving the results of ergonomics interventions, a larger perspective on the causes of problems identified and improved employee and organizational performance (Nobrega et al., 2017).

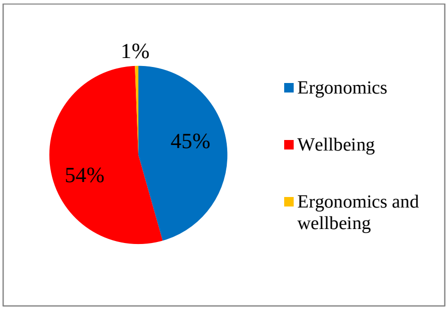

Figure 1: Prominence of analyzed fields during 1995-2018
Source: Based on authors' findings

Figure 1 indicates again that benefits, importance and innovation in ergonomics and wellbeing are treated separately, with few cases when the two fields were approached together. Percentages in Figure 1 differ from the analysis based on data in Table 3, as ScienceDirect does not retrieve the same number of results when applying different criteria, despite that all searches referred to the same research fields.

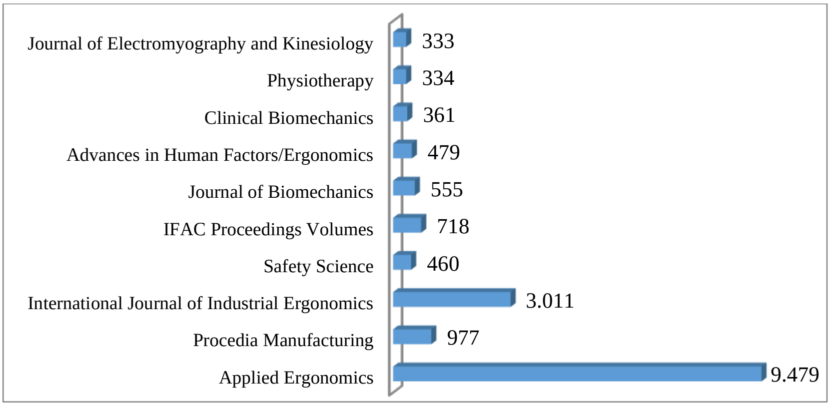

Figure 2: Leading publications comprising papers published in the field of ergonomics
Source: Based on authors' findings

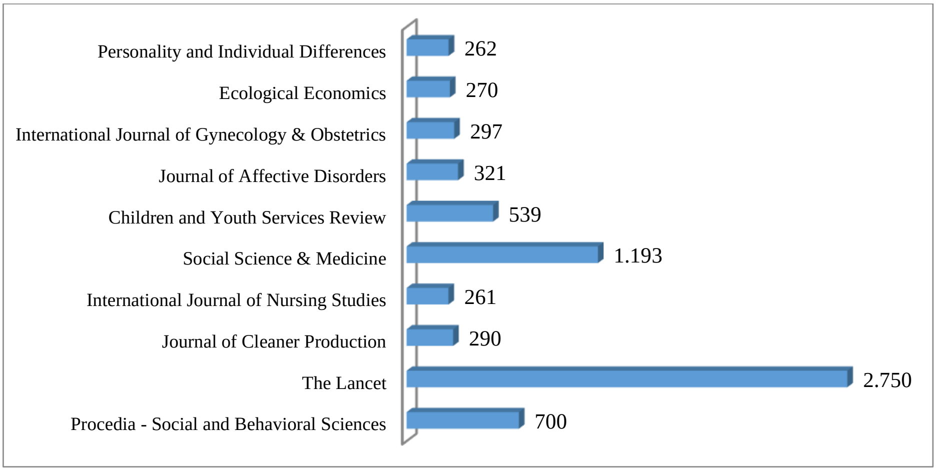

Figure 3: Leading publications comprising papers published in the field of wellbeing
Source: Based on authors' findings

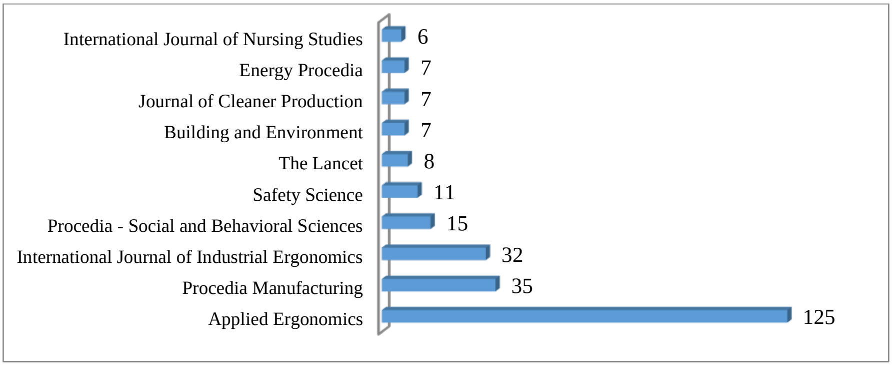

Figure 4: Leading publications comprising papers published in the field of ergonomics and wellbeing
Source: Based on authors' findings

Figures 2, 3 and 4 indicate top 10 publications where papers in each field were published during 1995-2018. 'Applied Ergonomics' is leading publication when it comes to ergonomics and ergonomics and wellbeing, while 'The Lancet' is the preferred publication for wellbeing-related articles.

Table 4: Statistical Distribution of Publications - by Article Type

Article Type	Field		
	Ergonomics	Wellbeing	Ergonomics and Wellbeing
Review articles	936	3,805	35
Research articles	18,022	24,129	296
Encyclopedia	153	379	6
Book chapters	2,564	2,349	66

Conference abstracts	5,431	3,121	48
Book reviews	914	457	4
Case reports	14	62	-
Conference info	350	76	-
Correspondence	165	710	6
Data articles	2	2	-
Discussion	230	1,455	3
Editorials	427	1,058	6
Errata	39	11	-
Examinations	1	11	-
Mini reviews	55	226	2
News	744	376	6
Patent reports	73	-	-
Practice guidelines	7	22	-
Product reviews	417	36	4
Short communications	530	815	5
Other	2,957	1,019	9

According to data in Table 4, majority of papers published in the fields of ergonomics, wellbeing and ergonomics and wellbeing are research articles (56.9%). Among the other categories of articles, review articles accounted for 6.4% and book chapters accounted for 6.7%. Therefore, review papers, research articles and book chapters are the most prominent types of papers (articles) published in the three fields.
In conclusion, there is a vast literature for both ergonomics and wellbeing that needs to be studied in order to understand key areas that enhance ergonomic interventions and employee wellbeing. Ergonomics and wellbeing as a single research field should be further developed in order to achieve higher outcomes of both ergonomics and wellbeing across all types of organizations.

3. CONCLUSION

The paper highlights the increasing interest for the interdisciplinary aspects analyzed in the paper. This conclusion holds true both for theoretical research and for day-to-day practical activities. In Romania, to address the latter, the authors consider that objective 7 from Global strategy on occupational health for all (WHO, 1995, p.57): “Development of Human Resources for Occupational Health” should be completed with ‘ergonomics’. Preparing specialists in the field of ergonomics and OHS is highly stringent in order to professionally address the problems that persist in the work systems across Romanian organizations and to create workplaces for happy and healthy people.

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PERFORMANCE OF A WINTER JACKET MADE FROM SPACER FABRIC

R. Chattopadhyay, A. Anand
[1]Indian Institute of Technology Delhi, India, rchat@textile.iitd.ac.in

Abstract

Spacer fabrics being light weight and voluminous offers an opportunity for its use as insulating layer. However, its structure being too porous, it needs to be sandwiched between two additional layers of fabrics to make it an effective insulating layer. In order to explore the possibility of its use in winter jacket, a spacer fabric was sandwiched between a polyester (inner layer) and cotton-wool blended fabric (outer layer). The fabric combination was evaluated for its thermal resistance, air-permeability and moisture vapor transmission rate. A prototype jacket was designed using this fabric combination. Its ergonomic performance was assessed following a test protocol consisting of a set of activities viz. resting, standing, resting, cycling and resting over a specified period of time. Physiological parameters such as heart rate, breathing frequency and skin temperature of participants were recorded using Equivital™ Life monitor. The jacket was found to perform as good as commercially available jacket available in the market.

Keywords: *spacer fabric, ergonomics, physiological comfort*

1. INTRODUCTION

Thermo-physiological comfort of winter clothing and garment assemblies has been investigated by many researchers [1-6]. Trapping of air within the fibrous assembly, creation of effective resistance to the penetration of external cold air and providing escape route for moisture vapour are the key design guidelines. Light weight, hollow and crimpy fibres have been very effective in this regard. Spacer fabrics being light weight and voluminous offers an opportunity for its use in winter jacket as insulating layer. However, being too porous in nature, it cannot be used in isolation as it will lead to significant convective heat loss. There is need to develop suitable fabric assembly using spacer fabrics to ensure its use in winter garments. An attempt has been made to explore such by developing a jacket for mild winter (temperature 5^0C -20^0C) and evaluate its ergonomic performance by measuring physiological parameters.

2. METHODOLOGY

First, two commercial jackets of exactly similar design and made by same manufacturer were procured from the market. One jacket was kept separate (J1) for wear trial and the other was cut for evaluation of fabric properties. The jacket consists of three layers. The nonwoven middle layer is sandwiched between a lining fabric and a knitted fabric. Fabric areal density was measured using GSM cutter and a weighing balance. The thickness was measured on Essdiel thickness tester under standard pressure. At least six samples were tested. The weight and thickness of the commercial Jacket (J1) were 640 g and 1.46 mm respectively.

Typical climatic condition in winter in New Delhi, India is stated below-

Temperature range: 5 - 20 ^{0}C
Relative humidity: 40-58 %
Wind velocity: light breeze: 2 -12 km/h

Design features of jacket

A three layer fabric assembly was made keeping spacer fabric at the middle. The inner layer was 100% polyester woven fabric and the outer layer was cotswool fabric produced from cotton and wool fibre blend. The fabric areal density was measured as stated earlier. The composite fabric was then converted into a jacket (J2). The weight and thickness of the jacket were 650g and 2.77 mm respectively.

The fabrics used for making the jackets were evaluated for thermal and transmission properties. Air permeability was measured using Air-permeability tester FX-3300 following ASTM standard D737-04. The thermal resistance was evaluated using Sweating Guarded Hot Plate Instrument (Model: 306-200/400) often referred to as 'skin model', following ASTM F1868-12 (dry test) standard. The moisture vapour transmission rate was measured using PERME® W3/060 test system following ASTM D1653/E96 standard at 80% humidity level and 38°C (100F) temperature. The property particulars of the jackets are shown in Table 1.

Table 1: Jacket and its properties.

Jacket Image	Jacket type & weight	Areal density (g/m^2)	Thermal resistance R_{cf} (m^2 $^oC/W$)	Clo value	MVTR ($g/m^2/day$)	Air-permeability ($cm^3/cm^2/s$)
	J1 (640g)	310	0.1229	1.19	5038	6.91
	J2(650g)	478	0.1334	1.26	5028	11.86

WEAR TRIAL

For user trial male Indian students with characteristics shown in Table 2 were chosen. The trial was taken at an average temperature of 18±2°C, RH% 35±5%. Each test was conducted for 75 minutes, which includes 10 min rest in sitting position, then standing for 20 min, 10 min rest in sitting position, cycling for 20 min, and at last 15 min rest in sitting position.

Table 2: Physical characteristics of the subjects participated in the wearing test

Subject	Weight (kg)	Height (cm)	Age (years)	BSA (m^2)
1	62.8	156	23	1.62
2	52.8	165	25	1.57
3	57.5	178	24	1.72
4	69.4	171	23	1.81
5	62.6	171	30	1.73

The heart rate, breathing and skin temperature of participants were recorded using Equivital™ Life monitor consisting of body worn sensor electronics module(SEM) connected to a fabric chest belt. Along with the jackets vest, innerwear, shirt, trousers, shoes, socks were used as a complete clothing ensemble.

The two Jackets (J1& J2) were tested on the same day and on the same subject. There was a resting period of at least two hours in between two successive test run. The sequence of trial was randomized in terms of subject chosen and jacket worn.

3. RESULTS AND DISCUSSION

Heart beat rate and respiratory responses

As the level of activity increases the heart rate also increases and it decreases as the activity level decreases (Fig.1). Almost same trend was observed for each participants during the wear trial. Heart beat rate was found to be in normal range for particular person. No particular trend was observed for breathing rate (Fig. 2). All the results were found in the normal range.

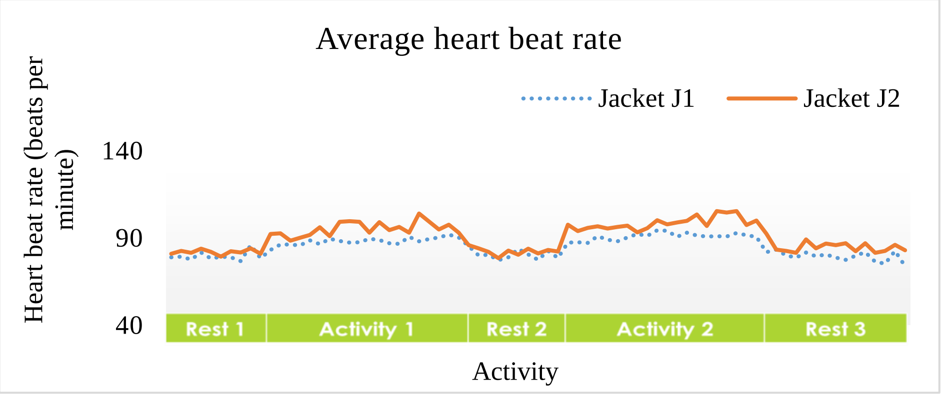

Figure 1: Average heart beat rate responses for jacket J1 and J2 during wear trial

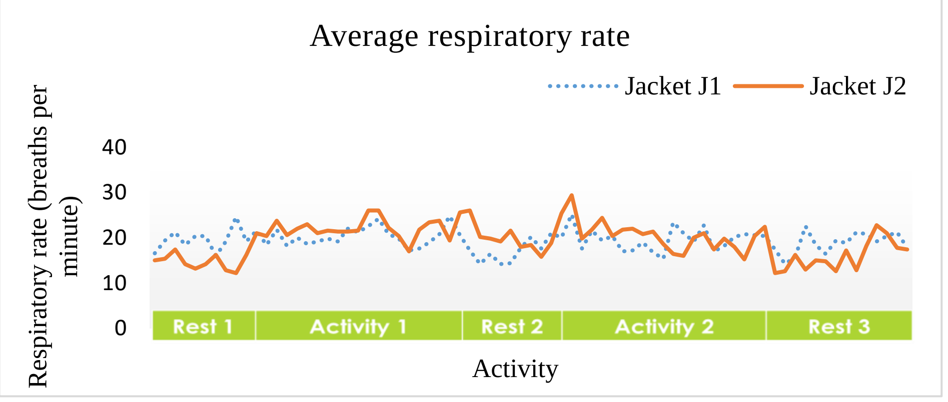

Figure 2: Average respiratory rate responses of for jacket J1 and J2 during wear trial

Skin temperature responses

Skin temperature was recorded using SEM (sensor electronics module). It can be seen from Fig.3 that for jacket J2, the average skin temperature is fairly constant during the whole wear trial as compared to jacket J1. Skin temperature increased slowly and dropped faster in commercial jacket J1 than jacket J2. Therefore, it is concluded that the developed jacket J2 is not inferior to the commercially available jacket J1.

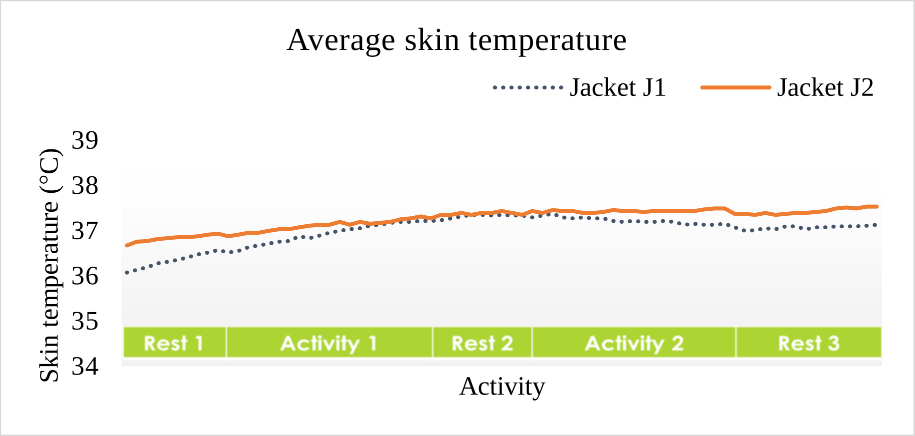

Figure 3: Average skin temperature of subjects wearing jacket J1 and J2

The summary of the results are shown in Table 3. The physiological parameters do not show much of a difference between Jacket J1 & J2. Thus the newly built jacket consisting of spacer fabric is as good as a commercial jacket.

Table 3. Summary of physiological parameters
(Average of the physiological parameters during the complete wear trial study)

Physiological parameters	Theory	Jacket J1	Jacket J2
Heart rate (bpm)	75 - 94	73.6 - 94.2	78.2 - 103.2
Respiratory rate (bpm)	8-10/12-18	14.2 - 25.2	12.2 - 29.4
Skin temperature (°C)	34-35	36.0 - 37.3	36.6 -37.5

4. CONCLUSION

No difference was observed in heart beat and respiratory rates. Skin temperature is slightly higher while wearing jacket J2, indicating better entrapment of body heat. The overall performance of developed prototype jacket was as good as commercially available jacket. Hence spacer fabric can be used as an insulating middle layer in winter jacket.

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STUDY ON COMPRESSION EFFICIENCY AND THERMO-PHYSIOLOGICAL COMFORT OF COMPRESSION ATHLETIC WEAR

A. Das[1], M. Manshahia[2]

[1]Department of Textile Technology, Indian Institute of Technology, New Delhi 110016, INDIA, apurbadas65@gmail.com
[2]Amity School of Fashion Technology, Amity University, Noida, 201301, INDIA, mmanshahia@gmail.com

Abstract

The fabric for compression athletic wear (CAW) are specially constructed in terms of geometry, packing density and structure of the constituent fibres in yarn as well as the construction of the fabric in order to achieve desired compression with the necessary dissipation of heat and moisture. The present study reports the effect of filament shape factor, elastane linear density and fabric tightness, on compression efficiency and thermo-physiological comfort properties of elastane polyester knitted CAW. Pressure drop and elastic recovery found to be significantly affected by fibre and fabric constructional parameters like loop length, linear density and cross sectional shape of filaments. The study suggests that filament shape factor significantly increase the fabric liquid transmission and overall moisture management capacity, however fabric becomes less permeable to air and moisture vapors at higher shape factor.

Keywords: *Compression athletic wear, Elastane Polyester plated fabric, Interface pressure profile, Thermo-physiological comfort*

1. INTRODUCTION

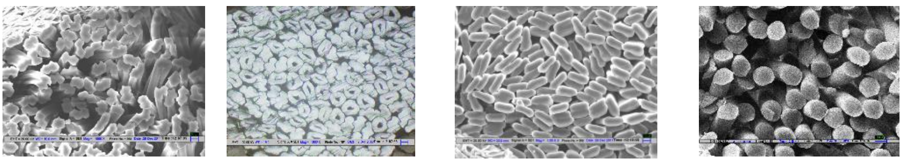
Compression athletic wear (CAW) provides the necessary interface pressure and anatomic fit to an athlete. The compression athletic wear (CAW), like tights, elastic shorts, improves the performance of players in number of active sports, like jumping, power lifting and running. In literature, some mechanisms have been proposed to explain the increased performance which is like reduced cardiovascular stress [1], increased lactate clearance [2] and improved leg power [3,4]. Compression garments create interface pressure on the muscles of wearer. Initial amount of interfacial pressure profile and its consistency with time are the two important evaluating factors to determine efficiency of CAW. It has been reported in past that interface pressure drops with time [5] as textile material get loosen at constant deformation due to stress relaxation [6]. Pressure drop in the range of 10-40% in eight hours has been reported for different

compression fabrics [7]. Increased running speed with reduced heart rate and muscle soreness has been reported with compression athletic wear [8].
Elastane content in fabric also affect the thermo-physiological comfort. Thermophysiological comfort deteriorates with increase in elastane content in compresioinal fabrics [9].Elastane can be included in the knitted structure with other filaments by using plating technique. Elastane in plating construction reported to make knitted fabric heavier and thicker with increased stitch density [10]. Tightness factor is reported to affect the dimensional parameters with increase in stitch density [11]. Fabric structural parameters, like thickness, pore size and pore density, reported to have significant effects on the comfort characteristics of knitted fabric [12]. Filament cross sectional shape with higher shape factor improves the moisture management [13,14] and affects the heat and moisture vapour transmission throught knitted fabric [15]. Another study [16] has been reported in past related to liquid moisture transmission of non-circular filaments in single jersey knitted structure but very few or no work has been found related to thermo-physiological comfort of profiled polyester elastane plated knitted fabrics. So the present work aims to study compressional efficiency and thermo-physiological comfort of elastane polyester plated knitted fabric.

2. EXPERIMENTAL

Polyester multifilament yarns of four types of different cross-sectional shapes i.e, tetrachannel, hollow tetrachannel, flat and circular, having shape factors 1.38, 1.28, 1.2 and 1.0 respectively, are selected. Elastane monofilament yarns at two levels of linear density, 44dtex and 78dtex, have been taken. Plated knitted fabrics have been prepared on 16 gauge flat knitting machine by feeding elastane and polyester at different feed positions such that elastane filament is on the technical back and polyester is on the technical face side of the fabric. Three levels of loop length were selected to study the effect of fabric tightness. All samples are dry relaxed and then heat set at temperature of 170ºC for 30 seconds in heating chamber. The wet relaxation has been done by washing, hydro extraction for 1 minute and tumble drying for 60 minutes at 70ºC. Samples are conditioned at temperature 27ºC ± 1ºC and relative humidity 65% ± 2% for 48 hours.

Filament cross sectional shape has been analyzed using scanning electron microscope (SEM) and cross-sectional images are given in Figure1. Air permeability of all fabric samples has been measured as per ASTM D737 by using Textest apparatus FX3300 at pressure of 100 Pa. Thermal and evaporative resistance has been measured using sweating guarded hot plate (SGHP) in non-isothermal conditions as per ASTM F1868 standard. Liquid moisture transmission was determined on M/K GATS instrument.



a. b. c. d.

Figure 1: Cross sectional shape of filament samples; a. Tetrachannel, b. Hollow tetrachannel, c. Flat, d. Circular

Fabric elastic recovery is evaluated on Instron tensile tester according to ASTM D 4964 – 96 standards. The fabric strip of width 50 mm has been tested at three extension levels of 20%, 40% and 60% at a gauge length of 100 mm and cross head speed of 500 mm/min for 10 cycles.The dynamic interface pressure of compression fabric is evaluated using instrument developed at IIT Delhi [17] as shown in Figures 2.

Figure 2: Schematic diagram of instrument to measure interface pressure

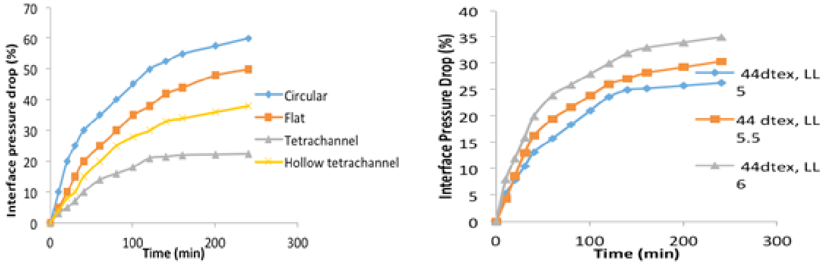
It consists of wooden mannequin limb of lower body including the foot, leg and thigh parts which are connected by ankle joint and by knee joint. These joints allow the wooden limb to bend at knee and ankle part which simulates the dynamic movement on an athlete, like walking, jogging and running. Two air bladders are placed on the leg part and thigh part which were just above and below of the knee joint respectively. An air inlet tube, connected both the bladders, has been filled with air by using a pumping assembly through separate air intake valve. The air pressure has been continuously monitored by differential pressure transmitter connected to other assembly. The pressure drop (%) was calculated by following equation (1):

$$\text{Pressure drop (\%)} = \frac{\_{0} - \_{t}}{\_{0}} \_100 \quad \ldots\ldots (1)$$

where $\_{0}$ is difference of initial pressure with and without compression fabric and $_{t}$is difference of initial pressure and pressure at any time t with compression fabric. Five tests have been carried out for each sample and their average is taken for analysis.

3. RESULTS AND DISCUSSION

The interface pressure determines the level of compression developed by CAW, whereas, the interface pressure drop profile gives an idea about consistency of compression with time. The results show that pressure dropped significantly with time for all the samples (Figure.3). This can be explained on the basis of change in mechanical properties of fabric due to plastic deformation of elastane material. It has been observed that pressure drops at faster rate initially and then rate of pressure drop slows down with time. This can be explained by stress relaxation phenomenon. At initial stages, the internal stresses are released by inter yarn slippage and yarn takes new position in structure leading to permanent deformation [18].



a. b.

Figure 3: a. Effect of filament cross-sectional shape; and b. Loop length on interface pressure drop (LL6- Loop length 6mm, LL5.5- Loop length 5.5mm, LL5- Loop length 5mm)

The results show that the fibre and fabric constructional parameters have significant effects on the elastic recovery and pressure drop with time. Modified polyester cross-sectional shape like tetra channel shows higher interface pressure retention with reduced pressure drop and improved recovery characteristics as compared to flat and circular cross sectional shape. It may be because filament frictional properties change for different cross sectional shape which may affect the level of inter yarn friction within fabric and level of stress relaxation.

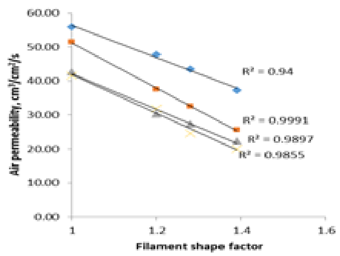
Fabric knitted at shorter loop length show better dynamic interface pressure characteristics as compared to fabric knitted at longer loop length. At shorter loop length, fabric stitch density increases and fabric becomes tighter. Tight fabric results in more crimped configuration of yarn in fabric with higher number of inter yarn contact points which resist the permanent extension of fabric and results in higher interface pressure with lower rate of pressure drop and good elastic recovery. Fabric knitted with coarser less initial interface pressure but with lower pressure drop over time.

Thermo-physiological comfort characteristics of elastane polyester plated high active sportswear have been studied by evaluating various properties, like air permeability, thermal properties, moisture vapor transmission and liquid moisture transmission. Filament dimension like cross-sectional shape is found to have significant influence on the fabric properties due to change in specific surface area. Multi-linear regression equations are calculated (Table1) which fit significantly for air permeability, permeability index, absorption capacity, in-plane wicking and OMMC, however equations for thermal resistance found to be insignificant with lower R^2 value.

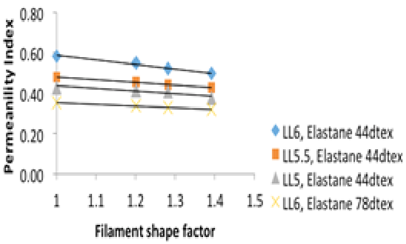
Table 1: Multi-linear regression equations with R^2 and p value

Comfort property	Multi-linear regression equation	R^2	p values for factor filament shape factor (X_1), loop length (X_2), elastane linear density (X_3)		
			$P(X_1)$	$P(X_2)$	$P(X_3)$
Air permeability ($cm^3/cm^2/s$)	$59.93 - 58.9X_1 + 13.88X_2 - 0.544X_3$	0.951	0.000	0.000	0.000
Dry Thermal resistance × 100 (ºC.m^2/W)	$-0.49 + 0.59X_1 + 0.58X_2 - 0.001X_3$	0.462	0.0030	0.000	0.000
Evaporative Resistance (Pa.m^2/W)	$0.923 + 3.24X_1 - 0.40X_2 + 0.77X_3$	0.76	0.0020	0.0210	0.000
Permeability Index	$0.288 - 0.13X_1 + 0.13X_2 - 0.007X_3$	0.966	0.000	0.000	0.000
Maximum absorption capacity (g/g)	$-4.577 + 3.90X_1 + 0.99X_2 - 0.04X_3$	0.985	0.000	0.000	0.000
Wicking speed (cm/sec)	$1.35 + 2.50X_1 - 0.81X_2 - 0.02X_3$	0.954	0.000	0.000	0.007
WT_t	$1.78 + 0.36X_1 - 0.87X_2 + 0.15X_3$	0.966	0.266	0.000	0.000
WT_b	$1.83 + 0.09X_1 - 0.66X_2 - 0.14X_3$	0.954	0.810	0.000	0.000
AR_t	$-83.3 + 48.6X_1 + 17.4X_2 - 0.9X_3$	0.854	0.000	0.000	0.000
AR_b	$-42.9 + 61.2X_1 + 10.2X_2 - 1.1X_3$	0.86	0.000	0.000	0.000
MW_t	$-54.7 + 39.94X_1 + 5X_2 - 1.93X_3$	0.904	0.002	0.000	0.005
MW_b	$-45.20 + 34.5X_1 + 5X_2 - 1.64X_3$	0.895	0.009	0.000	0.000
SS_t	$-17.8 + 7.2X_1 - 0.89X_2 - 0.01X_3$	0.854	0.000	0.000	0.420
SS_b	$5.19 + 3.87X_1 - 1.4X_2 - 0.01X_3$	0.924	0.000	0.000	0.031
AOTI	$-98.3 + 125.4X_1 + 50.2X_2 - 3.5X_3$	0.850	0.007	0.005	0.000
OMMC	$-0.42 + 0.89X_1 + 0.1X_2 - 0.014X_3$	0.964	0.000	0.003	0.001

WT_t: Top wetting time; WT_b: Bottom wetting time; Ar_t: Top absorption rate; Ar_b: Bottom absorption rate; MWR_t: Top Maximum wetting radius; MWR_b: Bottom Maximum wetting radius; SS_t: Top spreading speed; SS_b: Bottom spreading speed; AOTI: one way transport; OMMC: Overall moisture management capacity



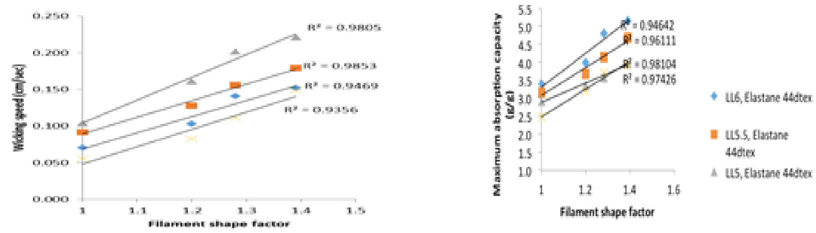
a.



b.

Figure 4: Effect of filament shape factor on, (a) air permeability; and (b) permeability index at various loop length and elastane linear density (LL6- Loop length 6mm, LL5.5- Loop length 5.5mm, LL5- Loop length 5mm)

The results reveal that fabric becomes less permeable to air and moisture vapours at higher shape factor and shorter loop length of fabric knitted with course elastane (Figure 4). Filament with higher shape factor offers more specific surface area which makes less space between fibres in the fabric and offers more drag resistance to air and moisture vapor flow resulting in low value of permeability to air and moisture vapour. Increased fabric tightness at higher linear density of elastane filament also explains the lower permeability index as compared to fabrics knitted with finer elastane filament.

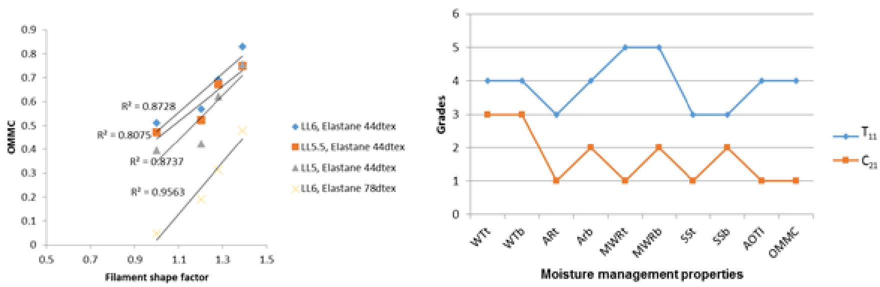


a. b.

Figure 5. Effect of filament shape factor on, (a) wicking speed; and (b) absorption capacity at various loop length and elastane linear density (LL6- Loop length 6mm, LL5.5- Loop length 5.5mm, LL5- Loop length 5mm)

Fabric knitted with tetrachannel cross-section showed higher wicking rate and absorption followed by hollow tetrachannel and flat, whereas circular filament showed minimum in-plane wicking (Figure 5). Higher specific surface area of tetrachannel filament as well as minute channels formed along the filament length increases the liquid moisture transportation through fabric.
Fabric liquid transmission and OMMC significantly increases with increase in filament shape factor (Figure 6). Filament of flat cross sectional shape make fabric thin with lowest thermal resistance but its absorbent capacity also decreases due to reduced fabric porosity.

Fabric loop length plays a vital role in determining the heat and mass transmission through fabric by changing fabric tightness. Fabric knitted at longer loop length make it more permeable to air and moisture vapours with better absorption capacity and OMMC but lower in-plane wicking as compared to fabric knitted at shorter loop length. Elastane content is also varied by changing elastane linear density. Increase in elastane linear density deteriorates the thermo-physiological comfort of sportswear.



a. b.

Figure 6. Effect of filament shape factor on OMMC index at various loop length and elastane linear density (LL6- Loop length 6mm, LL5.5- Loop length 5.5mm, LL5- Loop length 5mm)

4. CONCLUSIONS

Polyester knitted fabrics are widely used in active sportswear for its superior moisture management and it is combined with elastane to achieve necessary compression. Under dynamic conditions of test, interface pressure drop reduces with time due to stress relaxation of fabric during prolonged repetitive movement at knee position. Fabric knitted at longer loop length shows more permeability to air and moisture vapours but lower in plane wicking as compared to fabric knitted at shorter loop length. Fabric knitted at shorter loop length shows higher interface pressure with lower rate of pressure drop and good elastic recovery. The thermo-physiological comfort of sportswear deteriorates whereas interface pressure profile and elastic recovery improves with increase in elastane linear density. Filament shape factor significantly increase the fabric liquid transmission and overall moisture management capacity however fabric becomes less permeable to air and moisture vapours at higher shape factor. Filament shape factor also improves fabric elastic recovery and reduce interface pressure drop.

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ANTIOXIDANT SUPPLEMENTATION AND EXERCISE INDUCED FATIGUE: ROOIBOS ASPALATHUS LINEARIS

S. E. H. Davies[1], S. West[2], M. S. Taliep[3], F. Rautenbach[4], J. L. Marnewick[5]
Cape Peninsula University of Technology, Cape Town, 8000, South Africa,
[1]daviess@cput.ac.za, [2]wests@cput.ac.za, [3]talieps@cput.ac.za,
[4] rautenbachf@cput.ac.za, [5]marnewickj@cput.ac.za

Abstract

This study investigated whether rooibos (Aspalathus linearis) has an ergogenic effect during a fatiguing strength test to exhaustion. Sample included 33 male participants who ingested standardized rooibos or placebo capsules for four weeks; followed by a maximal fatiguing elbow flexion/extension exercise entailing 5 sets of 15 repetitions of maximum voluntary contractions separated by 10-second rest intervals on a Biodex System 3 at a speed of 60° per second. Peak torque flexion was significantly ($p<0.05$) higher in the Rooibos experimental (R_e) compared to the Placebo control (P_c) during the 3rd set and average peak torque across the 5 sets were significantly ($p<0.05$) higher in the R_e compared to the P_c Placebo. The antioxidant properties of rooibos appear to have allowed for an improved physical performance compared to the control during a repetitive isokinetic arm elbow flexion/extension exercise protocol to induce fatigue.

Keywords: *rooibos, antioxidant, exercise, ergogenic supplement*

1. INTRODUCTION

There continues to be considerable debate regarding the effect of antioxidant supplementation on oxidative stress during exercise in humans. Much of the research thus far has tended to concern itself almost exclusively within the field of sport and exercise science. However, less research has examined antioxidant supplementation in the context of physical work that forms part of habitual employment and related activities. Packer contends that while exercise is known to have many beneficial effects, there is much evidence that free radical production increases during exercise, and that oxidative damage occurs in the muscle, liver, blood and perhaps other tissues [1].
The nutritional status of the worker has the potential to influence many work tasks and will therefore impact on the outcomes derived from ergonomics assessments, however nutrition is very rarely considered in these investigations nor its potential to reduce the chronic-disease risk of the worker [2].
As previously mentioned the field of sports and exercise science has prioritized research into nutritional strategies to optimize performance and from these investigations best-practice evidence-based recommendations and position stands have been developed [3]

During physical exercise oxidative stress occurs, which can result with an imbalance in the human body homeostasis, i.e. the production of pro-oxidants becomes excessive, certainly during heavy bouts of physical exercise and the cellular antioxidant mechanisms cannot neutralize these radicals [4].
Ristow and co-workers highlight the dilemma that while exercise may induce undeniable health benefits, on the other hand exercise may also increase mitochondrial formation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which can cause cellular damage [5]. When produced in excess, free radicals promote cellular oxidation, damage in the DNA structure, resulting in aging and a variety of diseases such cancer, neurodegenerative diseases, arteriosclerosis amongst others [6], and furthermore impair skeletal muscle function that may cause pain and, thereby affecting exercise performance [7].
However, the body has some unique mechanisms to combat the formation of free radicals and other ROS and RNS notably an endogenous antioxidant defence system, composed of enzymes notably catalase, superoxide dismutase, glutathione peroxidase and glutathione reductase (GR) and non-enzymatic antioxidant (glutathione) whose major role is to detoxify and/ or attenuate the harmful effects of ROS [8].
Furthermore, the endogenous antioxidant system can be complimented by exogenous antioxidant supplementation, which can also protect the cells against deleterious effects of ROS, attenuate excess free radicals and generally maintain redox balance that provides further protection against diseases [9].
Exogenous antioxidant supplementation is often derived from herbal plants that have abundant polyphenols that act as chain breaking antioxidants and mop up active oxygen species that are normally engaged in free radical reactions of lipid peroxidation, furthermore, they can delay the rate of protein oxidation by either chelating metal ions, scavenger oxygen or transform hydrogen peroxide into non-radical product/form [10].
Thus in an attempt to minimize the effects of oxidative stress during physical activity, many athletes and sports professionals are ingesting herbal plants with known antioxidant qualities including rooibos *Aspalathus linearis* [11]; ginkgo biloba [12]; as well as research into oligomeric proanthocyanidins (OPCs), also referred to as polyphenols and more specifically polymers of flavanols found in grape extract [13].
Additionally nutritional antioxidant supplements such as selenium, vitamin C and E health impacts have been well explored within an exercise context in attempts to counteract and/ or minimise effects of ROS [1,] as well as Glutathione [14].
It is therefore apparent that there is considerable debate around the benefits of ingesting antioxidants for improvement in exercise and physical activity performance. However, Packer (1997) makes the point that antioxidant supplementation may be most relevant for persons who habitually engage in regular physical work, and the real benefits from antioxidant supplementation is more likely to occur over the long term by minimizing the damage as a consequence of exercise-induced free radical increase [1]. This paper alludes to the potential of rooibos *Aspalathus linearis* as an effective antioxidant for the mitigation of fatigue in occupations characterized by repetitive physical actions. Furthermore, rooibos may also provide scope for the amelioration and development of work related upper limb disorders (WRULDs), typically induced by assembly line activities, which are now a recognized occupational disease.

2. ROOIBOS - ASPALATHUS LINEARIS.

Rooibos *Aspalathus linearis* is naturally caffeine free and contains very low levels of tannins [15], and is known to have antioxidant qualities. Rooibos is an important dietary source of antioxidants containing mostly flavonoids, but also the unique C–C linked dihydrochalcone glucoside, aspalathin [16] and the recently discovered cyclic dihydrochalcone, aspalalinin [17].

The premise of this paper is based on a research study that investigated whether ingesting rooibos prior to repeated bouts of arm flexion / extension exercise to exhaustion resulted in an improvement in physical performance.

The present study was instigated to gain further insight into the possible benefits of rooibos ingestion to humans and reports on the modulation of exercise performance during an isokinetic fatigue exercise test. The rationale for the choice of study population was based on the view that elevated oxidative stress may be required for clear detection of improvements from dietary antioxidant intervention.

3. AIMS OF THE STUDY

The main aim of the study was to assess whether ingesting rooibos polyphenols prior to a repeated arm flexion/extension fatiguing exercise protocol (isokinetic controlled movement at 60 degrees per second) to exhaustion could result in enhanced physical performance (demonstrated by increased force (Nm) output).

4. METHODOLOGY

The sample included thirty three adult male participants (mean age 22.2 years) who were randomized in a single blinded, cross-over placebo controlled study. All participants volunteered and completed an informed consent form. The study conforms to the principles of the Helsinki Accord and approved by the institutional ethics committee (FOBREC 168).

The participants were required to ingest standardized rooibos or placebo capsules for four weeks prior to the exercise insult, which entailed a maximal fatiguing elbow flexion/extension exercise including 5 sets of 15 all-out voluntary contractions separated by 10-second intervals on a Biodex System 3 at a speed of 60º per second. Depending on which arm of the study the participant had been randomly assigned (rooibos or placebo), the protocol was repeated with a change in the supplementation regime.

Figure 1: Isokinetic elbow arm flexion/ extension set up on Biodex.

5. RESULTS

The results show the responses of particpants during a randomized single blinded, cross-over placebo controlled study. Descriptive data is presented in respect to the basic anthropometric characteristics of the particpants (see Table 1).

Table 1: Anthropometric chracteristics of particpants (Mean values with standard deviations in parentheses).

Age	Mass	Stature	Body Fat %
22.22 (4.27)	74.61 (13.50)	174.20 (7.17)	16.27 (3.21)

The data presented is divided into peak torque values (see Table 2 and Figure 2) and average peak torque values (see Table 3 and Figure 3).
The results show that the peak torque flexion was significantly (p<0.05) higher in the Rooibos compared to the Placebo trial during the 3rd set and average peak torque across the 5 sets were significantly (p<0.05) higher in the Rooibos compared to the Placebo.

Table 2: Elbow arm extension and flexion: Peak torque (Nm) (Mean values with standard deviations in parentheses).

Extension	Bout 1	Bout 2	Bout 3	Bout 4	Bout 5
Rooibos	32,43 (7,66)	31,10 (6,98)	31,74 (8,44)	30,29 (8,55)	31,89 (8,86)
Placebo	33,30 (8,28)	31,41 (7,67)	29,60 (5,84)	29,27 (5,84)	31,35 (7,58)
Flexion	Bout 1	Bout 2	Bout 3	Bout 4	Bout 5
Rooibos	48,20 (10,80)	41,71 (10,71)	39,17 (10,14)	36,46 (8,88)	37,06 (8,86)
Placebo	45,57 (9,58)	39,13 (8,82)	35,56 (7,56)	33,34 (7,02)	34,89 (8,04)

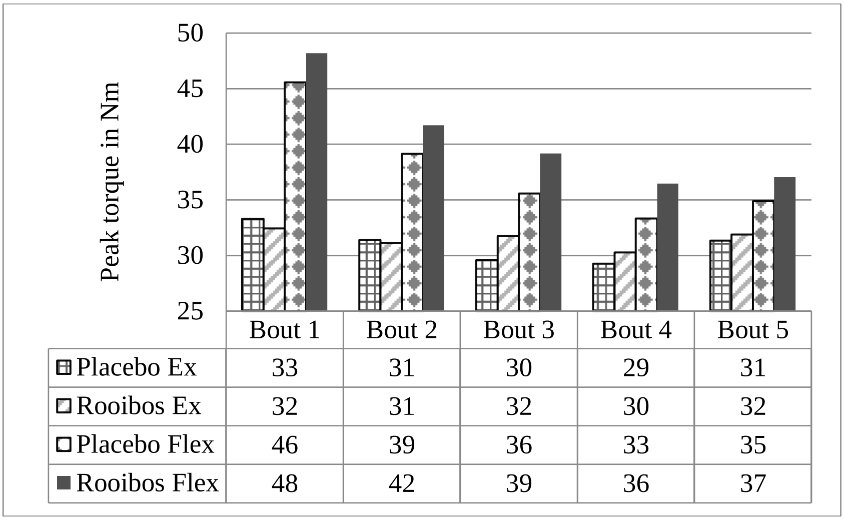

Figure 2: Elbow arm extension and flexion: Peak torque (Nm)

Table 3: Elbow arm extension and flexion: Average peak torque (Nm) (Mean values with standard deviations in parentheses).

Extension	Bout 1	Bout 2	Bout 3	Bout 4	Bout 5
Rooibos	26,22 (7,21)	25,14 (5,51)	24,44 (5,92)	23,59 (6,17)	24,56 (6,50)
Placebo	27,51 (7,81)	25,55 (5,51)	23,93 (4,90)	23,45 (4,65)	24,22 (5,24)
Flexion	Bout 1	Bout 2	Bout 3	Bout 4	Bout 5
Rooibos	41,56 (10,06)	34,93 (9,30)	31,53 (7,60)	29,37 (7,14)	29,88 (7,17)
Placebo	39,62 (9,54)	32,78 (7,65)	29,16 (6,73)	27,02 (6,21)	28,10 (6,72)

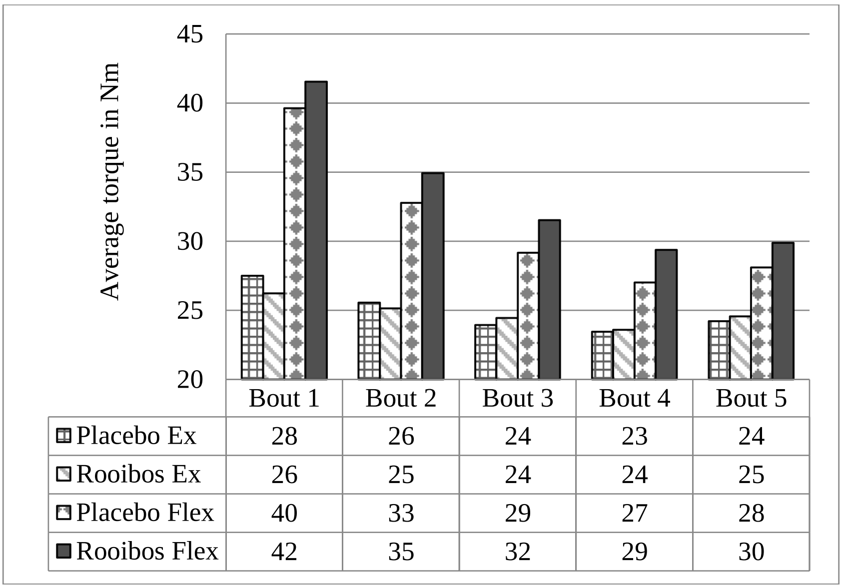

Figure 3: Elbow arm extension and flexion: Average peak torque (Nm)

6. DISCUSSION

The results form this study show that antioxidant supplementation during physical activity may have important considerations for ergonomic and human factors practitioners. It is argued here that the potential benefits of antioxidant ingestion, especially in tasks characterized by repetitive physical work may provide further support for Shearer's view that a better understanding of the nutritional status of the worker has the potential to influence many work tasks [2]. It is acknowledged that whilst a substantive amount of research has focused on the biomechanical and physiological parameters of workers [18], less attention, however has been given to nutritional issues. In particular the role of antioxidant supplementation has hitherto attracted little if any research in the field of ergonomic and human factors. The results from this study provide an indication that supplementation with a known antioxidant such as rooibos *Aspalathus linearis* may have benefits for those persons engaged in repetitive, and often fatiguing physical tasks. Furthermore, if the work task is characterized by rapid or repetitive motion, forceful exertion and excessive mechanical force concentration then the literature suggests there is a heightened risk of developing WRULDs [19]. The results from this study suggested that ingesting rooibos and/or other antioxidant supplements may not only lessen the onset of fatigue, but may also have important implications for the reduction and/or avoidance of reported WRULDs.

7. CONCLUSION

This study indicated that individuals who ingested rooibos *Aspalathus linearis* prior to a repetitive fatiguing exercise protocol generated a significantly ($p<0.05$) improved average muscular force output (Nm) over five the exercise bouts and furthermore demonstrated a significant ($p<0.05$) elevation of peak muscular force output during the 3rd exercise bout. It is tentatively suggested that a worker engaged in tasks of a repetitive nature requiring forceful actions may benefit from supplementing his/her diet with rooibos *Aspalathus linearis* a recognized antioxidant, because it may reduce perceived (and actual) physical fatigue, but also lessen the risk and onset of WRULDs. It is a recommendation that further research is conducted to establish the efficacy of rooibos as an effective supplement for enhancing physical performance for those persons engaged in repetitive physical tasks.

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THE INFLUENCE OF SUPPORT ELASTICITY ON SITTING COMFORT

L. Dénes[1], P. G. Horváth[2], E. Bálint[3], R. M. Antal[4]
[1] University of Sopron, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Sopron, HUNGARY, denes.levente@uni-sopron.hu
[2] University of Sopron, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Sopron, HUNGARY, horvath.peter.gyorgy@uni-sopron.hue-mail
[3] Transilvania Furniture Cluster, Cluj-Napoca, ROMANIA, ede.balint@mobiliertransilvan.ro
[4] University of Sopron, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Sopron, HUNGARY, antal.maria.reka@uni-sopron.hu

Abstract

The comfortable sitting plays an important role in reducing the risk of musculoskeletal disorders and linked with the continuous increase of the computer aided office work duration justify the intensification of researches focusing on healthy chair development. Majority of the body's weight is placed upon the supporting area of the seat pan therefore a special attention should be paid on the seat cushions. The main objective of this research is to evaluate the influence of support geometry and elasticity on the sitting comfort. For data acquisition, the Tekscan's CONFORMAT body pressure distribution measuring system was used. The effect of geometry and flexibility was evaluated by the peak pressure and contact surface values. Research data and analysis revealed that seat cushion structure and cushion support's characteristics significantly influence the body pressure distribution, an important factor in seat comfort determination.

Keywords: *sitting comfort, body pressure distribution, seat pan elasticity, seat geometry, ergonomics*

1. INTRODUCTION

Surveys and studies show that more than 50% of employees in the EU perform high- or low-skilled white collar work, predominantly in offices [1]. The prolonged sitting combined with reclining and sleeping results in a persistent contact of the body with a cushion having various flexibility. Statistics reveal the importance of ergonomic sitting since the proper ergonomic seating furniture with proper use can help to reduce injuries and the so-called cumulative trauma disorders (CTDs), which often results from repetitive movements for prolonged periods of time. From ergonomics point of view, the high comfort is related to the well-being, safety feeling and healthy sensation of the users. The comfort of a seating furniture is the combination of the embedded materials, construction and other design factors like dimensions, tilt angles, etc., which may either, add to or detract from the comfort of the finished product. Construction of upholstery, shape and hardness of the sitting surface are included also into features, which determine the sitting

comfort [2]. One of the basic factors of contemporary comfort is the specific pressure to the body, which is smaller when the contact surface of the human body is larger [3], [4]. Other scientific articles focused also on revealing the relationship between sitting comfort and design specifications with the aim of reducing the discomfort of chair users. For example, Manfield *at al*. analyzed the discomfort in vehicle seats and concluded that foam composition can have significant implications on people undertaking journeys of long duration (more than 40 min. in the conditions tested) [5]. They compared different foam types and determined the difference in overall seat discomfort. Small changes to foam composition were shown to affect the overall discomfort in the seat. An experiment conducted by Vlaović *at al.* determined the comfort index (support factor) of chairs obtained from elastic characteristics of materials in the seat of chair [6]. In another study analyzing different types of seats, they concluded that the chair with molded PUR foam is significantly more comfortable than the chair with springs, but statistically it does not differ significantly from the chair with polyurethane foam cushion. According to Vink and Lips the form of the area contacting the body and the softness of this area influence the contact area between the body and the product. The pressure sensitivity of the skin and underlying tissue also plays an important role in the comfortability. In order to create a comfortable seat it is important to define the foam characteristics of the seat pan or the flexibility of the material underlying the foam [7].
The main objective of this research was to evaluate the influence of different supports on body pressure distribution placed under a three layered foam cushion and using a standard loading pad. A second objective of this research was to determine the optimal arrangement of a cushion system consisting of the layered foams and elastic supports.

2. MATERIALS AND METHODS

Polyurethane foams are frequently used components of the upholstery furniture of nowadays. Combined with other flexible materials like springs, felts, belts, latex or using layered foam structures of various firmness assure the comfort of seating and sleeping. Flexible polyurethane foams are soft, durable yet provide good support and maintain their shape therefore are preferred as filling materials for seating cushions and mattresses and can be produced to the density required by the manufacturer. In this research open cell polyurethane foams with different densities (Soft N3530 – 35 kg/m3 (grey); Normal N2538 – 25 kg/m3 (violet); Comfort R4342 – 43 kg/m3 (green) produced by Eurofoam Hungary Ltd were used.

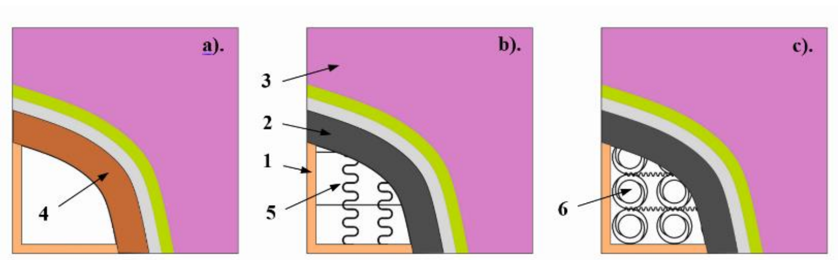


Figure 1: The foam support system, a – plywood (4); b – sinusoidal spring (5); c – bonell spring (6) (1 –wood frame; 2- protective felt; 3 – foam layers)

The selected foam types are commonly used by upholstery manufacturers in Hungary and belong to the Eurofoam Classic foam family, class N and R with the characteristics presented in a previous article [8]. Three types of support with different elasticities fixed on a wooden frame were placed under the foams: bonell spring, sinusoidal spring and plywood respectively (Figure 1). Between springs and foam sheets a protective textile was engaged. 600mm x 600mm sheets with a thickness of 20 mm were prepared from the selected foam types and a 3-layered structures arranged in different combinations of the foam and support types, resulting in 42 experimental setups, totally. The layered structures were loaded with an anatomical seat loading pad according to standard EN 1728:2012 [8]. On each cushion structure loads of 250 N, 500 N, 750 N, and 1000 N was exerted using the standard loading pad for chair tests, the maximum set load values were attained in 3 seconds. 42 measurements were made totally using the Tekscan's Body Pressure Measurement System (Conformat) with pressure sensitive foils size of 488 × 427 mm containing 2016 pressure points with pressure range of 0-350 mm Hg, and accuracy of + / - 3.5 mmHg. The computerized data recorder provides a real-time picture of the pressure distribution. Figure 2. shows the schematic principle of measurements:

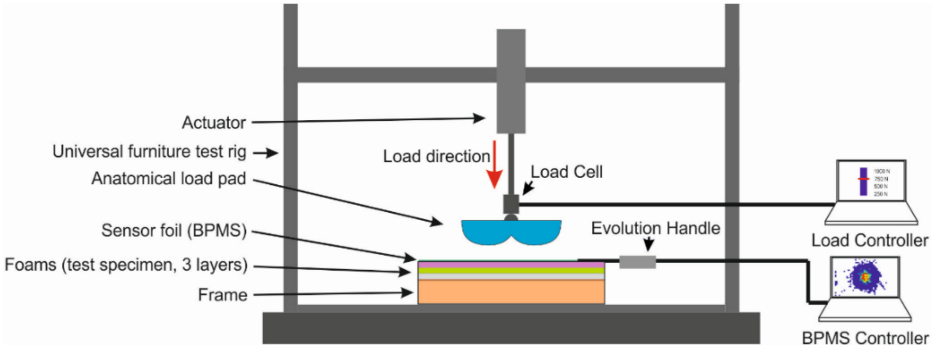


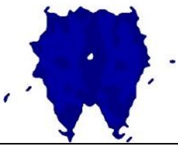
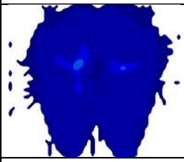
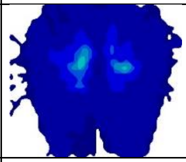
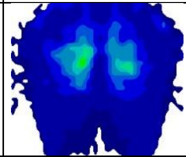
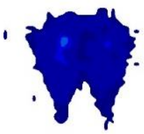
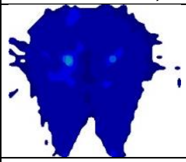
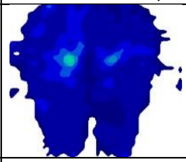
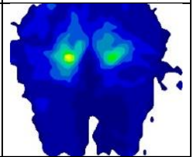
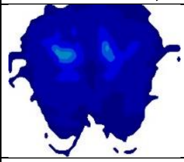
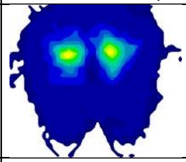
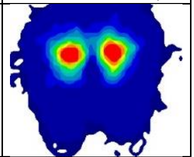
Figure 2: Pressure measurement system

Before using the BPMS measuring system the pressure sensor foils were calibrated with the help of a vacuum pump. After calibration the pressure maps of layered foam structures loaded with four compression force values were collected and analyzed with the software delivered with the system (BPMS Research 7.20) in the form of image (.fsx or .jpg) or short (0-200 s long) video files. On the recorded pressure maps, the contact surface area and peak pressure values were determined.

3. RESULTS

The pressure distribution maps were recorded for all cushion' variations at the set force values and analyzed based on the contact area, pressure dispersion, pressure intensity of different zones, etc. In Table 1. the results for the structure composed of three soft foam layers are presented.

Table 1: Pressure distribution maps of the soft foam

Soft foam	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm^2	823,7	1383,2	1563,9	1700,1
peak pressure, N/cm^2	0,41	0,83	1,20	1,58
Sinusoidal spring				
contact area, cm^2	624,5	1160,3	1407,0	1536,0
peak pressure, N/cm^2	0,76	0,94	1,34	1,95
Plywood				
contact area, cm^2	773,2	1226,3	1369,8	1464,8
peak pressure, N/cm^2	0,50	0,97	1,99	3,10

At lower loads the differences between supports are more moderate, the sinusoidal spring shows the lowest contact area and similar peak pressure as the plywood support. When using higher loads there the differences between the two contact areas are less then 5%, however the peak pressures are 30% higher. The bonell spring support assures the highest contact areas in all cases and the lowest peak pressures near the ischial tuberosity.
In Table 2. we find the pressure maps and data related to the use of comfort foam layers. At loads of 250N and 500N there are comparable values with soft foam usage. The load increase resulted in lower peak pressures when plywood support was used, the firmness of foam attenuated the load effect. The bonell spring support decreased the peak pressures even though the contact areas were lower than in previous case. The peak pressures decreased with approximately 20% compared with soft foam layers. Least differences were observed when sinusoidal springs were used.
Based on a prior research which analyzed the effect of density and elasticity of a layered polyurethane foam cushions [9], an optimum system comprising a soft-comfort-comfort foam layers was determined. Table 3 contains the pressure maps and contact area and peak pressure values measured in the case of optimum system. The softness of the top layer and firmness of the bottom layers combined with a bonell spring support offered the best comfort of the system with the lowest peak pressures and uniform pressure distributions. The foam layers could dampen the effect of the hard plywood support. Even though no differences between contact areas were observed at increased loads using the sinusoidal support, the peak pressures decreased with 13% at 750N and 21% at 1000 N.

Table 2: Pressure distribution maps of the comfort foam

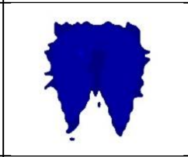
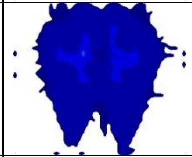
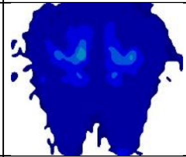
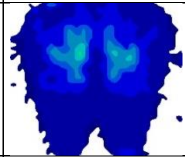
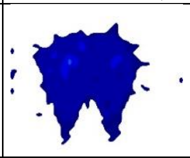
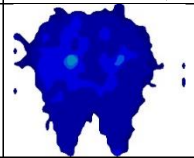
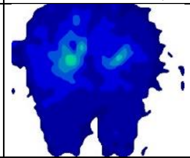
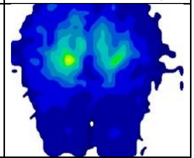
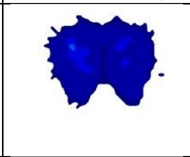
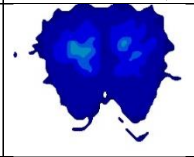
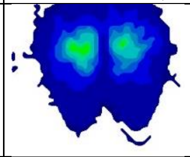
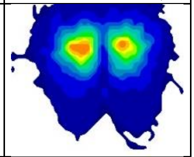
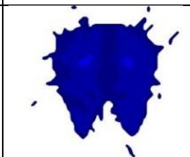
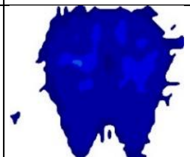
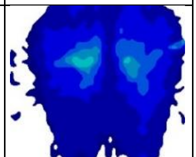
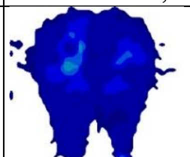
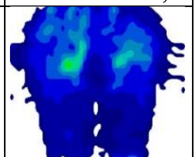
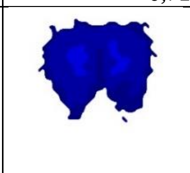
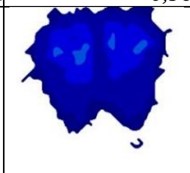
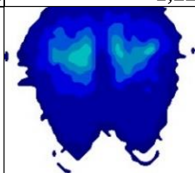
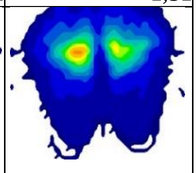
Comfort foam	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm^2	631,7	1107,6	1398,7	1570,1
peak pressure, N/cm^2	0,42	0,66	0,99	1,28
Sinusoidal spring				
contact area, cm^2	607,0	1052,9	1365,7	1489.6
peak pressure, N/cm^2	0,66	0,98	1,40	1,91
Plywood				
contact area, cm^2	571,9	970,3	1157,2	1254,2
peak pressure, N/cm^2	0,64	1,01	1,55	2,46

Table 3: Pressure distribution maps of the layered structure

3 layered structure	250 N	500 N	750 N	1000 N
Bonell spring				
contact area, cm^2	717,4	1180,0	1462,7	1613,4
peak pressure, N/cm^2	0,47	0,64	0,93	1,18
Sinusoidal spring				
contact area, cm^2	693,7	1140,6	1384,3	1491,6
peak pressure, N/cm^2	0,71	0,96	1,22	1,51
Plywood				
contact area, cm^2	632,8	1033,3	1266,6	1378,1
peak pressure, N/cm^2	0,53	0,80	1,20	2,30

4. CONCLUSIONS

In this paper the comfort related pressure distribution on layered foam system combined with a flexible support was measured using a body pressure measuring device and standard loading pad. Based on results the effect of support on the contact area and peak pressure was confirmed. The peak pressure attenuation depends on the applied load too, at higher pressure forces (500 N, 1000 N) the damping effect is more accentuated. The bonell spring support with its highest elasticity demonstrated to be the best combination of the analyzed variables from comfort point of view.

ACKNOWLEDGEMENT

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ERGONOMICS FOR PRODUCTIVITY IN ORDER-PICKING PROCESSES FOR AGING WORKFORCE

B. Gajšek[1], H. Cajner[2], G. Đukić[2], T. Opetuk[2], B. Lukač[2], N. Puškadija[2]
[1] Faculty of Logistics, University of Maribor, Celje, SLOVENIA, brigita.gajsek@um.si
[2] Faculty of mechanical engineering and naval architecture, University of Zagreb, Zagreb, CROATIA, goran.dukic@fsb.hr

Abstract

With better healthcare, longevity and lower birth rates the world is seeing a major change in demographic trends. The impact of this transition means that there will be a change in the labour supply. Many industries will have to adjust either by bringing more of the youth population into their workforce or by attracting more workers from the older population. One of interesting areas under a challenge is manual order-picking, a process in which humans are routed to items' storage locations to retrieve items for customers. Its activities are costly due to large resource and time consumption. Care for workers' health is often neglected at the expense of productivity due to ambiguity around argument that costs can by reduced by lowering of ergonomic risks. Analysing experimentally obtained data on time consumption and ergonomic loads for younger and older order-pickers we define possible scenarios and measures for adaption on changed demographic trends.

Keywords: *ergonomics, aging population, order-picking, picker-to-parts, productivity*

1. INTRODUCTION

By 2050, two billion people will be aged 60 or over, a proportion that brings with it many implications for society [1]. One of them is an increased percentage of older workers. Studies about aging workers demonstrated that the functional capacities, mainly physical, show a declining trend after the age of 30 years, and the trend can become critical after the next 15–20 years, so that from 45 to 64 years old there is a significant decrease of their capacities, both physical and cognitive ones [2]. Such loss is about 20–25% in respect to the full capacity considered at 30 year old, and it affect both workers involved in physically demanding jobs and mentally demanding positions. Therefore, the age of 45–50 years have often been used as the base criterion to refer to ‘‘aging worker” [3].
The impact of mentioned transition means that there will be a change in the labour supply. The concerns are especially critical for industries which are well-known for their high level of labour intensity and above-average labour turnover rate. International Labour Organization (ILO) suggests that such sectors should review their employment practices, work processes and working environment to improve their ability to attract and retain more people aged 50 and over [1]. We are joining this initiative with the research of

manual order-picking (MOP), a process in which humans are routed by picking lists to items' storage locations to retrieve items for customers.

Numerous scientific articles confirm that MOP is one of the most labour- and time-intensive process in warehousing [4-8], preferably done by younger people. Over the last decades, research has focused on developing mathematical decision support models that help to increase the efficiency of MOP, for example by defining optimal warehouse layouts, storage assignments or picker routes [4]. The existing studies have, in most cases, a one-sided focus on cost efficiency objectives and its direct determinants, and little attention has been paid to the human factor (HF) in designing the system that would ultimately determine the performance of the operators and their long-run health and safety [4]. Only recently some research papers appeared, including ergonomics/HF as a part of decision making process in MOP [4, 5]. However, there are no experimental comparisons of the MOP process execution between young and older order-pickers. Therefore, the problems related to aging workforce in MOP are still not addressed. Authors of literature reviews motivated us for researching the possibilities of incorporation of HF in order picking at maintained or even increased productivity. Knowing the differences/similarities in the execution of the order picking (OP) process between the two groups of employees would help to create working environment and conditions, which would allow to the both groups of employees to achieve the expectations of the employer. Consequently, the hypothesis that older order-picker are slower than their younger colleagues is stated. This paper presents experimental research results and answers in which steps of performing order picking process larger differences occur, followed by proposed guidelines for improvements.

2. OLDER PEOPLE AND ORDER PICKING PROCESS

2.1 AGEING

According to a recent review on welfare in Europe [9] the item 'ageing' is at the first rank of social expenses of the European Union, covering 33.4% of the total costs. Hence, one the most important issues is now to maintain good health conditions of ageing workers, in order to promote their work ability, autonomy and social integration, despite the increasing social and work discrimination of aged workers, which is evident both in their recruitment and career perspectives, as well as professional recognition. These trends and conclusions are followed by the scientific sphere, which explores the changes in work ability of various age groups and factors that influence them. The age range targeted by ergonomics intervention for the ageing worker is defined as from 45 to 65 years of age [10].

During literature review we found some interesting results that could also apply to the MOP. Costa and Sartori [11] noticed a decreasing trend of Work Ability Index (WAI) over the years of work, but also that it may change differently over the years according to several factors dealing, on one hand, with working conditions and, on the other, with personal health status. In jobs with higher mental involvement and autonomy, but lower physical constraint (e.g. clerks, physicians and biologists), the WAI remains quite constant and high over the years, while it significantly decreases with a steeper trend the higher the physical work load and the lower the job control (e.g. light manual workers, nurses, heavy manual workers). It is expected that WAI will lower with years of work as order-picker. It will probably be lower for women than for men. Work at shifts, night work and the occurrence of illness can further reduce WAI. Scientific literature in order to maintain WAI suggests limitation or abstention from night work after 45–50 years of age, reduced work load, shorten working hours and/or increase rest periods, arrange more frequent health checks, give proper counselling and training on the best coping strategies concerning sleep, diet, stress management, and regular exercise [11]. Studies recommend monitoring individual worker and taking measures to improve working conditions according to his/her current psycho-physical condition. Crawford et al. [12] come also to very similar conclusion. Their research on ageing workers has highlighted both physical and psychological change occurring in those aged >50 years; however, those changes are subject to large inter-individual differences and can be reduced by maintaining activity. They propose more research to aid in the health and safety management.

2.2 DIFFERENT AGE GROUPS AND MOP

MOP process in “picker-to-parts” systems theoretically consists of several types of activity, namely traveling, searching, picking and setup [6]. Usually, the most time consuming task is traveling [6], which mostly consumes worker’s time and energy. The most critical activity from ergonomic viewpoint is picking, which is obligatory linked to lifting and lowering of loads and demands more or less unfavourable postures.

Several authors [5, 7, 13] reported that more than 80% of all orders processed by warehouses are picked manually. The situation will not change much in favour of humans wellbeing in near future because humans are still more flexible than machines/robots and able of logical reasoning in reacting to unexpected changes in the order picking process [8, 14].

Manual work in warehouses is associated with frequent sick leave and musculoskeletal disorders. Musculoskeletal disorders are the most reported causes for absence from work and account for over 52% of all work-related illnesses and more than 2% of the gross national product in the European Union [5, 15], where low back disorders are the most costly of the musculoskeletal disorders [16]. In addition, the population is aging, which highlights the additional question of the employability of older people in the MOP processes. Current figures of the demographic change show that the average age of employees working in Germany is increasing [17]. The Federal Statistical Office of Germany predicts a nine percent decline of the population level in Germany from 2000-2050 and a decreasing proportion of the group, which is relevant for the industry (20 to 60 year old people - 45.5 to 35.4 million) [2]. Companies are often not able to find suitable candidates for personnel gaps, due to a lack of young and skilled workers [17]. Therefore, it is not only socially sensible, but also economically reasonable to hire employees of advanced age (50 years and older) and employees with disabilities in the industrial sector [3].

Considering above described trends, there is a need to research the work characteristics of order-pickers of advanced age in the processes of MOP and compare the results with findings about the work of the younger population. The physical strain as well as the metabolism decreases with an advanced age [18]. Kluth and Strasser [18] further state, that in anthropocentric oriented ergonomics there is an agreement on the stance that older people are not necessarily less efficient than younger ones. Their competence is especially expressed in terms of characteristics and abilities such as reliability, experience, responsibility, motivation, and commitment and their health ultimately depends on the work organization during the whole working life. So the companies are to a certain extent also responsible for their workers' ability to work and employability. As such, they should be interested in the research activities, which are rare but on the rise. Some scientific research papers and their results are listed below.

Baechler et al. [19] evaluate the effectiveness of pictogram meanings for order picking processes with disabled people and people with altered performance. Pictograms were created for guidance and feedback of process steps in order picking. Authors evaluated the comprehensibility and colours of the pictograms through a survey.

Karsten et al. [20] researched whether an age-related organization of the work and rest times for order-pickers working in deep cold-storage depots with chill room and cold store is necessary or not. There were no age-related differences in the results of the measured skin temperatures. They concluded their research, that in order to make "working at low temperatures" more agreeable to an aging work force in the long run, closer attention has to be given to the combined parameters of age and cold.

It is of concern that the work of order-pickers is often harmful to completely healthy people. Ciriello and Snook [21] conducted a study summarizing typical manual materials handling tasks performed at 2,442 locations across the country. They collected and analysed data on lifting, lowering, pushing, pulling, and carrying activities covering a 13-year period. The results show that lifting tasks were acceptable for 81 percent of the men but for only 10 percent of the women; for lowering tasks, the percentages were 89 and 14; and for carrying tasks, they were 88 and 36 percent, respectively. Moreover, the median weights for the lifting and lowering tasks were significantly higher than the weight limits recommended by the National Institute for Occupational Safety and Health (NIOSH). The authors concluded that additional work was needed to reduce the risks in industry associated with manual lifting tasks.

Grosse, Glock and Neumann [22] systematically evaluated the literature on order picking planning models with respect to human factors. The results showed a clear gap in considering human factors aspects in order picking planning models. The content analysis showed that typical human factors related keywords, such as 'ergonomics' or 'human factors' were only mentioned 18 times in a literature sample of 98 works. In comparison, the keyword 'routing' was mentioned over 1780 times. Consequently they direct researchers to consider human factors in MOP, such as maximal acceptable weights for the carrying of items, avoiding awkward body posture while storing and picking items, and also bear in mind the effects of learning and fatigue in worker assignment. This kind of research will set the stage for the development of future work to achieve long-term efficient order picking processes with reduced occupational health risks. But they will not give an answer on question what can be expected from older workers in MOP processes.

The scientific literature examines the characteristics of the older population, but very rarely in connection with picking.

The study of rare scientific articles on human factors in MOP processes revealed that they often:

- do not at all describe the demographic structure of studied workers,
- use data about the average worker,
- create different types of workers (e.g., highly experienced, experienced and novice),
- use average data obtained by studying a specific case.

Researchers try to contribute to the improvement of working conditions and to make it easier to assess the work environment in order to maintain order-pickers' health. There are, however, no studies on the characteristics of the work of older people in the actual environments where MOP processes are implemented. We agree with the claim that the scholarly treatment of workplace trends has focused almost exclusively on organizational issues and personnel policies rather than on changes in the content of specific jobs and occupations [23].

3. METHODS

The aim of the laboratory experiment was to investigate existence of significant differences in order picking times between younger (50-) and older (50+) order-pickers.
Nine men with mean age of 42 (SD 17.8) years, height of 179 (SD 5.2) cm, weight of 86 (SD 9.4) kg and eight women with mean age of 40 (SD 15.2) years, height of 163 (7.4) cm, weight of 62 (12.4) kg participated in the experiment. Four women and three men were over 50 years old. The participants were of different professions. Five men and four women are physical workers, two male and three female are students and the rest are office workers. None of them has ever worked as order picker in warehouse or distribution centre. They all signed a consent form approved by Senate of the Faculty of logistics at University of Maribor.
The participants picked cardboard boxes without handles in three different volumes and with four different loadings from shelves on five different heights in steel warehouse rack (Table 1).

Table 1: The values of the workplace design characteristics

Box dimensions (height x width x depth) [cm]	Box mass [kg]	Heights of the shelves in the rack [cm]	Height of the surface for disposal [cm]
Large (L): 31 x 37 x 45	0.1, 1, 5, 10	13, 56, 100, 143, 172	76
Medium (M): 20 x 30 x 40			
Small (S): 7 x 11 x 18			

Source: Own

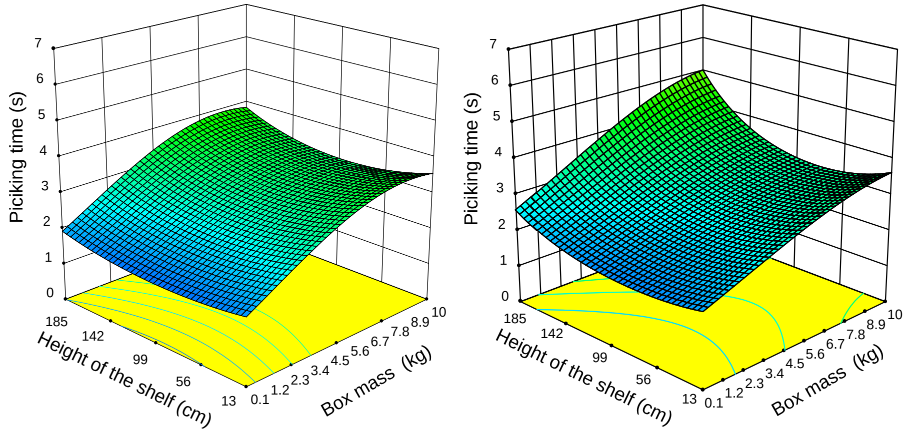
On each height of the shelves we randomly stored three large (L), three medium (M) and three small (S) boxes, each with three different loads (L (0.1, 5, 10 kg), M (0.1, 5, 10 kg), S (0.1, 1, 5 kg) (Fig.1). All together we stored 45 combinations. Boxes were numbered with Arabic numbers from 1 to 45. The numerical designations served to identify the box that had to be picked.
During the experiment each participant picked ordered box from a rack and lowered or lifted the box on a surface for disposal, using a grip of the box's side surfaces between the palms (Figure 1). Sequence of boxes on the picking list was determined randomly and was the same for all participants. The participants did not know how heavy the box they should pick is. After unloading the box on the surface for disposal, the assistant immediately read the new number of the box for picking and immediately after that removed unloaded box from improvised surface for disposal. Different masses were distributed equally at bottoms of boxes. A video camera with a rate of 60 frames per second recorded the participants while they performed the tasks. Later a time study was conducted by applying direct measurements on the video recordings.

Figure 1: Laboratory environment with rack and surface for disposal
Source: Own

The participants performed order-picking process at room temperature of 20°C, which consisted of: 1) searching and traveling to the required box; 2) lifting/lowering the box from one of the 5 shelves arranged at different heights, 3) transfer of the box to the surface for disposal by rotating the entire body by 180° without displacement from the front (mid-sagittal plane) of the participant's body at the beginning or ending of the lift; 4) lowering the box on the surface for disposal; 5) returning to the starting position (view is directed to the boxes in the rack). The box retrieval starts when the participants palms are placed on both sides of the required box and it starts moving on shelve and ends when the box stops moving placed on the surface for disposal. The elapsed time between start- and end-position is defined as picking time.
Each participant was accurately informed about elements of the work environment (shelves, cardboard boxes, box masses, the desired motion of the body, a process). Each participant performed a practice session of the work process until he or she felt relaxed, become ready to perform the required work and stabilize his/her work pace. They started the experiment after approximately 7 minutes. They were asked to move all 45 boxes from shelves in the rack to the surface for disposal in required sequence and in the required manner. Each participant performed each combination only once. They were instructed to work continuously at a pace that they could maintain for eight hours, and to stop the procedure if any difficulties or obstacles occurred. No time limit was set for completing the tasks.

4. RESULTS AND DISCUSION

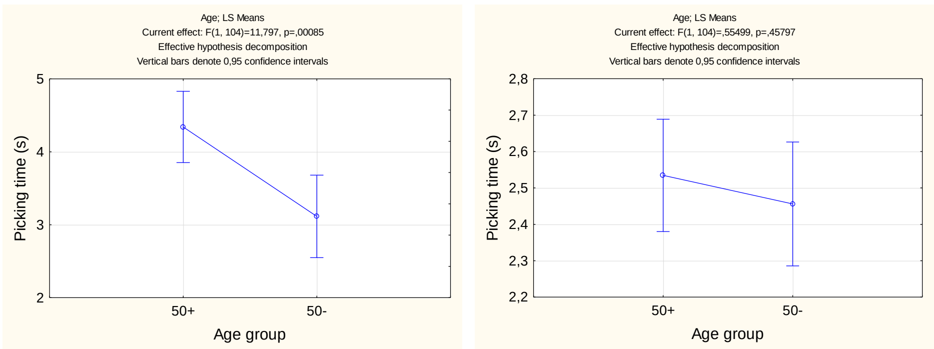
Using the methodology of statistical modelling from DOE the response models for picking time have been developed. The response surfaces of the developed models are presented in Figure 2.



a) **b)**

Figure 2 Response surfaces for average box size for: a) younger b) older order-picker
Source: Own

Analysing the resulting response surfaces it is obviously that there is a significant difference in picking time between two groups. The difference is even larger in the cases where the large and heaviest boxes are picked from the highest shelf. In order to justify the given assumptions on differences the several statistical tests were performed. Using analysis of the variance with error margin of 5% the difference between picking times regarding highest shelf was confirmed and presented in Figure 3a. The difference in the golden zone (Figure 3b) wasn't statistically significant which supports the previous assumptions.



a) b)

Figure 3 ANOVA for picking time at: a) 172 cm shelf height, b) 100 cm shelf height
Source: Own

Analysing the variance of the age groups regarding all influential factors, the result shows that there was a significant difference in the picking time, which suggests that workers over the age of 50 are significantly slower in terms of picking than the group below 50. The differences are larger in cases of large masses and at the highest shelves, which suggests that the ideal layout of the items should be calculated using the given models. Furthermore, taking into account the age of the working force regarding the picking time,

the largest and heavier boxes should be placed in golden zone (at shelfs about 100 cm height) where there is no significant statistical difference. When the boxes are placed in the golden zone, consequently the ergonomic impact will be improved so another important criterion is included.
According to the above results and discussion, our hypothesis, that older order-picker are slower than their younger colleagues, can be partially confirmed.

5. CONCLUSION

We are facing with increased percentage of older workers. Studies about aging workers demonstrated that there is a significant decrease of their physical and cognitive capacities. It is likely that older people will need to be more involved in the MOP processes, since the rapid increase in the degree of automation of these work environments is not expected in near future. The study of rare scientific articles on human factors in MOP processes revealed that they often use data about average worker and do not describe the demographic structure of studied workers. For practitioners, who need to think how to employ older people and not significantly reduce productivity or increase absences from work, these results are partly useful and do not give the right answers. In order to contribute to closing the gap, the existence of significant statistical differences between order-picker's age and the picking times of boxes of different weights at different heights were experimentally researched. Workers over the age of 50 are significantly slower in terms of picking than the group below 50. The differences are larger in cases of large masses and at the highest shelves. The importance of placing the largest and heavier boxes in golden zone is increasing by increasing the number of employees over 45 years of age where is no significant statistical differences between order-picker's age and the picking times.
However, order-pickers' age might not be the only data needed for planning the working environment. People of the same age have very unlikely the same physical and cognitive capacities, as well as working history. From previous research, employers are recommended to monitor Work Ability Index (WAI) for each order-picker over the years of work, and based on results take decisions on the assignment of work. Research and comparison of the characteristics of the work of older and younger employees certainly represent a great research potential.

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DRESS DESIGN FOR AUTISM: AN ERGONOMIC APPROACH TO DEVELOPING GOOD FEELING FOR KIDS

B. Ghasemi[1], H. Sadeghi Naeini[2], M. Mounesi Sorkheh[3], H. Haghgoo[4]

[1]Applied Art University, Tehran, Iran, behnooshghasemi@yahoo.com
[2]Associate Prof., Industrial Design Dept, School of Arch. & Urban studies, Iran Univ. of Science & Tech.(IUST), Tehran, Iran, naeini@iust.ac.ir
[3]Assistant Prof., Alzahra University, Tehran, Iran,
[4]Department of Occupational Therapy, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

Abstract

The main objective of this paper is to dress design for autisms based on ergonomics approach. Kids who suffer the autism have some problems with their dressing up. Their daily activities faced with some limitation, in this regards, independence is a critical factor for these patients. In this cross-sectional study, cloth design based on micro and cultural ergonomics were focused. In this research, 25 parents, as our volunteer samples, were participating. Exist clothes for these sorts of kids were assessed. Based on pre and post tests and questionary, and considering with market design, a new cloth was developed. Anthropometric design and ergonomics problem during their dressing up was evaluated. Statistical analysis of questionnaires shows that cloth design based on ergonomics and feeling assessment make a better condition for them in terms of quality of life. User center design and using the designed cloth shows that the anxiety and dissatisfaction are decreasing among the kids. Fashion design is influenced by cultural and social attitudes, in this regards, ergonomics plays an efficient role. This ongoing study shows that ergonomics consideration makes an effective outcome in dress design, especially for vulnerable groups.

Keywords: Autism, kids, ergonomics, dress design, cloth design

1. INTRODUCTION

1.1 Autism

Autism means to live in himself. In Greek 'aut' means self and 'ism' expresses the state and condition. It means the person who has cut his social relation and has gone in to seclusion. (Iranian autism society, 2014) the word autism was been used from 100 years ago. This word used for the first time by Youngen Bloler, swiss psychologist in 1911 that was called to a group of schizophrenia in 1943. this word was redefined by Leo Kaner American psychologist. Autism had the same meaning with schizophrenia for a long time until 1960. After this year researchers preference between two words and separated them from each other. (rafei,2006)
Autism disorders are a set of disorders of brain's development. These disorders in fact are a kind of inability in nerves that disorder brain's performans and with delay and

decrease in quality in social interactions, verbal and cognitive connection are specifial. (kousha,2013)
Main signs of autism's disorders can be pointed in 3 parts:

1) Social communication
2) Verbal connection and body language.
3) Samples and repeated behaviors (kousha ,2013. Johnson, 2002)

Decrease in social communication and totally having connection is the most important sing of autism. In fact a true conception of a social situation and showing a suitable reaction to that needs having verbal conception , body mood and also analyzing them function of this part of these people's brain has problem and in practice they can't realize the signs of starting a communication. (Iranian autism society,2014)
Autism incidence in boys is four of girls. And according to last reports the number of that has reached from 1 to 10000 person into 1 to 68 person (kousha,2013. Autism society 2013) in recent years sensory processing problems are known of common problems in autism children. Who have autism the amount of showing sensory processing disorders in researchers about autism has been reported between 42% to 88% (Jamshidian – Jalili – Haghgoo 2015). All information that human gets from his around world is reached by sensory system, senses are the only received way of receiving information from our environment. (Rafei,2006). Sense entirety is a process of nerve cognition that during it received senses of environment are merged and explained for using. Whenever this process is disordered the person will not have a good reaction in respond to environment requests. In this process every problems in function causes disorder in showing skills and adaptability with his around. According to sensory entirety point of view autistic children in process above are disordered.
Clothes and dress as a first need of mankind can be annoying for sensity disordered people cause of direct touch with human body's skin. From other side the process of wearing clothes for disabled people is a complex activity that including different stages. because wearing clothes is one of daily activity therefore disability in this matter is one of the reasons of decreasing self confidence in Autism Children. Autistic children and adult have special condition so this causes their clothes having special sensitiveness. They own bad function of sensory system specially sense of touch like other growth disability [3], on the other side autism children have problems in doing delicate actions. that seems doing delicate actions with fingers is difficult for them like do a button.in addition to this back and front of clothes most of the time is disappointing.
The important things in designing of clothes of this group of children consist of :
- Slip-on clothes
- Minimum use of fastening and embellishment
- Disuse of stimulus color
- Dis use of clothes inside tags

1.2 Ergonomics

An ergonomic planning in design will be ended to safety, and also productivity. Ergonomics and economics have a firm connection. Surely lower human errors and safer environments make better conditions for manufacturing systems. This multidisciplinary science study about human abilities and limitation and also works conditions. The main objective of ergonomics is fitting the task to the man and NOT vice versa. Ergonomics or Human factors engineering as a multidisciplinary science are related to several kinds of science such as medical and health science, management, engineering disciplines, art and design, psychology. So, some different activities and performances are covered by ergonomics.[5]

2. Methods

Autistic Children namely the target group in this research and from the groups of special clinical conditions that can be identified and be in groups with high members seldom and because the considered object in this research namely designing clothes for these children in one of matters that has not been accomplished yet and needs to more probe.

3. Results

Test method to control the effect of production on these children. This research has done in first and second midyear of 2017 in Tehran and the target group in this research included of 20 boys at the age of 5 to 7 years old that were affected by Autism disorders spectrum with high limitation from volunteer families from 3 clinic was considered. at the begining 20 questionnaire distributed among these children's parents.after gathering, questionnaires was marked and adding up in a table.second group of questionnaires is related to clothes , design and color is analyzed and based on them a list of needful things of these children was available. Then according to the list early models were designed. 5 model were sewn and were accommodated to their parents but cause of parent's noncooperation and evevn in some cases denying that their children are not autism so that model were back to the enperienced doctor to reconsider children's feedback in remedy time. after tow weeks all registered cases were received from Experienced doctor, Evidently, considering adductive conceptions and responds in this research are not received directly from the target person and based on this, impossibility of using usd technique in this research, all answers of accountable based on his recognition of his patient will have a percent of probability research tools:

1-Dunn sensory questionnaire (sensory profile by Winnie Dunn) sensory questionnaire is made and published by Winnie Dunn in 1999 and assesses children's sensory of 3 to10 years old. This questionnaire includes 125 items. Questionnaire results classifies in 9 factors:

Factor 1 (sensory secking)
Factor 2 (emotional reaction)
Factor 3 (law muscle tone and endurance)
Factor 4 (oral sensory sensitive)
Factor 5 (inattention and distractibility)
Factor 6 (poor sensory registration)
Factor 7 (sensory sensitivity)
Factor 8 (sedentary)
Factor 9 (fine movement / perception)

2-Questionnaire designed by me researcher:
Includes 25 classified items about clothes and color and design for the purpose of necessing assessment and analysis of the rype of problem and the need for children that were collected from theire parents due to the inability of these children to respond to the questionnaire of responses.

Table 1: Descriptive statistics for the binomial test of the relationship between different parts of the baby's clothes and the comfort and relaxation of the child's autistic.

Attributes	Average	Standard deviation
The children pleasure of contacting different level	10/39	28/18
Check out the type of distressing baby clothes-19	10/06	24/39
The kind of dress for the child-21	20/45	57/53
Kind of preference baby clothes-22	5/69	15/06

Source: research findings

Table 2: Descriptive statistics for binomial test of relationship between defferent designs and child autistic attention.

Attributes	Average	Standard deviation
Having a special outfit and child refusal of weaving it-5	11/13	45/61
Interest in special clothes-6	16/55	48/95
The amount of interesting design and the role of clothes for the child-7	10/20	29/98
The importance of the theme of baby clothing-12	10/28	29/36
The kind of your baby's noted problem-18	11/60	18/64
Atracting special design for baby-20	2/26	20/52

Source: research findings

Table 3: Descriptive statistics for the binomial test of relationship between the amount of autistic child anxiety and kind of his/her clothes

Attributes	Average	Standard deviation
To bite sleeve, neckline or other parts of clothes in stress occasions-15	6/73	24/39
The effect of engaging the child's fingers in decreasing stress-16	6/73	24/39
Kind of baby clothes-21	9/86	25/45
Kind of baby soothing device in stress occasions-17	20/45	57/53

Source: research findings

Table 4: Descriptive statistics for the binomial test of relationship between color and autistic children morales

Attributes	Average	Standard deviation
The importance of clothing color for your child-8	9/37	32/35
The effect of the color of clothes on your child's morales -9	6/82	30/36
The most favorite colorful group of your child-10	8/45	30/11
Your child's favorite color-11	4/71	12/43

Source: research findings

Based on above tables:
1) There is a significant relation between attribute of different parts of clothes and the level of autistic children comfort.
2) There is a significant relation between attribute of different parts of clothes and level of autistic children pleasure.
3) There is a significant relation between the role of clothes and the amount of autistic children attention.
4) There is a significant relation between kind of clothes and the amount of children anxiety.
5) There is a significant relation between color and children morals.
6) Emotional responses, visual state, social emotional sensory conditions, the threshold response, reactivity, oral sensivity, have significant association.

4. Conclusions

This research goal was about clothes design for kids with autism. Our results show very few studied cases responded to the clothes color .The material of clothes was suitable for children and had a meaningful relation with children's comfort . Although in the questionnaires about 25 % of the parents agreed to the autism sign on the clothes, but almost all parents that were asked to test the clothes had negative reaction to autism sign on clothes. Silicon parts and plastic springs inside of the pockets were interesting for children.
According to the findings of this study, the design of clothing for autistic children can greatly influence the skills of the child in dressing and also responding to some of the sensory needs of children, but the estimation of the impact of designs due to the characteristics, complex and strange characteristics of these children need more time, more interaction and more extensive collaboration.

There is a clear need for more research in this field to study the relationship between clothing design and the improvement of some of the problems of these people. Considering the findings of the present research and the research carried out abroad, the attention to this category is of great importance; while in the country no significant attention has been paid to this area in the field of research and production. The Fig 1,2, and e show our recommended design.
No.1 / Design: colorful pasta

Fig.1

1- The long collar with buttons and covers the baby's face. To prevent eye irritation and make a feel good.
2- Double-shoulder pattern (wear on both sides)/ cotton

3- Separating colored straps for chewing, oral stimulation and play
4- Great pocket for comfortable putting toys and chewy items
5- the chewing parts: Plastic spring for engaging the chewing gum-fingers to stimulate the sense of mouth.

No.2 / Design: Red silk worm

Fig.2

1- Double-shoulder pattern (wear on both sides) / cotton
2- Sleeves and different parts to stimulate the sensation of touch and mouth and experience the touch of different tissues.

No.3 / Design: balloons

Fig3

1- Double-shoulder pattern (wear on both sides) / cotton
2- Movable felted design for stimulating tactile senory, attention and concentration
3- Outstanding velvet colored bullets for stimulating the tactile sensory, attention and concentration of the child.
4- Hidden pocket to put the address or the GPS

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MODELLING OF FUZZY LOGIC BASED DISPATCHER SUPPORT SYSTEM FOR RAILWAY TRAFFIC CONTROL

H. Haramina, D. Sumpor, M. Širol
Faculty of Transport and Traffic Sciences, Zagreb, Croatia,
hharamina@fpz.hr, dsumpor@fpz.hr, marin.sirol2@gmail.com

Abstract

Modern approach to rail traffic control on major corridors implies centralized train and traffic control. In such approach, the main role in traffic management has dispatcher. With the aim of reducing the dispatcher's workload while simultaneously raising the performance level and increasing the efficiency of the dispatcher's work, with a goal of greater efficiency in the process of traffic control, adequate decision support systems are being applied. Within this paper, a model of the dispatcher support system in decision-making in the railway traffic control process based on the application of artificial intelligence is presented. The proposed model of fuzzy logic based dispatcher support system in decision-making will, to a certain extent, decrease the possible negative impact of different distractors and factors of unfavorable circumstances from the working and traffic environment on the performance of the dispatcher's work.

Keywords: *railway traffic control, dispatcher decision support, fuzzy logic*

1. INTRODUCTION

In the situation when two trains are approaching the same railway station sometimes they are not able to enter the station at the same time but one of them gets the advantage of entering the station (train 1 in the picture), while the other one must begin to slow down after the distant signal and stop in front of the home signal (see figure 1).

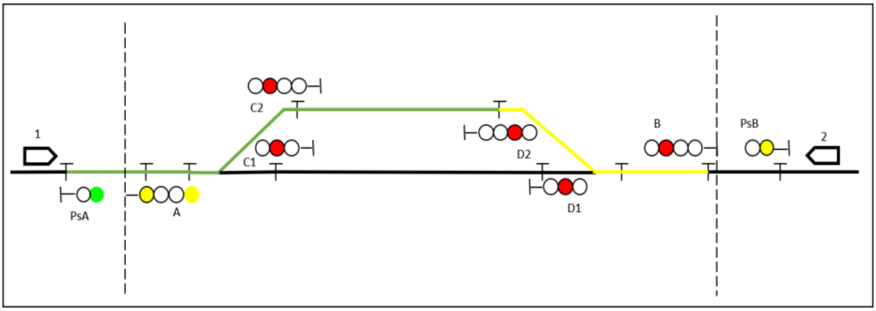

Figure 1: Trains approaching station conflict

This is because of safety reasons defined by station interlocking which is preventing parallel setting of some train routes to avoid dangerous situations. Regarding to this, the second train will be allowed to enter the station after the first train successfully entered it and stop in front of the exit signal. The decision about which train has the advantage of entering the station is given by dispatcher. This decision making process depends on dispatcher`s skills and experience and the quality of this process can be result of his cognitive workload and human factors. Because of this it is possible to develop a system that will assist the dispatcher in making such decisions, or completely replace him. In this paper a new model of fuzzy inference system for this purpose is presented.

2. STRUCTURE OF THE DECISION SUPPORT SYSTEM

On the figure 2. structure and properties of fuzzy inference system for dispatcher decision support in traffic control process are presented.

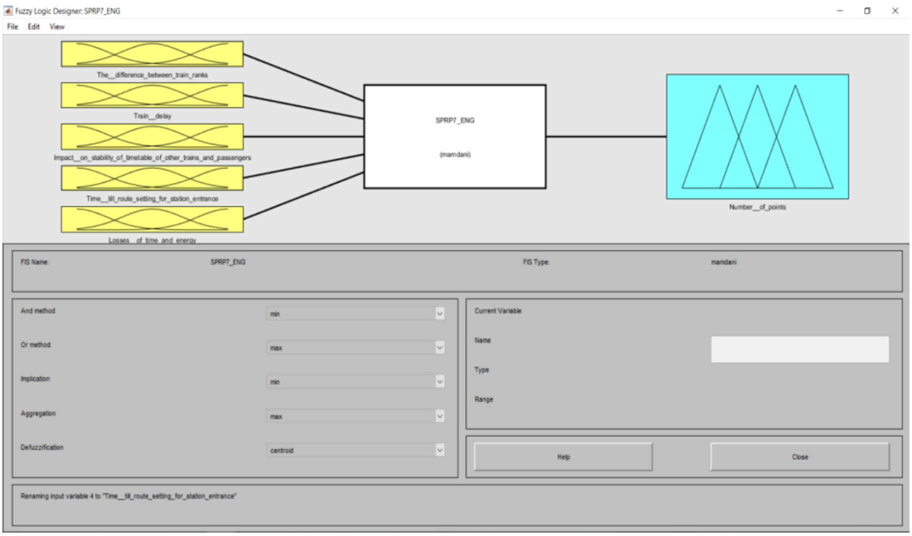

Figure 2: Structure of the decision support system

The system has five input variables and one output. Input variables are presented by factors influencing decision making process for train priority selection. As input variables the difference between train ranks, train delay, impact on stability of timetable of other trains and passengers, time till route setting for station entrance and losses of time and energy are selected.

2.1. The difference between train ranks

According to regulations in Croatia there are 21 ranks of trains. Because trains of the same rank from international traffic have an advantage over domestic trains, there are in total 24 different levels of train priority. Due to this and because the difference in rank may be in favor to one or another train in this input parameter for the comparison of trains considering the rank the range of 47 degree of difference between the priority level of trains is defined. This range is grouped into 7 fuzzy sets defined by membership functions (see figure 3).

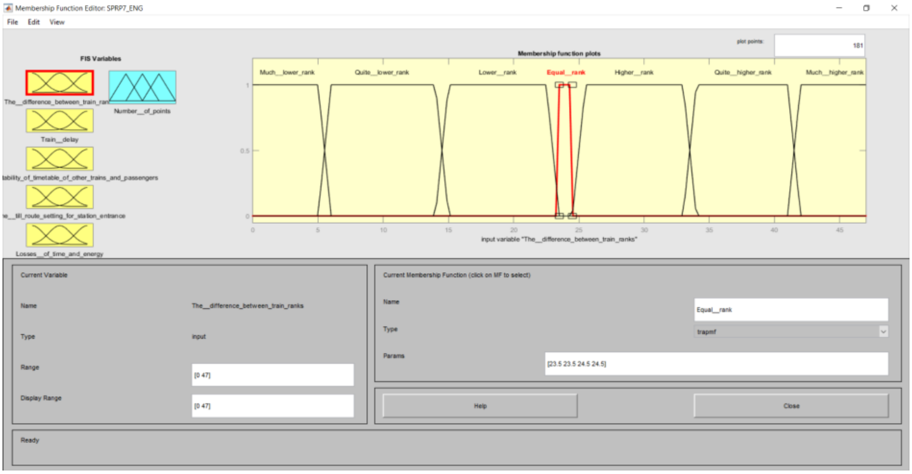

Figure 3: The difference between train ranks

2.2. Train delay

The amount of train delay can affect the priority of that train. A train that already has a big delay should try as far as possible to reduce or at least not increase existing delay. That is in rail transport primarily referred to passenger trains, as well as higher-rank trains which, because of their rank can have higher negative impact on delays of other trains. On figure 4 input parameter for train delay is presented.

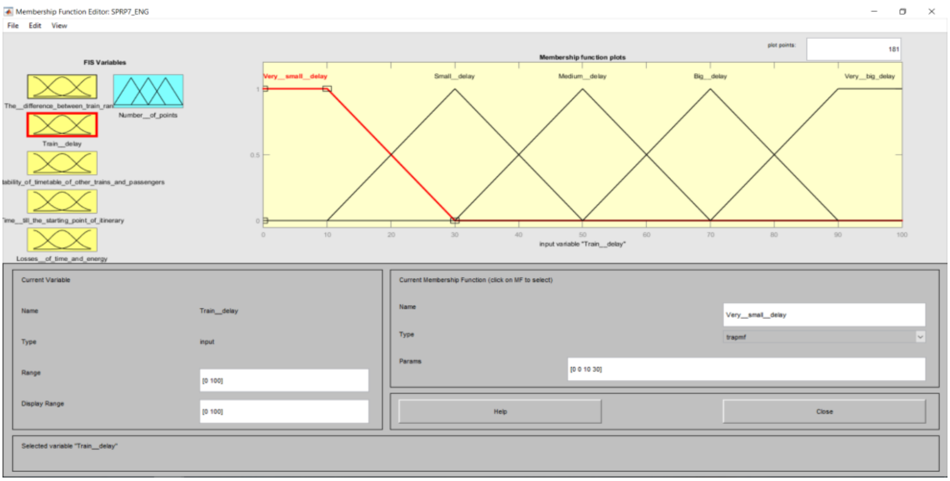

Figure 4: Train delay

2.3. Impact on stability of timetable of other trains and passengers

This parameter refers to the impact of a train on the delay of other trains in the network, and especially the delays of passenger trains depending on how many passengers they actually transport. This input parameter is grouped into 5 fuzzy sets (see figure 5).

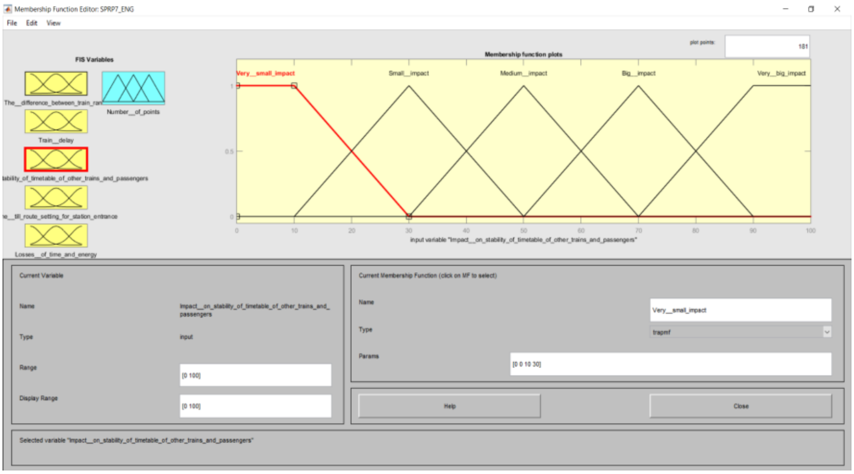

Figure 5: Impact on stability of timetable of other trains and passengers

2.4. Time till route setting for station entrance

The priority given to a train which is at a greater distance from the starting point of its route occupation can affect the railway line capacity and the delay of the competitive train. On the figure 6 range and membership functions for this input value are presented.

Figure 6: Time till route setting for station entrance

2.5. Losses of time and energy

In case when we have massive freight train which is running at full speed, it is more worth it to give the priority to this train than much less massive higher rank train that would not be too late in that case, because the massive freight train would have significantly saved its time (avoiding delay) and energy. This is connected with the fact that long massive trains using indirect brakes cannot start their run again immediately after stopping, but after the pressure in braking pipes is achieved again. On the figure 7 range and membership functions for this input value are presented.

Figure 7: Losses of time and energy

2.6. Designing of output variable

The output variable is designed in way that some train can be compared with its competitive train and by this reach between 0 and 100 points (see figure 8). If the train which is compared with competitive train reaches 50 or more points it will get advantage over its competitive train.

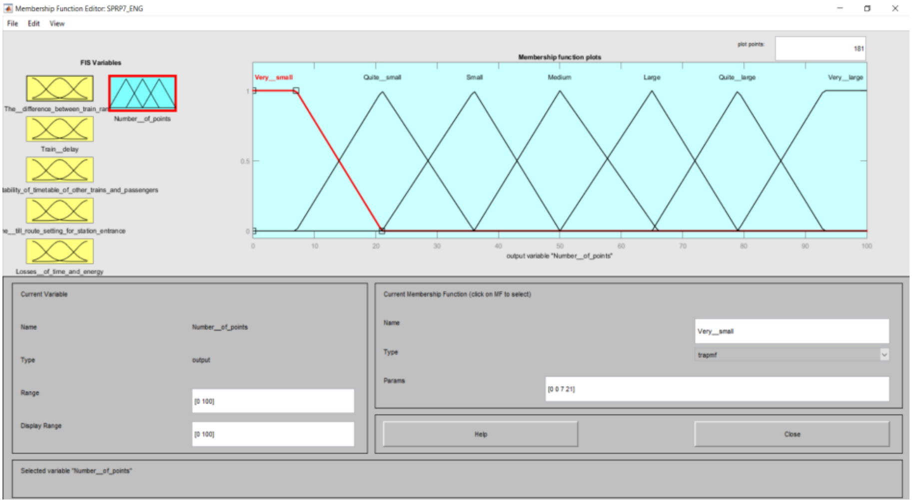

Figure 8: Designing of output variable

3. KNOWLEDGE DATABASE OF THE SYSTEM

The inference process is conducted by rules stored in the knowledge database. The rules are created based on the experience in traffic control by relations between input and output variables. These relations are derived with logical operators in the Matlab graphical user interface (see figure 9).

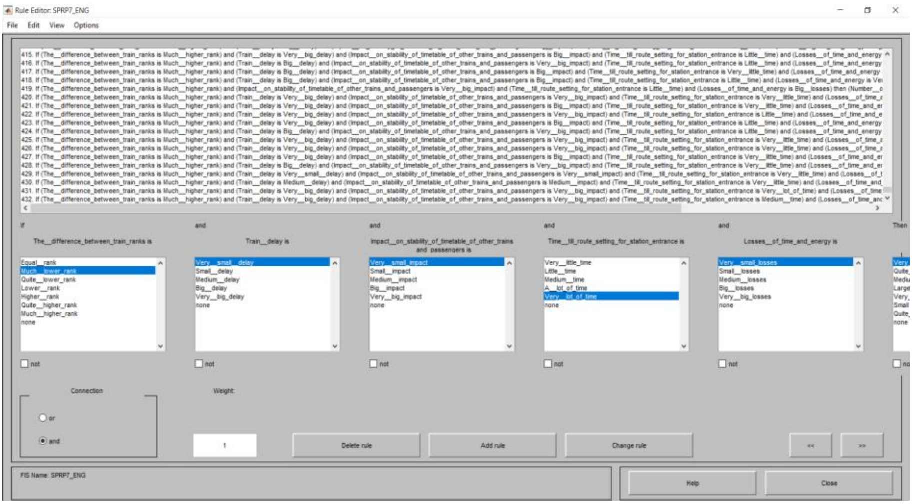

Figure 9: Definition of rules in knowledge database

4. TESTING OF THE SYSTEM

The system was tested with scenario where the difference between train ranks was 3, delay of observed train was 37, impact on stability of timetable of other trains and passengers was 36, time till route setting for station entrance was 66 and losses of time and energy were 41. Result of the inference process showed that this train is achieving 25,3 points and has no priority over conflicted train, as it is shown on the figure 10.

Figure 10: Testing of the system

5. CONCLUSION

In this paper a new model of fuzzy inference system for train priority selection aimed for train dispatcher decision support was presented. This kind of system can reduce dispatcher's cognitive workload. The input variables were selected and the rules in knowledge base were created based on experience in railway traffic control. The model is tested and results proven the quality of system performance.

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A LIVING LAB APPROACH TO STUDY USER EXPERIENCE OF AN INTELLIGENT POWER WHEELCHAIR

A. Hébert[1], P. Archambault[1], D. Kairy[2]
[1] McGill University, Montreal, CANADA, anne-marie.hebert@mail.mcgill.ca, philippe.archambault@mcgill.ca
[2] University of Montreal, Montreal, CANADA, dahlia.kairy@umontreal.ca

Abstract

This paper describes an approach to shed light on the user experience (UX) of real end-users in order to iterate on the development of an intelligent power wheelchair (IPW). In order to assess common activities with the IPW, we resorted to a Living lab approach (LL) in a shopping mall with twelve participants. The goal was to recreate common activities in an ecological setting to assess UX. Participants used the IPW to perform fourteen daily tasks. Assessment of the UX with the IPW was performed through self-confrontation interviews and questionnaire. The results provided insights on several points of the human-robot interaction (HRI). End-users emphasized the need to have multimodal feedback on the functions activated, on the state of the IPW and elements of the environment. Furthermore, a map from the HRI should be redesign within a global perspective and incorporated with the user's inputs as few participants used the map.

Keywords*:* *assistive technology, usability, human-robot interaction, intelligent power wheelchair, ecological setting*

1. INTRODUCTION

On the continuum between in vitro and in vivo experiments, the living lab (LL) approach represents a point set closer to the in vivo category. It is a promising approach when considering the inclusion of the disabled or the aging population. The LL approach can provide a more realistic portrait of its users' ability to carry out common activities. The purpose of this paper is to present a study that was conducted within a LL approach. We will first present the concept of the LL and assessment of usability of intelligent powered wheelchairs (IPW). Then, we will present our method and results. We will finally discuss our results with the proposal of technical specifications related to our analyses.

2. THE CONCEPT OF THE LIVING LAB

The concept of the LL is defined as an 'open innovation environment in real-life settings in which user-driven innovation is the co-creation process for new services, products, and societal infrastructure' [1]. Three dimensions are encompassed in the LL concept, namely the user involvement, real-life environment and a network of actors [2].

When referring to the LL concept, there are different types of user involvement. One involves the participation of the users and other stakeholders into the co-creation of the project, similar to participatory design and the other provides a real-world environment for the pursuit of research, where collected data will be used to shed light on the questions of a specific project [3]. The latter one is focusing on users as the providers of observable behaviors and performance to inject into the development of a product or service. This is the type of LL that we resorted to.
More studies resort to LL to develop systems and technologies and assess their usability. In those studies, the approach in LL is often focused on qualitative methods [1]. On the contrary, rehabilitation medicine's investigation remains in most part performed in laboratory-like conditions [3]. Hitherto, assessments of IPWs were performed mostly in laboratory settings, often without end-users, and a few in ecological settings. We argue that resorting to an ecological environment such as a LL can be a means to bring significant insights from users in order to iterate on the development of a system. It is acknowledged that assistive technologies (AT) bring significant improvements for the independence of people with disabilities [4]. In order to fulfill such goals, AT need to be properly assessed.

3. USABILITY OF THE INTELLIGENT POWERED WHEELCHAIR

Operating an AT such as an IPW involves several task categories: navigation, perception, management, manipulation and social tasks [5]. Assessing the usability of an IPW involves the user's abilities and skills to operate the IPW, environmental factors and activity needs, that should be added to the IPW device itself [6]. Furthermore, according to [6], none of the available metrics allow researchers to clearly pinpoint which factors (user, wheelchair, environment and activity) impact usability. With this difficulty, using complementary measures and methods might provide a clearer picture of the impact of the IPW's usability.
Our research goal was to assess the usability of an IPW with end-users in order to gain insight from tests in an ecological. For this purpose, daily tasks, self-confrontation interviews and questionnaire were used. In that framework, a LL provided an opportunity to investigate the IPW'S usability.

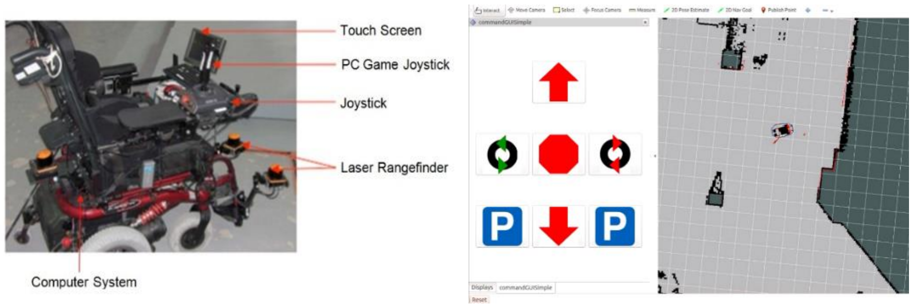
4. METHOD

4.1 Participants: power wheelchair (PW) users

We recruited twelve participants (n=12). They were included if they had been using a PW in the community for at least one year, were 18 years of age or older, were able to express themselves in French or English, and had a long-term severe mobility limitation. They were excluded if they had communication, hearing or vision deficits, or emotional or psychiatric problems or cognitive disabilities that would limit their participation in the tasks required or in the interview. PW users were identified from the Technical Aids Services in three Montreal rehabilitation centers, from our previous studies in which participants agreed to be contacted or through associations for people with mobility impairments. The ethical approval was obtained through the research ethics board of the Interdisciplinary Research Center in Rehabilitation (CRIR, Montreal, Canada).

4.2 Procedure: participants perform common daily tasks in an shopping mall

Our study was conducted at Alexis Nihon in Montreal, a shopping mall that is involved in the CRIR’s Mall as a living lab (MALL) project, which aims to test accessibility in a public space and test technologies, procedures or services in an ecological setting.
In order to test daily activities of PW users, we identified some tasks from the Wheelchair Skills Test (WST) [7]. The WST has been developed to assess PW performance using a standardized course. It proposes a set of 30 tasks that are considered as important components of daily activities, e.g. rolling forward on a short distance, turning in place, crossing a door threshold, etc. From this set of tasks, we selected fourteen tasks that were relevant to perform with the IPW in the ecological setting.
The IPW prototype used has intelligent navigation features, which combines technologies related to artificial intelligence (AI) and robotics. It is built from a PW available on the market and a tactile interface was added to the original joystick interface (Figure 1). Several navigation sensors, i.e. laser rangefinder and sonar, are mounted on the IPW. The IPW prototype makes it possible to determine trajectories, to follow a planned path, to avoid static and dynamic obstacles, to cross doors and to follow a specific object such as a wall, a person or a group of people.
For each participant, a training period of 20-30 minutes with the IPW was conducted with a computer scientist or an engineer. Afterwards, participants performed the fourteen tasks of the WST with the IPW (Figure 1) with and without activation of the intelligent module. These tasks were administered by clinicians followed by complementary questions (see next section). Self-confrontation interviews were administered two weeks after the participants’ test in the LL.



a. b.

Figure 1: The AT used in the LL: a shows the IPW used and b, the user interface implemented in the IPW’s tactile tablet

4.3 Data: questionnaire, video recordings and self-confrontation interviews

We collected a questionnaire that was designed to provide information related to each task performed in the LL with the IPW. Examples of questions included: “Evaluate the level of difficulty of the function ‘Roll forward’ of the intelligent power wheelchair”;

"what are the difficulty faced with the 'Roll forward' function"; and "what did you like about the 'Roll forward' function (if applicable)". Answers to all these questions were transcribed by the first investigator.

We collected video recordings of the tasks performed with the IPW. We had five cameras. One (1) captured the context of the environmental surrounding, and four were installed on the IPW. From those latter, two captured a front view with (2) one being above the participant's head and slightly angled to capture the participant's perspective and (3) one was placed on the PW's tray, to capture all events in front of the IPW. We added (4) a screen recorder to collect which buttons were pressed and (5) a video camera from the tablet to capture the participant's facial expression.

With the five video feeds, we created split screens videos for self-confrontation interviews [8, 9] with a sub-group of the participants (n=5) who accepted to do this additional interview. Self-confrontation interviews consisted of watching video-recordings of tasks performed by the participant with the IPW. The videos were used as a support material to ask the participant to comment on his/her use of the IPW in order to (1) reveal the underlying cognitive processes and (2) provide an understanding of activity [8, 9]. We provided the participants with a split-screen of four of the camera's video with only one for the participant's view, thus excluding the one on the PW's tray. Self-confrontation interviews were video-recorded and each participant's verbatim was transcribed.

4.4 Analyses: qualitative and quantitative analyses

We adopted a mix-method approach in this study. For the qualitative analysis, a content analysis was performed on our interview and questionnaire data with the software *NVivo* 10. A collective discussion was performed with the lowest level of the coding schemes produced in order to organize and define the higher level categories. The coding schemes' frequency of occurrence were defined as *Few* if mentioned by 1-25% of participants, *Some* if by 26-50%, *Many* if by 51-75% and *Most* if by 76-100%. The coding schemes were not mutually exclusive. For the quantitative analysis, we performed descriptive analyses with the results of the questions' scoring scales from the questionnaire. We used *SPSS Statistics* 24.

5. RESULTS

5.1 Testing functions and HRI implemented from the indentified anticipated needs

The LL approach, interviews and questionnaire enabled us to verify the correspondence of some highlighted needs regarding the mobility and the IPW's reliability [10].

5.1.1 Testing the mobility afforded by the use of the IPW: improving the turn task

A user's perspective related to the difficulty of achieving the daily tasks, was collected through the questionnaire. Some questions were related to the level of difficulty of navigational tasks on a five-point Likert scale ranging from 1 (very easy) to 5 (very difficult). The following table (Figure 2) underlines that the majority of the participants experienced little difficulty in performing the tasks. Indeed, the questions highlighted a low level of difficulty for the navigation interactions to roll forward (M = 1.57; SD = ± 0.82), roll backward (M = 1.79; SD = ± 0.86) and to park (M = 1.71; SD = ± 1.09). Contrastingly, the results underline mitigated opinions on the level of difficulty for the turns with a higher level of difficulties for turn right or left (M = 2.79; SD = ± 1.26). The other ten tasks were combinations of one or more of those four main tasks.

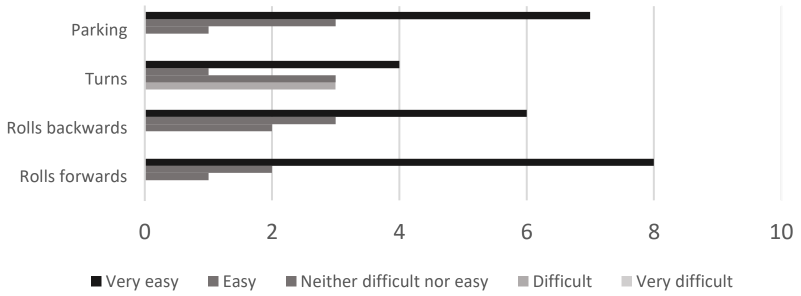


Figure 2: Frequency of the levels of difficulty of navigation tasks

Most of the users commented in the interviews and questions related to the turns by highlighting that this required too many steps and manipulations. Indeed, one participant stated: “there are all the stops between each step of one turn”. Another participant proposed to enable the turns while going forward “put arrows to turn when you’re going forwards”. Another comment on the parking was “there is a need to explain to users to allow time for the IPW to position itself or to take its final position because when I activated the parking function, it will take a minute, for example a minute to park itself”.

5.1.2 Testing the reliability provided by the system: a need for clearer and multimodal feedback

The self-confrontation interviews underlined that some users needed to have more feedback from the IPW. Specifically, participants mentioned the need for feedback on: 1) the state of the system such as the speed and level of the battery; 2) the command launched or activated by the user “(the IPW) doesn’t give feedback on the commands taken into account” or by the IPW; 3) location information on the position of the IPW in the environment “a map oriented with what you see”; 4) information taken into account by the system regarding the environmental elements and people around the IPW in order to navigate in a safe way “a question in order to make sure that the powered wheelchair will stop or if the user has to stop it”; and 5) error message and problem solving information on the decisions of the IPW from the IA and error message “when it stops functioning, why does it stops”.
Moreover, some participants also highlighted the need for multimodal feedback (in particular, visual and auditory feedback). Indeed, we gathered several types of auditory feedback that future users would like to get: 1) to get attentional recalls/warnings from the system, 2) to control the system through vocal inputs and 3) to obtain information about the state of the system. A participant highlighted that getting information related to the location of the IPW and its potential actions would reduce anxiety. For example, the IPW cannot be maneuvered too close to a wall or obstacle, so “information to know at

which distance from the wall or an obstacle the IPW is not able to function, to lower user's anxiety".

5.2 Technological specifications to implement or redesign the identified needs

From the needs underlined in the self-confrontations interviews and questionnaire, we will in this section describe the new HRI according to those needs.

5.2.1 A global HRI for feedback and activities monitoring

The need to redevelop an interface to maneuver the IPW arose from the fact that participants found it hard to accomplish what they wanted, especially the turns. First, a joystick-like navigational input will be implemented in the next iteration. A simple touch by the user could trigger movement of the IPW. It would remove the additional manipulation required to stop the IPW between turning and going forwards, considered to be problematic with the four arrows inputs tested. Moreover, the joystick-like input would reenact the navigational inputs acquired from traditional joystick maneuvering and might ease the switch between the joystick and intelligent/tactile modes as they would be similar in terms of type of interaction. Thus, it might lower the learning curve for maneuvering the IPW. This navigational input system could be illustrated within a map of the IPW's surroundings. It would be formed by circles around the IPW's representation. The outer circle could delimit the maximum speed for the user; the user's touch approaching the outer circle would navigate at the highest speed. The user's touch entering the inner circle would stop the IPW. Moreover, it would provide location information on the position of the IPW in the environment underlined by users.

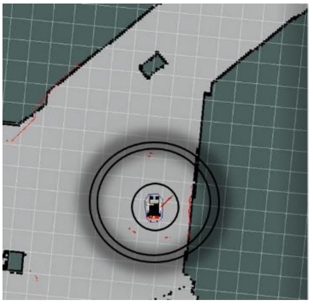


Figure 3: The track-up display with the joystick-like navigational inputs

Second, an egocentric user view (Figure 3), track-up view (display that is oriented in function of the user's view) should be used for the map display. This would lower the cognitive load for spatial information processing. Indeed, this track-up mapping display is considered to be useful in navigation situations with a high cognitive load where the map display and cognitive processing might impede the system's maneuvering [11].

5.2.2 Control and Feedback to Emphasize System Reliability and Security

Feedback needs to be improved in order to give users the sense that they have meaningful interaction with the system. In that vein, the self-confrontation interview and questionnaire highlighted some potential feedback that the participants would have wanted.
The navigation of a IPW/PW is a visual activity combining the characteristics of pedestrian and motorized navigation [12]. Some information supporting the navigation of an IPW/PW can be presented by different modalities besides the visual modality. This might have the effect of decreasing the demands of visual processing, and therefore the cognitive load, of the user. In that vein, it is considered that spatial information should be presented visually, and that action and description information should be provided verbally or with auditory feedback [11]. Following those directives while taking into account the insights of the participants, we will propose specifications for the different categories of feedback in the following Table 1.

Table 1: Categories of feedback and priorities

	Feedback	
Categories	***Elements to implement***	***Modalities***
State of the system	Battery level	Visual and blinking (low)
	Speed	Visual
Commands launched	Command launched by user	Visual highlighted and auditory
	Command to be launched by system (AI)	Visual blinking and auditory
	Steps of command launched	Visual blinking and auditory
Location information	Global location (city map)	Visual
	Immediat surrounding with elements in that environement track-up	Visual with different shades
	The limits of elements of environment that would cause the inability of the IPW to move	Visual with different shades
Problem solving	Reset button	Visual
	Error message on the cause of the inability to function and the action required	Visual highlighted
	Message to resolve the IPW's inability to launch a command	Visually written window with command/s to launch
	Function to call emergency	Visual
Information taken into account by system	Secure planned action based on environments' obstacles	Visual with different shades
	Environment's elements	Visual with different shades

6. DISCUSSION

The results of interviews and questionnaire highlighted the need to redesign the HRI in several ways in order to improve the quality the mobility tasks and the system reliability. They highlighted the need to enhance the clarity of the IPW's state and behavior through relevant feedback, to provide multimodal feedback and to offer multiple angles of navigation instead of only four 90° arrows. We propose to implement a display with a map, as the background, integrating a representation of the IPW and its state and behavior so as to provide ongoing feedback. This could be complemented by a 360° controller as a navigational input centered in the IPW's representation in the map. We argue that this display would counteract the disruptive displays used in the LL tests. Furthermore, it might require less cognitive effort to mentally process spatial information.

7. CONCLUSION

This paper presents one of the few studies performed in an ecological setting. It provided some useful information from end-users for the next iteration on the IPW. Indeed, insights from end-users highlighted that more feedback was needed from the IPW. Additionally, multimodal feedback was mentioned for the IPW's functions, the IPW's state and elements in the environment. The respective technological specifications will be implemented in the next iteration of the IPW.

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IMPORTANCE OF ANTHROPOMETRIC DATA IN DESIGN OF PRESCHOOL FURNITURE

B. Iliev, D. Domljan, Z. Vlaović
Department for Furniture and Wood Products, Faculty of Forestry, University of Zagreb, Zagreb, Croatia, iliev_bor@yahoo.com, danijeladomljan9@gmail.com, zvlaovic@gmail.com

Abstract

The accurate knowledge of children's anthropometric data facilitates the manufacture most of the products used by children. At the same time, it helps to achieve adequate design of products, aimed to adopt to children's anthropometric characteristics. In the manufacturing of products for children of preschool age several problems are funded, specially related to dimensions, healthy materials and safety. The lack of adequate and the insufficient literature further complicates the process of designing products for preschool children. The aim of this paper is to highlight the main components that directly affect the dimensions of preschool children and are related to design of children's products, with emphasis on furniture. This paper describes the influence of certain factors and overview of the anthropometric data used in the production of furniture for this target group.

Keywords***:*** *preschool, anthropometry, furniture, children, body dimension*

1. INTRODUCTION

Complete anthropometric data for children, especially for those of preschool age, are shamefully less frequently found in specialized literature than those for the adult person. Human measures, and therefore those of children, belong to a group of certain anthropometric data of one population. In existing and available literature, the anthropometry for adults of both sexes is relatively better collected than child anthropometry that is almost non-existent [1, 2].

Knowing the anthropometric data of children's age is of immense importance when making products that are used by them [3, 4]. Through precisely determined measures, clothes, toys, equipment of rooms used by children are produced. Moreover, through the knowledge of anthropometry, the physical development of each young generation can be determined, which is an essential indicator of the health situation of each nation and together with this also reflect the social and economic and hygienic conditions of each society [5, 6].

2. IMPORTANCE OF ANTROPOMETRIC DATA IN DESIGN OF PRODUCTS (PRESCHOOL FURNITURE)

As an essential and indispensable prerequisite for the design and production of furniture, besides the safety, functionality, use of materials, durability and comfort of the furniture, is the knowledge of anthropometry. Studying the needs of preschool children related most directly to their growth and development reflects on designing furniture that corresponds to their age and dimensions [4, 7].

Anthropometry facilitates information about the physical characteristics of children are of great importance to designers and manufacturers of children's products. If we have this data, we can adapt the design of the product to the majority of this population.

Proper product design is conditioned by accurate body data that will be related to its purpose. Consideration should also be given to the great differences in body dimensions in children of the same age, hence the design of furniture suitable for this entire population is very difficult. This means that using age categories for design purposes (in years, or in months for very young children) will probably misrepresent the real picture. The large variations among children of the same age make it more difficult to design products for children than for adults. Designers of children's products must consider such a key stage in child development and important developmental factors (Figure 1) [8 - 11].

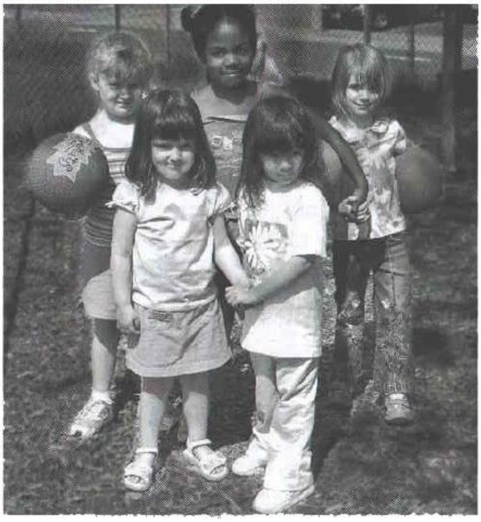


Figure 1: Child anthropometry between children of the same age
Source: Lueder, R. & Berg Rice, V.J., 2008 [8]

The great difference in the anthropometrics dimensions of children even at the same age, as well as their fast and rapid growth, is a big challenge in designing furniture. Differences in child development can sometimes lead to overlapping of anthropometric data for different ages. For example, a 4-year-old child may be taller than the shortest 6-year-old child. These differences between children from different age groups lead to the design of children's furniture according to their development, and not according to the age group they belong to. The anthropometric differences between the sexes of preschool children are not so huge that they can be considered for each sex separately [8, 12-17].

With serial production of furniture, it is impossible to know all the specific characteristics of each individual future user. Hence, an arbitrary sample should be measured of the users for which the product is intended, in order to be able to evaluate the data. For this reason, furniture of varied sizes should be manufactured or be adaptable with various mechanisms [8, 9, 18].

Obtaining massive anthropometric data, even in the most developed countries, is hardly feasible. Large-scale anthropometry surveys are very expensive, time-consuming, and difficult to preform [19]. Anthropometric measurements of pre-school children are carried out in almost all countries at children's checkups, where usually only height, weight and BMI are measured [20].

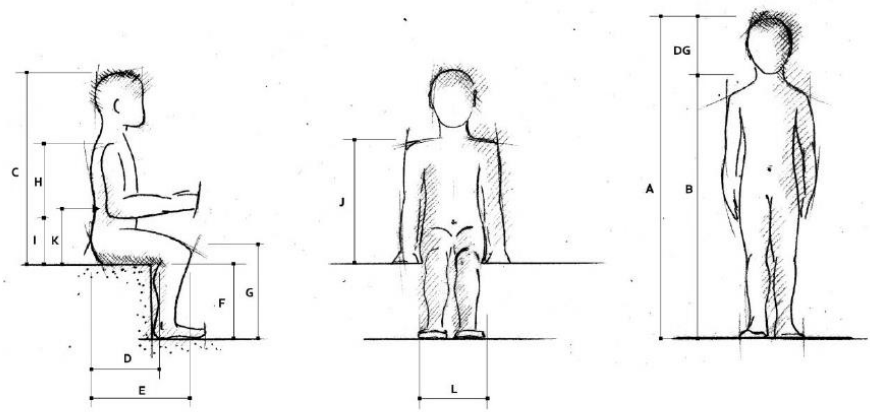
Anthropometric researches are carried out worldwide on different parts of the body, useful for the design of preschool furniture. Those researches are focused on different populations in different geographical zones, sex, nation, or race. This creates a high heterogeneity of the database that cannot be used on the same anthropometric basis in all countries or for a larger number of countries together. Moreover, one anthropometric survey sometimes provides data that are used only for a particular product for a particular population, while not being able to be used for another product or a different population [21- 26].

When designing preschool furniture, the most of designers/producers in many countries use outdated anthropometric data or the data taken from other countries. All this leads to the irregular size of the furniture used. Another element that indicates lack of sufficient anthropometric data is the small number of conducted expert studies. The same view is shared by Panero and Zelnik [27] who point out that the designers are given very little data on the dimensions of the child's body. In some studies that have been made, there are some data missing that are very important for furniture design, while in others, the number of respondents participating in the study is too small to be generalized for each nation separately [28].

The countries where research was conducted on part of the anthropometric data useful for furniture design for preschool children are Finland, UK, Netherlands, USA, Japan, and France [28].

In all anthropometric research, as well as in the collection of data on anthropometry used for furniture design, particular protocols are observed, especially concerning the design of seating elements. Measures should be made by well-trained people and the same should participate in each measurement session. Measures should be taken with the same anthropometric devices. When taking measures in a sitting position, a cubic chair with an adjustable footrest and backrest is used. Children should be seated at angles between body parts of 90° (Figure 2). An example of anthropometric data to be taken in measurements for the furniture design needs is shown in Figure 3. Some of the authors point out the fact that in everyday conditions in schools, kindergartens and at home, children do not stand and sit constantly in standard positions in a natural way [29]. Therefore, the dimensions taken from the measured poses should be changed so that they reflect the actual position of body posture. The positions occupied by the body are many, so designers and producers need to know exact requirements and parameters of all the elements needed to be created [28, 30, 31].

Figure 2: Cubic seat with adjustable footrest
Source: Education and culture Bg 1, [28]



Legend:

A	Stature
M	Weight
DG	head height
B	stature up to head height
C	sitting height
D	upper leg length, buttock–popliteal length, seated
E	upper leg length, buttock to knee, seated
F	popliteal height, seated
G	knee height, seated
H	upper arm length, shoulder to elbow
I	elbow height, seated
J	shoulder height, seated
K	lumbar height
L	hip breadth, maximum when seated

Figure 3: Measured anthropometric variables
Source: Domljan, D., 2011 [12]

2.1. Inconsistency between anthropometric dimensions and children's furniture

Due to old furniture based on outdated anthropometric data, as well as due to lack of new data, the inconsistency between children's anthropometric data and the dimensions of furniture, there is almost no country that does not face the same problem [12, 13, 15].
Numerous authors point out the problem that occurs when sitting on inadequate furniture which is the main cause of poor posture and curvature of the back (kyphosis and scoliosis), as well as MSD/LBP problems [32]. Moreover, it is confirmed that the inconsistency between anthropometric data with the functional dimensions of the furniture is the main cause of back, neck, head and leg pains [12-17, 32].
In the literature, the data related to the mismatch of anthropometric variables with the dimensions of furniture for children of school age are in greater numbers in contrast to the data for preschool children. Such a study that confirms this has been done by Barli [33] in Turkey, which includes 288 preschool children. Eighteen (18) anthropometric variables had been measured during the period 2001-2002. Also, types of furniture such as chairs, tables, coat hanger, washbasin, mirror, WC pan and TV table were measured. A comparison of each furniture variable has been made. The results suggest that in the case of all pieces of furniture that are subject to research at least one of the dimensions does not correspond with the anthropometric data of children. For example, the tables are 'very problematic' in depth, and 'problematic' in width. On the other hand, the chairs are 'problematic' in depth and height.
Research by Voigt and Greil [34] in Potsdam, Germany, conducted on 122 children aged 3-7 years in three (3) kindergartens, suggests that knowing the appropriate anthropometric data helps obtain elements of furniture that are fully functional for children. Six (6) anthropometric variables were taken (sitting height, leg length, elbow height over seat, lower leg length, etc.). This study points out that the detailed knowledge of seated body relevant measurements is necessary for the construction of optimal adapted chairs and desks. An optional chair is marked by the facility to arrange both feet completely on the floor. In this position, the compression on the back of the thighs with their blood vessels and nerves is minimized. For the evolution of optimum height boards, the knowledge of the height of the seat and the elbow height above the seat is essential.
Iliev [16, 17] has conducted research in Skopje, Macedonia on 80 children aged 2-6 years, measuring 13 anthropometric variables and comparing them with the dimensions of existing tables and chairs. According to the obtained data from the measurements of the chairs and tables in the facilities, it can be concluded that the children from the first small group (aged 2-3 years) cannot use the existing chairs and tables, because they are taller than the furniture dimensions. Children from the second small (aged 3-4 years) and middle group (aged 4-5 years) can use the smaller-sized chairs. Children from the oldest group (aged 5-6 years) can use only larger-sized chairs by reducing the height of the seat.

3. CONCLUSION

The proper development of preschool children aged from one to six years, the period in which the greatest changes in body development occur and when the personality of a child forms the basis for a healthy psycho-physical development is the primary responsibility for any society. In the earliest years of childhood most of the changes take place, more than in any other period of life. Physically, the body grows and develops the most, but changes occur as well in social interaction, in speech, in memory, in reasoning, and in all other human functions. In that direction, the physical space in which children spend most of the day, such as in preschool institutions, should be functionally and properly organized in order to achieve correct psycho-physical development.

The lack of adequate literature as well as the insufficient data available on the anthropometric variables of preschool children impose the need for further research involving multiple institutions to obtain relevant data in which the design of furniture would be easier, but on the other hand, suited to children.

Existing anthropometric data are either too old or incomplete. Knowing that studies of this type need the comprehensive work and well financial resources to collect amount of anthropometric data, a small number of data is published. Research conducted in one area or country cannot always be applicable in another because of lot external factors that influence the development of the child, both natural and geographical, as well as socio-economic.

To be concluded, we need more up-to-date literature and references which cover wide spectrum of children's' anthropometric and ergonomics data, as we already know that the most of world population, regardless of sex, age, nationality, etc., accelerated specially in growth and weight, but as well in the other anthropometric variables in last 30 years [3].

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THE INFLUENCE OF SHORT PERIODS OF ACTIVATION ON THE DRIVERS' STATE AND TAKE-OVER PERFORMANCE IN CONDITIONAL DRIVING AUTOMATION

O. Jarosch[1,2], S. Paradies[1], K. Bengler[2]
[1] BMW Group; Research, New Technologies, Innovations; Parkring 19, 85748 Garching, Germany
[2] Technical University Munich, Chair of Ergonomics, Boltzmannstr. 15, 85748 Garching, Germany

Abstract

Conditional Automated Driving (CAD), SAE Level 3, is short before introduction to the consumer market. In this level of automation the human driver can engage in non-driving related tasks as the system takes over longitudinal and lateral steering. Although not obliged to monitor the system, the human driver represents the fallback performance and hast to be able to take-over control of the vehicle if requested by the system. In previous experiments on the drivers' state in CAD, it could be shown, that fatigue can occur due to passive task related fatigue. Take-over performance was affected in prolonged automated rides. In the current study, effects of short periods of activation during CAD were examined in a driving simulator study. Results suggest, that short periods of activation can impede extreme fatigue in CAD. The different activations affected reaction times and take-over behavior of the drivers.

Keywords: *Conditional Automated Driving, Driving Simulation, Non-diving related tasks, take-over performance*

1. INTRODUCTION

With increasing automation of vehicles the role of the human driver changes drastically. An overview of the different levels of automation is given in the SAE report J3016 [1]. From Level 0, *no automation*, over Level 1, *driver assistance*, and Level 2, *partial automation*, the systems increasingly support the driver in the dynamic driving task. In these lower levels of automation, the human driver still is in duty to monitor the driving environment and responsible for the correct execution of the dynamic driving.
With introduction of SAE Level 3, this will be different for the first time. From this level on, the human driver does not have to monitor the driving environment and the driving task anymore. That also brings along, that the human driver can engage in non-driving related tasks while driving automated. Unlike to the higher SAE Levels 4 & 5, in SAE Level 3, the human driver represents the fallback performance and has to regain control of the vehicle if requested by the system. This can be the case if the driven route contains sections that are not authorized for automated vehicles and the human driver has to take-

over control (e.g. construction-work zones or the end of a highway) or when the on-board sensors of the automated vehicle detect a situation that necessitate an intervention of the driver (e.g. obstacles on the road or insufficient lane-markings). The first mentioned situations can be categorized to long-term and uncritical take-over situations as the driver can be prepared for the imminent take-over far in advance. Things look different, when it comes to a short-term and critical take-over situation detected by the on-board sensors. The available time budget for a human drivers' intervention in such a short-term take over situation is no longer than 5 – 10 seconds [2]. Because of that, an adequate drivers' state seems to be essential in CAD, SAE Level 3.

Based on human factors research of the past it has to be assumed, that it can be quite difficult to maintain an adequate drivers' state when driving automated. Especially monotonous situations and prolonged automated driving seem to cause fatigue and drowsiness which can be incompatible to the target drivers' state.

To counteract emerging fatigue of the human driver while driving automated, short periods of activation could be used to keep the driver in an adequate drivers' state.

To examine effects of activations during CAD on the drivers' state 60 subjects participated in a driving simulator study. Two different activations were examined in a between-subjects design and occurred for two five minute intervals during the ride. Additionally a control-group without activation represented the third group. The participants drove about 50 minutes, when a take-over situation occurred. We assumed differences in the drivers' state and take-over performance according to the occurring activations during the automated ride.

2. THEORETICAL BACKGROUND

2.1. Fatigue

In manual driving relevant consequences of fatigue are poor reaction times and an impaired driving performance. Therefore it has to be assumed, that fatigue in CAD impairs take-over performance in a same manner.

In their fatigue model May & Baldwin [3] represent causations and consequences of fatigue in manual driving. It is distinguished between active task-related fatigue, passive task-related fatigue and sleep-related fatigue. Active task-related fatigue is related to overload conditions like high traffic density and bad sight conditions. Passive task-related fatigue instead can be caused through monotony and increased automation. Sleep-related fatigue is dependent on the circadian rhythm. Consequences, of all forms of fatigue described in the model, are bad driving performance and an increased crash risk.

Neubauer et al. [4] assume, that with introduction of CAD factors causing active task related fatigue can be reduced due to the system taking care of the driving task. Factors causing passive task-related fatigue indeed can be intensified with the introduction of CAD as the human driver acts more as a system-supervisor than an active operator.

2.2. Previous studies on the influence of NDRT's on take-over performance

In previous studies on the influence of non-driving related tasks (NDRTs) in CAD on take-over performance it could be shown, that within 25 minutes passive task related fatigue emerges when participants had to engage in a monotonous monitoring task compared to an activating Quiz-task [5]. Take-over performance was not affected after 25 minutes of engaging in the NDRT's. In a further study, Jarosch et al. [6] used the same NDRTs and the same take-over situation again and just increased the time on-task / time of automated driving to 50 minutes. Take-over performance was impaired in both groups. Especially when participants had to engage in the monotonous monitoring task, reaction times like first glance-on road or braking reaction increased significantly. The drivers' reaction upon the request to intervene (RtI) differed depending on the NDRT: When engaging in the activating Quiz task, people often reacted with a more complex lane-change maneuver whereas people who had to engage in the monotonous monitoring task more likely reacted with emergency braking. Six people lost control of the vehicle and crashed (four of the monotonous monitoring task and two of the quiz task).

2.3. Assessment of Take-Over performance

In CAD take-over performance can be assessed using driving-performance measures or measures of reaction times upon the RtI. Common take-over reaction time measures are eyes-On road, hands-On-detection, first braking reaction, steering wheel angle exceeding 2° and brake-pedal actuation exceeding 10%. Measures concerning the quality of the divers' input are maximum accelerations (longitudinal as well as lateral), time-to-collision and measures of the tracking in the lane (standard deviation of lateral position, SDLP) [7].

2.4. Assessment of the drivers' state

The drivers' state can be assessed with objective data (physiological data, eye-lid based measures) and subjective ratings. Suitable physiological parameters are heart-rate, heart-rate-variability and EEG. Next to physiological measures, eye-lid based measures like percentage of eye-lid closure (PERCLOS) [8], blink duration and blink frequency have frequently been used in driving simulator studies. The Karolinksa-Sleepiness-Scale (KSS) [9] is a frequently used method for the subjective assessment of fatigue. Subjective fatigue is rated on a nine-point Likert-scale (1 = no fatigue; 9 = very tired).

3. METHOD

The main aim of the study was to assess the influence of short periods of activation on i) the drivers' state and ii) on take-over performance in CAD. Therefore a driving simulator study was conducted to assess the influence of three different activations on the drivers' state and resulting take-over performance.

3.1. Participants

N = 57 (female: n = 13, male: n = 44) employees of the BMW Group participated in the study. Mean age was 30.42 yrs (*SD* = 8.64). Mean driving experience was 11.95 yrs (*SD* = 8.31). The majority of the sample had experienced adaptive cruise control or other assistance systems (64.9 %). Reported trust (0 – 100%) in assistance system was M = 57.61 (SD = 32.68).

3.2. Apparatus

The study was conducted in a static driving simulator at BMW facilities in Munich. As mock-up a BMW 3 series was used. PERCLOS was measured with Dikablis Professional glasses and D-LAB 3.0 software. The quiz task was presented on a Windows Surface tablet mounted in the vehicle in front of the central information display.

3.3. Specifics of the automated system

The status of the automated system was indicated with a HMI. Three different states could be displayed: CAD available (grey steering wheel and "Autobahnpilot verfügbar"), CAD activated (blue steering wheel and "Autobahnpilot aktiv") and RtI (visual: red steering wheel with grabbing hands "Bitte manuell fahren", auditory: warning-tone). When the system was activated, the vehicle overtook lateral and longitudinal control, changed lanes and kept speed at a level of 130 km/h. Speed limits were adjusted automatically. In case of a take-over situation the RtI was presented.

3.4. Experimental Design

Upon arrival participants had to fill out a demographic form including information on personal data, experience with drivers' assistance systems and experience with driving simulator studies. A sheet including information on the specifics of CAD and the possibility of take-over situations was handed-out to the participants. After this first part, participants were equipped with the Dikablis eye-tracking system. A familiarization ride with the driving simulator followed. In this trainings ride, participants first drove manually, to accustom with the simulator. After about five minutes of manually driving, participants had to activate the system for CAD. When the system was switched on, after about two minutes, the examiner again explained that take-over situations can occur when driving conditionally automated. Thereupon the examiner triggered an RtI to demonstrate the HMI signal and participants had to take-over for the first time. Two more RtIs followed to familiarize participants with the different possibilities for taking over.

After the trainings session the actual experimental ride followed. In this experimental ride participants were instructed to switch on the system for CAD when they entered the highway. They were instructed to enjoy the automated ride and were forced to not take-over control unless the system requests them. Dependent on the assigned group, participants were forced to deal with the respective activation when they occurred.

After 50 minutes of automated driving, the take-over situation occurred. After the ride a questionnaire concluded the experiment.

3.5. Take-over scenario

The ride was conducted on a three-lane highway with a hard shoulder. After about 50 minutes of the automated ride a take-over situation occurred. Time-to collision (ttc) with the accident on the own lane was seven seconds. On the lane left of the ego vehicle there was a gap of 100 m between two cars. One car was 50 m in front, the other car 50 m behind the ego vehicle. The take-over situation could be solved either with a braking maneuver or a more complex lane-change maneuver.

3.6. Periods of activation

In previous studies positive effects of an activating quiz task on the drivers' state were demonstrated [10]. In reference to findings of Jarosch et al. [5], [6] it can be assumed, that these positive effects disappear after a certain time of automated driving when the NDRT has to be processed for the entire ride. One explanation can be found in the model of May & Baldwin as one causation for passive task-related fatigue is monotony. Therefore, the activations used in this experiment were chosen to prevent the drivers' from increasing monotony. The activations lasted for five minute intervals and occurred for two times during the automated ride (min 17. – 22. and 32. – 37.) Activations used in the experiment were:

- Quiz-task: visually and cognitive demanding
- Manual driving: visually and manually demanding
- Baseline: no activation

3.7. Measurement of the drivers' state and take over performance

The drivers' state was measured using PERCLOS (1 min intervals) and subsequent subjective KSS ratings for defined points of time over the course of the experiment (min 2-3, 15 – 16, 30 – 31, and 45 – 46). Take-over performance was examined using the parameters mentioned in section 2.3 in the take-over situation.

4. RESULTS

The main aim of the study was to investigate effects of short periods of activation on i) the drivers' state and ii) how this affects take-over performance of the subjects.

4.1. Effects of activations on the drivers‘ state

For the assessment of effects of the activations on the drivers' state mixed ANOVAs were calculated. Time of measurement (within) and the type of activation (between) were used as the two main factors.

4.1.1 KSS

Results suggest, that the factor time of measurement significantly affects KSS, F = (2.46, 132.99) = 75.715, $p < .001$, partial $\eta^2 = .584$). The main factor activation did not affect KSS significantly, F = n.s.. Highest KSS scores were reported in the Baseline group after 46 minutes of automated driving (M = 7.13, SD = 1.63) compared to manual driving (M = 6.2 , SD = 1.91) and the quiz-task (M = 6.19, SD = 2.02).

4.1.2 PERCLOS

Due to technical problems, two participants had to be excluded from analysis resulting in N = 55. The factor time of measurement significantly affects PERCLOS, F = (2.39, 124.19) = 12.464, $p < .001$, partial $\eta^2 = .193$). The main factor activation did not affect

PERCLOS significantly, F = n.s.. Highest values were measured in the Baseline group (M = 11.88, SD = 6.71) compared to manual driving (M = 9.21, SD = 7.25) and quiz-task (M = 9.64, SD = 5.96).

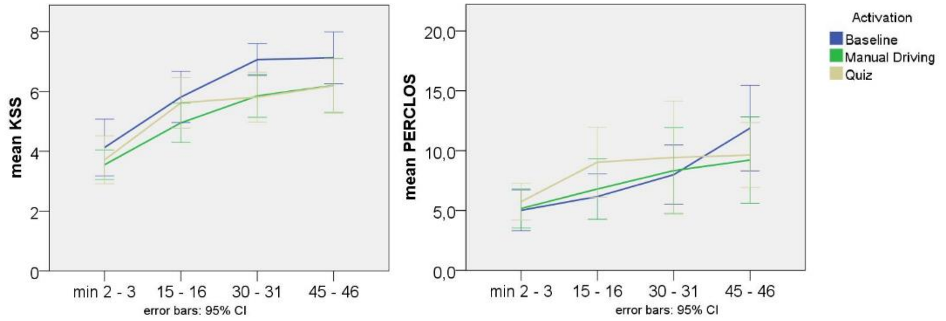

Figure 4: mean KSS and PERCLOS over the course of the ride

4.2. Effects of activations on take-over performance

Effects on take-over performance were analyzed using one-factor ANOVAs with the factor activation (Baseline, Manual Driving or Quiz).

4.2.1 Reactions after RtI for the different activations

Drivers could either react with a braking-maneuver or a lane-change maneuver. In some cases the drivers could not react appropriately and lost control or crashed. The drivers' reactions upon RtI can be seen in Fig. 2. Due to technical problems one participant had to be excluded from analysis resulting in N = 56 participants. Differences due to activities are not significant (*Fisher's exact test*).

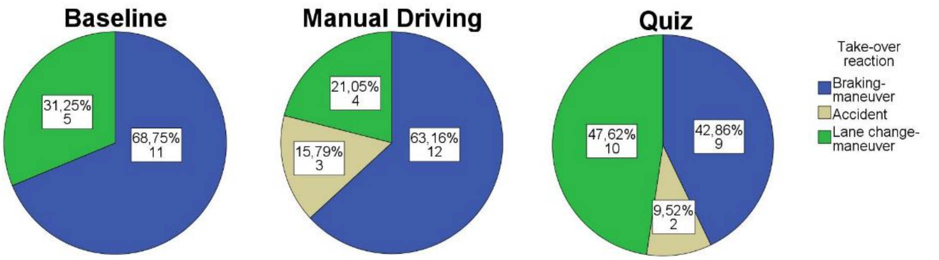

Figure 2: Reactions of the drivers upon RtI

4.2.2 Reaction times & Driving Performance Measures

Measured reaction times upon RtI did not differ significantly between the activations. The reaction times upon RtI can be seen in Fig. 3.
The parameters concerning the quality of the drivers' input did not differ significantly amongst the groups of activation. For further information see Fig. 4.

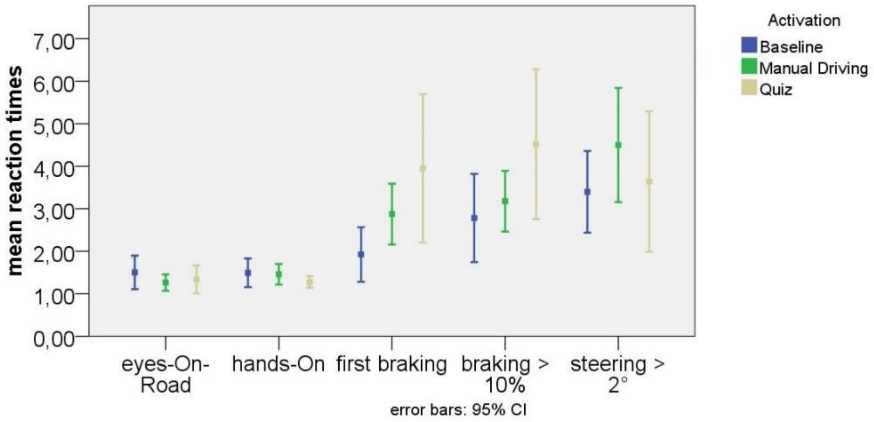

Figure 3: Reaction times upon RtI

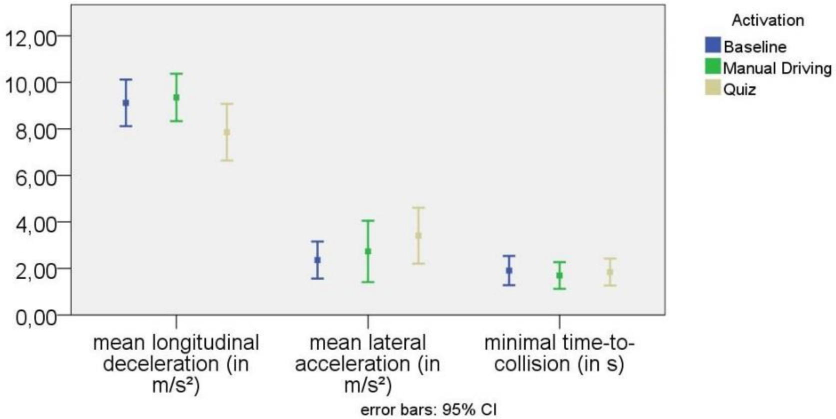

Figure 4: Driving Performance Parameters after the take-over

5. DISCUSSION

The main objective of the study was to find out if different activations during CAD can be used to i) hold the driver in a designated drivers' state and ii) if activations during CAD has an impact on take-over performance when it comes to an RtI.
Results suggest, that fatigue cannot be completely prevented through short activations during CAD. However, participants that had to deal with a quiz task or had to drive manually for two five minute intervals had lower subjective KSS ratings and lower PERCLOS values compared to the Baseline group that had to do nothing for the entire ride. In the Baseline group PERCLOS especially rose between the last two points of measurement. This means, that a manual task (manual driving) as well as a cognitive task (quiz-task) can be advantageous for keeping a driver in an adequate drivers' state in CAD. Another aim of this study was to examine effects of activations during CAD on take-over performance. Five participants could not react appropriately and either crashed into the

accident on the own lane or lost control over the vehicle. None of these accidents or losses of control happened in the Baseline group. In both other groups, quiz-task and manual driving, accidents occurred. One possible explanation for this phenomenon can be, that the majority of participants from the Baseline group reacted with a braking maneuver instead of doing a lane-change maneuver. Many drivers from the Baseline group did not recognize the gap on the left lane or view in the mirrors. Maybe they were shocked through the RtI and reacted reflexively. When considering the reaction times upon RtI this gets reinforced as the Baseline drivers' showed the fastest braking and steering reactions. The period of time between eyes-On road and braking or steering was lowest in the Baseline group. This also means that the time to understand the situation was lowest in this group. In both other groups, especially in the quiz-task group many participants reacted more appropriate and more deliberate. Nevertheless, accidents just occurred in these two groups. Participants of these two groups often overestimated themselves and wanted to perform a more complex lane-change maneuver which often led to losses of control due to inadequate steering. Concluded, long periods of automated driving can lead to panic or stress reactions of the participants when a take-over occurs. Therefore it is recommended, that the driver has to be supported when it comes to a take-over situation.

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INTERIOR NOISE ANALYSIS OF SUPERSONIC FIGHTER AIRCRAFT MIG-21 UMD

D. Jerinić[1], M. Maradin[1], T. Bucak[2]
[1] [1]Ministry of Defense, Croatian Air Force, King Petar Krešimir 4 Square, 10000 Zagreb, Republic of Croatia, dominik.jerinic01@gmail.com, mmaradeen@gmail.com
[2] [2]University of Zagreb, Faculty of Transport and Traffic Sciences, Vukelićeva 4, 10000 Zagreb, Republic of Croatia, tbucak@fpz.hr

Abstract

This paper contains overview and analysis of supersonic fighter's MiG-21 UMD cabin noise parameters measured during typical aircraft engine power settings in static i.e. on-ground conditions: idle power, maximum continuous power, 1st afterburner stage and 2nd afterburner stage. The research aims to evaluate the ergonomic aspect of noise impact on supersonic fighter pilot's hearing. Assessed data show cabin noise levels above recommended under all aircraft engine regimes.

Keywords: *aircraft interior noise, supersonic fighter, Mig-21*

1. INTRODUCTION

Noise, vibrations and gas emissions are the main presentation parameters of aviation harmful impact on environment. On the other side of the fuselage, pilot or crew feels the interior, a.k.a. cockpit noise which impacts their concentration, attention, effectiveness and flight safety [1]. Due to different engine and flight regimes, the noise has different impact levels on common airmen tasks, their nerve system and concentration while aircraft is airborne, stationary or steering on maneuvering areas.

2. AIRCRAFT AS A SOURCE OF NOISE

During operation, aircraft is a high intensity artificial source of noise which contains numerous particular sources, while power plant, i.e. engine(s) being the most prominent one. The lowest noise levels are produced during engine minimum power (IDLE) regime. This regime is used after engine start-up for engine warm-up, aircraft and pilot/crew preparation for flight, taxing and holding at the holding points. The highest noise levels from the engine are produced during take-off flight phase. That operation requires maximum power which can be even more than 100% of the continuous one. After take-off, pilot usually sets power to maximum continuous power for climbing. Figure 1 shows noise source identification with levels measured during approach at two discrete frequencies.

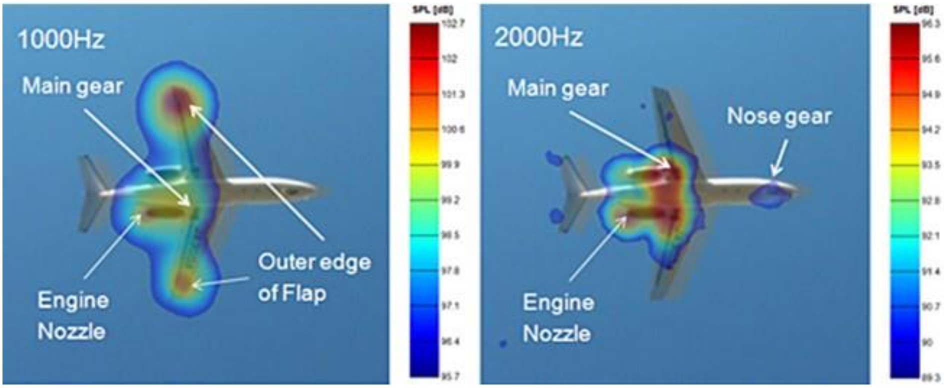

Figure 1: Noise spreading into environment
Source: [2]

For many years, aircraft engine and fuselage constructors and aviation authorities alike are putting strong efforts to reduce the impact of air traffic on civil population and environment. The outcome of their work results in aircraft noise levels decreased by 80% during last six decades. Figure 2 presents the development of noise reduction during mentioned period. Along with external noise mitigation process, a considerable improvement was achieved in internal noise reduction as well. The noise can be reduced by three basic methods: at the source (the most efficient way), on the propagation path(s) (passive protection) and at the observer position (active and passive protection).

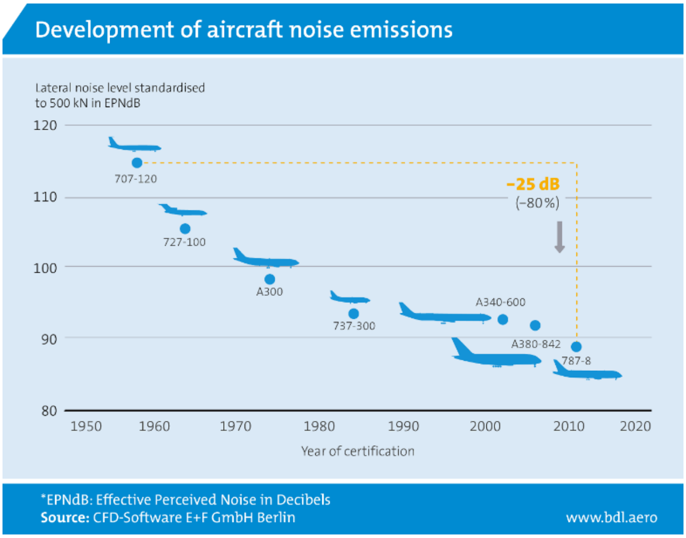

Figure 2: Development of aircraft noise mitigation
Source: [3]

3. MEASUREMENT OF INTERIOR NOISE OF SUPERSONIC FIGHTER MiG-21 UMD

3.1. Characteristics of MiG-21 aircraft

MiG-21 UMD aircraft is Russian supersonic fighter, single engine two-seater, made for fighter pilots training from basic to advanced flying. It's been made mostly by aluminum with steel additions, magnesium and fiberglass. It has delta wings with conventional tail. On the front side of an aircraft is automatic cone for intake regulation. First type of this aircraft has been made in 1960s and the MiG-21 UM from 1971 was upgraded to MiG-21 UMD for Croatian Air Force in 2003. Some tactical-operational characteristics of MiG-21 UMD aircraft are presented in Table 1.

Table 1: Technical-operational characteristics of MiG-21 aircraft

Description	Value
Seat number	2
Engine	Tumansky R-13-300
Maximum Thrust	41,55 (without afterburner) 64,73 (with afterburner)
Length (with pitot-tube)	15,76 m
Wing span	7,15 m
Height	4,10 m
Wing area	23 m^2
Basic empty mass	5730 kg (with crew)
Take-off mass (with two R-3S)	8000 kg
Maximum take-off mass	8500-9500 kg
Maximum speed at mean sea level	1300 km/h (1,06 Ma)
Maximum speed at 12000 m	2150 km/h (2,02 Ma)
Maximum rate of climb	6400 m/min
Maximum celling	15250 m (theoretically 18000 m)
Maximum range	1100 km
Maximum fuel capacity with additional tanks	3090 litres

MiG-21 UMD aircraft of the Croatian Air Force is presented on Figure 3.

Figure 3: MiG-21 UMD aircraft of the Croatian Air Force
Source: [4]

3.2. Measurement method and equipment

Interior noise measurement of MiG-21 UMD aircraft was performed at Zagreb Airport using Class 1 Sound Analyzer according to ISO5129 standard at the copilot seat position with opened and closed canopy (the former due to service procedures during preflight checks). Throughout both measurement conditions, engine regimes were as follows: idle power (in further text: IDLE), maximum continuous power (in further text: MCP), 1st stage afterburner (in further text: 1A) and 2nd stage afterburner (in further text: 2A).

3.3. The results and analysis

Review of the results is given in following tables and figures, while presented noise values are LA_{eq} expressed in dBA. Table 2 and Figure 4 show noise values measured with open canopy, which is standard position during ground engine run-up and testing after maintenance cycle, while Table 3 and Figure 5 contain the results with standard inflight position, i.e. closed canopy.

Table 2: Measurement results of MiG-21 UMD noise with open canopy

Engine regimes	LAeq (dBA)
IDLE	94,6
MCP	107,8
1A	111,4
2A	109,8

The highest noise level of 111,4 dBA is measured during engine regime 1A., which is expected due to maximum engine power setting with afterburner.

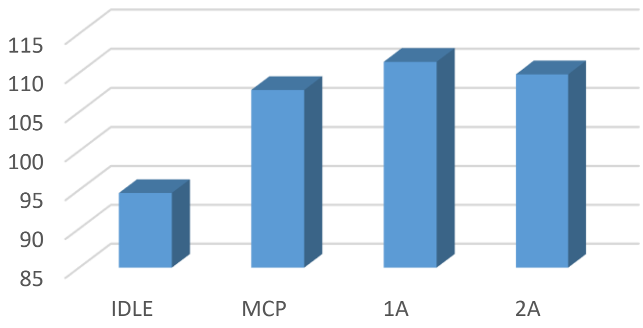

Figure 4: MiG-21 UMD noise levels with open canopy for various power settings

Measurement results of interior noise with closed cabin are presented in Table 3. Measurement position was the same. It is important to notice that MiG-21 UMD cabins, front pilot and rear copilot, are not isolated from each other. That allows front cockpit noise to impact rear cockpit and vice versa.

Table 3: Measurement results of MiG-21 UMD interior noise with closed cabin

Engine regime	LAeq (dBA)
IDLE	93,2
MCP	105,6
1A	106,1
2A	105,8

Again, as expected, the highest equivalent noise level of 106,1 dBA was measured during engine regime 1A . This result confirms the previous measurement with open cabin due to maximum engine power setting with afterburner.

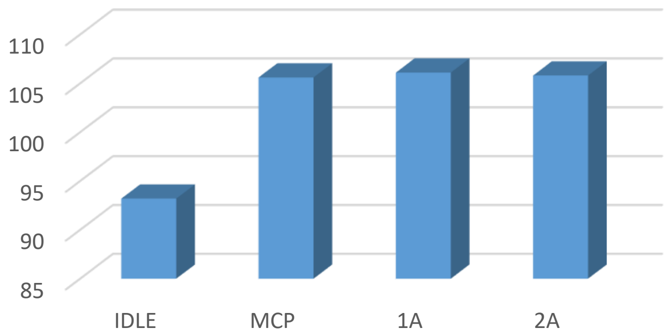

Figure 5: MiG-21 UMD equivalent noise levels with closed canopy for various power settings

4. CONCLUSION

In the last six decades, aircraft noise decreased by 80% or more than 25 dBA, which influenced interior noise levels as well. During ground operations, the biggest ″culprit" for noise impact on airmen, both pilots and ground crew, is aircraft engine. The intensity of noise depends primarily on engine power settings and regimes. It has been scientifically proven that exposure to high intensity noise can deteriorate pilot/crew hearing hence it's important to use adequate means of protection. Taking into account maximum recommended values not exceeding 90 dBA for tolerable acoustical comfort, which is also time-dependent, all results show deteriorated ergonomics within pilot's cabin in Mig-21 UMD aircraft. Even the minimum interior noise level of 93,2 dBA is measured with closed cabin and IDLE engine regime. For comparison, maximum noise level of 111,4 dBA with open cabin is measured in engine regime 1A. All other results are expectedly between mentioned noise levels. The aim of this study is to raise the awareness among airmen about negative noise impact on their hearing. However, to get the more detailed review about noise impact on Mig-21 UMD pilot/crew, the more comprehensive measurements during all inflight phases should be performed.

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DETERMINATION OF FORCES AND MOMENTS OF HAND JOINTS FOR DESIGNING A REHABILITATION DEVICE

J. Kamenar, D. Ćurko, T. Jurčević Lulić, J. Leder Horina
Faculty of Mechanical Engineering and Naval Architecture, Zagreb, CROATIA,
jelena.kamenar@gmail.com, daria.curko@fsb.hr, tanja.jurcevic@fsb.hr,
jasna.leder.horina@fsb.hr

Abstract

Rehabilitation devices are used for hand rehabilitation in patients with finger paralysis, which happens as a consequence of stroke. The most commonly used rehabilitation procedure usually involves movements of flexion and extension of fingers. When designing rehabilitation devices, it is possible to analyse, at an early stage, using a computer model, the device characteristics, and efficiency of interaction of the device and the body part that is in need for rehabilitation. The aim of the research was to develop a mathematical model of a human hand describing flexural and extensional motion and behaviour of the hand while interacting with a rehabilitation device. Kinematic data was determined by measurement in a biomechanical laboratory. Moments in the hand joints were calculated and used as indicators of activity of individual muscles. The proposed mathematical model provided an analysis of the characteristics of the future rehabilitation device.

Keywords: *finger paralysis, rehabilitation device, mathematical model*

1. INTRODUCTION

The human hand allows different functions important for everyday life [1]. After an injury or a stroke, it is necessary to carry out the hand rehabilitation. Rehabilitation can be carried out using devices designed especially for this purpose. When talking about rehabilitating patients with finger paralysis, which is the result of a stroke, rehabilitation devices that enable flexion and extension of fingers are used [2].
Moments in the joints are indicators of the activity of individual muscles [3]. When designing a rehabilitation device, it is important to know the forces and moments of hand joints since it enables in the early stages of designing, by using a computer model, analysis of device characteristics and efficiency of interaction of the device and the body part in need for rehabilitation.
Different biomechanical models have been developed for analyzing the internal load of tendons and muscles during movement and action of external loading [4]. These hand models have advantages and disadvantages with regard to the measurement method and complexity.
Each finger has four joints, proximal to distal: CMC (carpometacarpal joint), MCP (metacarpophalangeal joint), PIP (proximal-interphalangeal joint) and

DIP (distal-interphalangeal joint) [3, 5-8]. The movements that occur in the hand can be divided into three levels: joint motions between the carpal and the metacarpal bones, joint motions between the wrist and the phalangeal bones and joint motions between the phalanges. It is important to distinguish flexion, extension, adduction, abduction and circular motion or rotation of the first metacarpal bone. Flexion is the most prominent movement.

Finger muscles can be divided into external and internal [3, 5-8]. External muscles are long flexors (causing a joint to bend) and extensors (causing a joint to straighten) and are called external because the muscular body is located on the forearm. Fingers have two long flexors, located on the lower side of the forearm. Extensors are located on the back of the forearm.

Anatomy measurements and determining the range of motion (ROM) are the basis for biomechanical analysis. The three-dimensional (3D) motion analysis system is the most commonly used technique to measure kinematic variables such as the trajectory and angle and to determine velocity and acceleration.

The aim of this research is to develop a mathematical model of a human hand that describes flexural and extensional motion and behaviour of the hand in interaction with a rehabilitation device. The proposed model should enable the analysis of the characteristics of the future rehabilitation device for patients with finger paralysis.

2. METHODS

The future rehabilitation device should provide flexion and extension of fingers, where the device acts upon rigidly connected fingers and the hand laterally leans against the underlying surface. This way, it is sufficient to make a two-dimensional (2D) mathematical model because the motions in the third plane are negligible. The problem is set as an inverse dynamic problem that determines the forces and moments for a system where the motions are known, and a planar multibody model with natural coordinates is used. The model does not take into account gravity because its force acts vertically on the observed plane. The connection with the rehabilitation device is presented as a force with which the device acts upon the fingers. The model is shown in Figure 1.

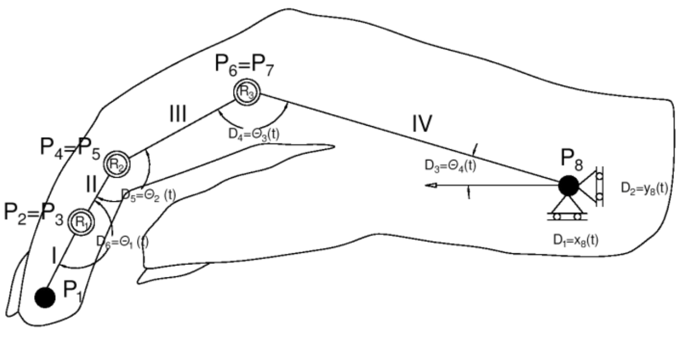


Figure 1: Planar multibody model of the hand with six degrees of freedom
Source: Taken from Kamenar, J., 2016 [9]

The model consists of four rigid bodies (metacarpal bone – IV, proximal phalange – III, middle phalange – II, and distal phalange – I) that are linked by three revolute joints (R1-DIP joint, R2-PIP joint, R3-MCP joint). The model is described with a total of eight points (i.e. sixteen natural coordinates) that are represented in the form of a vector:

$$\mathbf{q} = \{x_1, y_2, x_2, y_2, x_3, y_3, x_4, y_4, x_5, y_5, x_6, y_6, x_7, y_7, x_8, y_8\}^T \quad (1)$$

The model has six degrees of freedom: two translational and one rotational in the wrist and three rotational in finger joints, hence, the number of kinematic constraints needed to express the interdependence of natural coordinates equals the difference between the number of natural coordinates and the number of degrees of freedom. Kinematic constraints include the ones of a rigid body that strive to preserve the constant length of rigid bodies labeled with Roman numerals I to IV, kinematic constraints of revolute joints and kinematic constraints of kinematic drivers that fully describe the motion of the system during kinematic and dynamic analyses. Kinematic constraints are included in the vector [9]:

$$\mathbf{\Phi}(\mathbf{q},t) = \begin{Bmatrix} (x_2 - x_1)^2 + (y_2 - y_1)^2 - L_{12}^2 \\ (x_4 - x_3)^2 + (y_4 - y_3)^2 - L_{34}^2 \\ (x_6 - x_5)^2 + (y_6 - y_5)^2 - L_{56}^2 \\ (x_8 - x_7)^2 + (y_8 - y_7)^2 - L_{78}^2 \\ x_3 - x_2 \\ y_3 - y_2 \\ x_5 - x_4 \\ y_3 - y_2 \\ x_7 - x_6 \\ y_7 - y_6 \\ x_8 - x_8{}^*(t) \\ y_8 - y_8{}^*(t) \\ -(y_7 - y_8) - L_{78}\sin\theta_4(t) \\ -(y_8 - y_7)\cdot(x_5 - x_6) + (x_8 - x_7)\cdot(y_5 - y_6) - L_{78}\cdot L_{56}\cdot\sin\theta_3(t) \\ -(y_6 - y_5)\cdot(x_3 - x_4) + (x_6 - x_5)\cdot(y_3 - y_4) - L_{56}\cdot L_{43}\cdot\sin\theta_2(t) \\ -(y_4 - y_3)\cdot(x_1 - x_2) + (x_4 - x_3)\cdot(y_1 - y_2) - L_{34}\cdot L_{12}\cdot\sin\theta_1(t) \end{Bmatrix} = 0 \quad (2)$$

By partial derivation of the vector of kinematic constraints, the Jacobian matrix is determined. The motion equations of the system, written in matrix form, read:

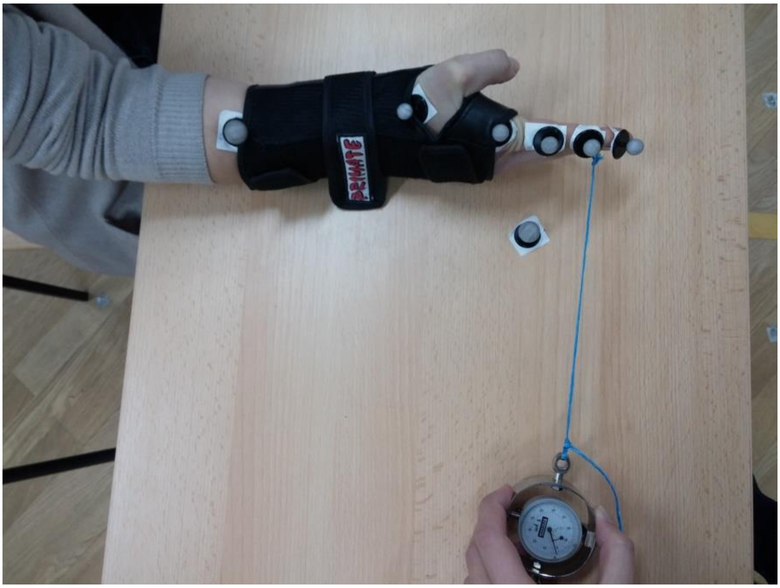
$$\begin{bmatrix} \mathbf{M} & \mathbf{\Phi_q^T} \\ \mathbf{\Phi_q} & \mathbf{0} \end{bmatrix} \begin{Bmatrix} \ddot{\mathbf{q}} \\ \boldsymbol{\lambda} \end{Bmatrix} = \begin{Bmatrix} \mathbf{g} \\ \boldsymbol{\gamma} \end{Bmatrix} \quad (3)$$

where $\mathbf{M}$ represents the mass matrix, $\mathbf{\Phi}$ the vector of kinematic constraints, $\mathbf{\Phi_q}$ the Jacobian matrix of kinematic constraints, $\boldsymbol{\lambda}$ the vector of Lagrange multipliers, $\ddot{\mathbf{q}}$ the vector of generalized acceleration, $\boldsymbol{\gamma}$ the vector of acceleration equations, $\mathbf{g}$ the vector of generalized forces. In order to obtain the response of the model, the equation of motion of the system should be integrated in time.

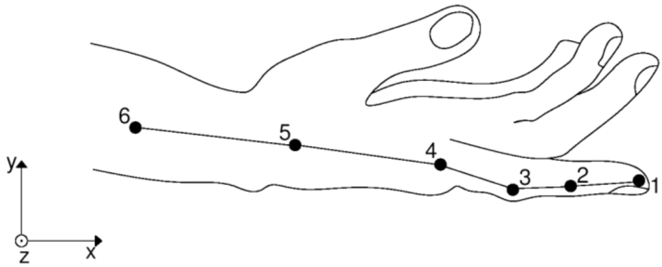
Required kinematic data was determined by measurement carried out using the BTS Elite system (producer BTS Bioengineering, Milan, Italy). The system allows you to track and capture spatial coordinates of markers placed on specific body points. The system consists of 8 cameras, whose arrangement can be seen in Figure 2 (one camera is not seen because of its position in the upper left corner), operating at a frequency of 100 Hz. Before the recording starts, the system is calibrated and the global coordinate system is determined. The cameras have built-in LED diodes that are synchronized with them and emit infrared beams. Markers that receive reflected infrared beams are placed on the specific points on the hand and they convert them into a digital record that is sent back to the computer processor. The computer analyses each frame what serves as the basis for computing the marker coordinates in a spatial framework.

Figure 2: The BTS Elite System

Eight markers were used (Figure 3), 5 of which were on the hand, 1 on the forearm, 1 on the base, and 1 on the dynamometer to determine the direction of motion and the direction of the force acting on the fingers. The markers were placed on the index finger: one on the fingertip (marker 1), one on each joint of the finger – DIP (marker 2), PIP (marker 3) and MCP (marker 4), and one on the wrist joint (marker 5). Marker 6 was placed on the forearm.



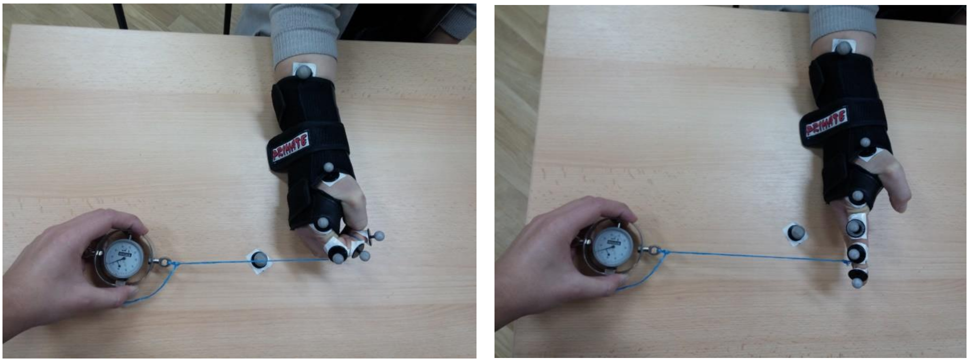
a.



b.

Figure 3: Marker placements: a. photo, b. schematic drawing

A motion was recorded that simulates opening of the hand and finger movements during the rehabilitation of patients with finger paralysis, the result of a stroke. On the wrist, a hand immobilizer was placed to stiffen the wrist. The fingers were pulled by a rope at end of which there was a dynamometer. This way, in the middle of segment II a constant force was applied that was measured by the dynamometer. The force acted in the direction of the link that connected the segment II to the dynamometer. Since the movement took place in a plane perpendicular to the direction of gravitational force, this force was excluded from the calculations. The only external force that acted on the system was the force measured by the dynamometer. The examinee was a 24-year-old girl, and the measured movement was flexion-extension of her right hand (Figure 4). The inertial characteristics of the hand were calculated according to data found in the literature [2, 10]. The center of mass of each segment was assumed to be at the half of its length. By recording the movement, marker displacements were determined, as well as the corresponding speeds, accelerations, and required angles. The force acting on the hand was determined by using the dynamometer.



a. b.

Figure 4: Hand movements: a. flexion, b. extension

3. RESULTS

A dynamic analysis code [9] was written in the Matlab software. The code allows the determination of internal forces and moments in the joints, and for the input data uses the kinematic data specified by the BTS Elite system, the data on external force acting upon the hand, and calculated data on masses and moments of the hand parts. The moments are the greatest indicators of how the rehabilitation device affects the hand. An example for this, Figure 5 shows the calculated moments in finger joints (R1, R2, and R3) and in the wrist (R4) when an external force of 2 N is applied. The abscissa shows the number of frames, while the ordinate shows the moment values expressed in Ncm. Frames on the abscissa can be converted to time expressed in seconds if the frame number is multiplied by 0.1. Moment *M1* refers to the moment in the joint R1, moment *M2* in the joint R2, moment *M3* in the joint R3, and moment *M4* in the wrist of the hand. The moment in R1 is very close to zero since the external force acts on the body segment II and there is no force acting on the body segment I. The diagrams show that the magnitude of moments increases towards the wrist, which is understandable as the external moment arm increases. The highest absolute values of torque correspond with the maximum extension. Moment values show that during the movement the most active muscles were hand extensors, while the flexors role was to stabilize the movement. Hence, according to these analyses, the rehabilitation device mostly affects extensors.

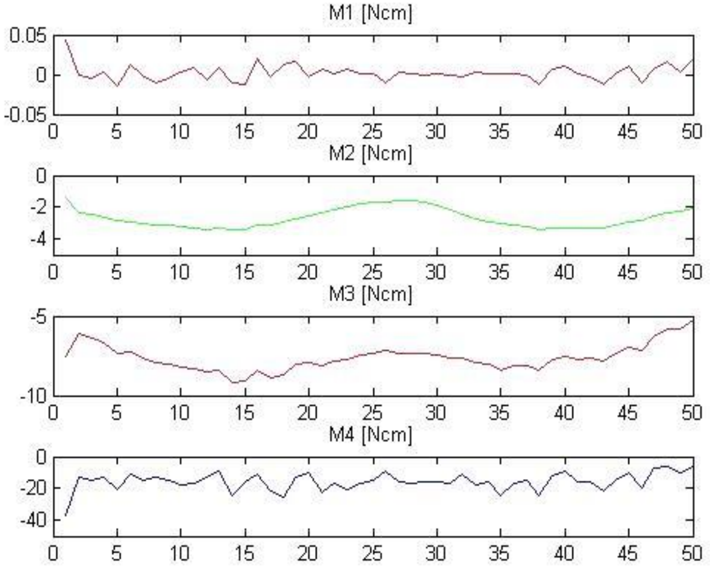


Figure 5: Internal moments in the joints R1-DIP, R2-PIP, R3-MCP, R4-hand wrist

3. CONCLUSION

A simple 2D mathematical model of the human hand was described, which includes flexion and extension of the hand and assesses the behaviour of a hand in interaction with a rehabilitation device. A Matlab code was also developed for the purpose of dynamic analysis. The calculated joint moments are an indicator of the effect of the rehabilitation device on the hand since the activity of individual muscles can be evaluated by knowing the moment values. Depending on the desired activation of muscles, it is possible to influence the characteristics of the rehabilitation device in the design phase in order to treat a specific group of hand muscles and to conduct a therapy efficiently as possible, with the goal of restoring normal function of the hand during the rehabilitation.
The proposed mathematical model provided an analysis of the characteristics of the future rehabilitation device. Using the model proposed in this paper, it is possible to determine the activation of the muscles in the hand. On the basis of the desired muscle activity, it is possible to influence the construction of the rehabilitation device through an external load provided by the device.
This research was conducted on a healthy subject. After approval of the Ethics Committee, the research will continue to study hand movements of patients who suffered a stroke and ended with finger paralysis. For those patients, abnormal increase in muscle tone will cause spasticity that results in abnormal movement and position of the various hand joints. Further research should also include a 3D model and the use of electromyograph (EMG) for assessing the muscle activity.

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(NON) OCCUPATIONAL FREE-LIVING PHYSICAL ACTIVITY IN CRANE OPERATORS AND OFFICE WORKERS

K. Kastelic[1,3], N. Šarabon[1,2,3]
[1] University of Primorska, Andrej Marušič Institute, Department of Health Study, Koper, SLOVENIA, info@iam.upr.si
[2] University of Primorska, Faculty of Health Sciences, Izola, SLOVENIA, info@fvz.upr.si
[3] S2P, Science to Practice, Ltd., Ljubljana, SLOVENIA, info@s2p.si

Abstract

Sedentary behavior is a well-known risk factor for several non-communicable diseases. The aim of our study was to investigate sedentary time and physical activity in crane operators and office workers within work and non-work context. Fourteen crane operators and 15 office workers wore activPAL continuously for up to five consecutive working days to obtain sitting/lying, standing and stepping time, objectively. Working time and sleep time were also documented. Both groups spent work hours (72.9 % and 72.9 % for crane operators and office workers, respectively) and non-work hours (60.3 % and 54.1 %) mostly sedentary. Subjects of the two groups (crane operators and office workers, respectively) accumulated 3036 and 3177 steps at work and 6236 and 6181 steps outside work on workdays. No significant (p < .05) changes were found between the two studied occupational groups. Health promotion activities for all sedentary occupations to reduce prolonged sitting time should be encouraged.

Keywords: *activPAL, sedentary behavior, sitting time, number of steps, working time*

1. INTRODUCTION

Due to technological development, modern man is substantially less physically active than their ancestors were. According to objectively measured physical activity, not more than 15 % of adult population met the recommendations for moderate to vigorous physical activity for health [1, 2]. Studies also show that adults spend on average between 55 and 65 % [3, 4] of awake time in sedentary behaviors, which is an equivalent of around 10 hours per day. For active population, a great source of sedentary time comes from working-hours (which are around one third of the day), since many employees are predominantly sedentary while at work. Furthermore, Clemes and coworkers [5] reported that those who sit most at work also sit longer outside the working hours.
In the last decade, sedentary behavior obtain a lot of attention as a health-related behavior. A plethora of studies has shown that being excessively sedentary is an independent risk factor for several non-communicable diseases, like cardio-vascular diseases [6], type 2 diabetes [7], metabolic syndrome [8], some types of cancer [9] depression [10] and all-

cause mortality [11]. Some public health organizations have already addressed sedentary behavior as an important health risk factor. In 2011, a guideline for minimizing the amount of time spent in prolonged sitting and to break up long periods of sitting as often as possible, has been included into the Australian national physical activity guidelines and in guidelines from American College of Sports Medicine. Also, UKs' national physical activity guidelines have included the recommendation to minimize the amount of time spent being sedentary for extended periods. Many experts and scientists agree, that we urgently need quantitative recommendations on sedentary behavior – but the research area is still in its infancy, thus further investigations are needed. Nonetheless, the first meta-analysis of dose-response by Chau and coworkers [11] has shown that the risk of all-cause mortality start to grow rapidly when one is sitting for more than 7 to 8 hours per day. Hamilton and coworkers [12] have suggested promotion of spending more time in light intensity physical activity than in sedentary behavior. However, not more than 17 % of male and 24 % of female adult population achieve this "healthy balance" [13].

In the process leading to evidence-based interventions targeted at populations, several phases of systematic sequence of studies have been established [14]. One of the steps is to identify groups of people who are at most risk, thus most in need of interventions. Additionally, it is important to quantify the level of exposure in a high-quality (i.e. valid) way. So we used highly valid [15] objective physical activity monitor (activPAL3), to quantify sedentary behavior and daily walking in two sedentary occupational groups – crane operators and office workers. While office workers are large occupational group, which has been studied frequently, substantially less attention has been paid to crane operators (small specialized group of workers exposed to several occupational risk factors, e.g. prolonged sitting, whole body vibrations, awkward working posture, shift work, noise, environmental heat, psychological stress). Previous studies have shown, that office workers spend about 65 to 79 % [16, 17] of their working time in sitting position and that they accumulate about 4000 steps (Clemes et al., 2014) during working-hours. They are also highly sedentary outside the work, spending additional 4 to 5 hours per day in sitting position [16, 18]. Several intervention options for reducing occupational sitting in office workers has already been proposed and evaluated [16, 17, 19]. From our knowledge, there is no studies of behavioral aspects of sitting and walking in crane operators, nor proposed interventions for reducing occupational sitting. The aim of our study was to objectively obtain sitting/lying, standing and stepping time in crane operators and office workers during work and non-work hours. We hypothesized that crane operators are as sedentary as office workers.

2. METHODS

2.1. Participants

The interested healthy workers of Slovenian logistic company participated in the study. 14 crane operators (crane operators; 14 male; age 38.1 ± 6.8 years, body height 181.6 ± 7.8 cm and body mass 89.0 ± 14.6 kg) and 15 office workers (office workers; 9 male, 6 female; age 45.1 ± 8.1 years, body height 175.1 ± 7.3 cm and body mass 77.9 ± 13.9 kg) with full time (8 hours/day) employment participated. Crane operators work for 70 – 80 % of working days on crane, when two hours on crane follows two hours of rest, then the cycle is repeated once again (cumulatively there is four hours of working on crane and four hours of rest in one working day); on days when not working on crane they work on camion, forklift truck, manipulator. The study was conducted in line with Helsinki declaration.

2.2. Study design and measurement procedure

Each participant was monitored for one working week (with a start of working hours in the morning). ActivPAL3 was used to objectively obtain sitting/lying, standing and stepping time and Garmin FORERUNNER 920XT to determine sleep time. Working diaries were used for documenting the exact time of work/non-work hours.

Participants were introduced to the study and equipped with wearable measurement devices (activPAL: placed by researcher on the participants' right tight (Figure 1) according to the manufacturers' recommendations for waterproof attachment and Garmin watch: placed on the left wrist) in the first day of the monitored week (prior their working hours). They were instructed how to use Garmin watch (turn the modus "sleep" when intended to go to sleep and switch it off at wake up) and how to treat with the activPAL (dressing up with cautious, showering rather than bathing, do not swimming). Both measurement devices were worn continuously (except when battery in Garmin watch must be charged; battery was charged while awake). They were also introduced to the working diary, where start/end of working hours, work site for each day (crane or any other; for crane operators) and any other specialty that occur were recorded.

The researcher was available (day and night) to the participants by phone (in case of any questions or troubles with the equipment). On the fifth consecutive day (after working hours), the participants returned the measurement devices and fulfilled diaries.

Figure 1: Placement of the measurement devices: activPAL on the middle-line of the right tight (one third of the way between hip and knee) and Garmin watch on the left wrist.

2.3 Evaluation of data and statistical analysis

Data from wearable devices were downloaded to personal computer using the associated software (activPAL3^{TM} software and Garmin Express). Diary data was entered into the computer manually. Firstly, for each participants' monitored day start/stop time of sleep time was read from the Garmin Express data analyzer (Garmins' algorithms for detecting sleep time in frames of participants' reported time from their intention to asleep to arise; additional checkup was done by manual examination of activPALs' data (in sleep time frame, there were no standing or stepping time detected)) and start/stop time of work

hours was read from the diary. Then, time spent sitting/lying, standing, stepping and number of steps in work and non-work hours were read from the activPALs' data sets (after raw data was analyzed by activPALs' algorithm – Intelligent Activity Classification™ for classifying the acceleration signal into sitting/lying, standing and stepping). Due to incomplete first and last monitored day, data from 2pm of the first day and data to 2pm of the last day were grouped into one day (we selected 2pm cut point, because this was the end of work-hours for crane operators). Subjects with three or more completed days were included into the further analyses.
Descriptive statistics were calculated (mean, standard deviation). Average times were expressed as a % of time spent in relevant domain (work and non-work hours). Normality was tested using Shapiro-Wilk test (logarithm was used for the data from % of standing and number of steps at work). Independent-Samples t-test was applied to test differences between two studied groups (non-parametric Mann-Whitney U test was used for parameter: % of sitting at work). Statistical significance was set at $p < .05$.

3. RESULTS

Both groups spent work hours (72.9 ± 10.8 % and 72.9 ± 8.8 % for crane operators and office workers, respectively) and non-work hours (60.3 ± 9.9 % and 54.1 ± 13.4 %) mostly sedentary (sitting or lying) (Table 1). Subjects of the two groups (crane operators and office workers, respectively) accumulated 3036 ± 882 and 3177 ± 1308 steps at work and 6236 ± 1979 and 6181 ± 2510 steps outside work on workdays. In comparison with work hours, there were relatively more standing (18.9 % and 18.6 % for work hours; 25.6 % and 32.5 % for non-work hours for crane operators and office workers, respectively) and stepping time (7.8 % and 7.6 %; 14.1 % and 15.3 %) on non-work hours. In total, crane operators and office workers spent on average 701 ± 95 min and 656 ± 88 min per workday in sitting/lying position. No significant ($p < .05$) changes were found between the two studied occupational groups.

Table 1: Sitting/lying, standing, stepping and number of steps (average (SD)) during work and non-work hours.

	Crane operators n=14	Office workers n=15	Between groups differences	
			Mean difference	p-value
WORK HOURS				
average time (min)	480 (0)	510 (75)		
% of time				
Sitting/lying	72.9 (10.8)	72.9 (8.8)	0.0	0.880
Standing	18.9 (9.2)	18.3 (5.6)	0.6	0.822
Stepping	7.8 (2.2)	7.4 (2.5)	0.5	0.598
No. of steps	3036 (882)	3177 (1308)	141	0.940
NON-WORK HOURS				
average time (min)	581.5 (39.3)	535.5 (88.7)		
% of time				
Sitting/lying	60.3 (9.9)	54.1 (13.4)	6.2	0.174
Standing	25.6 (8.1)	32.5 (10.4)	6.9	0.057
Stepping	14.1 (4.2)	15.3 (5.0)	1.2	0.489
No. of steps	6236 (1979)	6181 (2510)	55	0.949

4. DISCUSSION AND CONCLUSION

To our knowledge, this is the first study that objectively evaluate free-living physical activity in work and non-work hours in crane operators. Our results show that crane operators are as sedentary occupational group as office workers, which has already received much attention for reducing prolonged sitting at work. They both spent 73 % of work hours and 60 % and 54 % (for crane operators and office workers, respectively) of non-work hours in a sitting/lying position. Cumulatively, they are spending around 11 hours per day in sitting/lying position, which present a great health hazard. According to the Chau's meta-analysis [11]; an adult who sits for 10 h/day is having a 34% increased all-cause mortality risk (after taking physical activity into account).
Despite high sitting time, crane operators and office workers accumulated on average around 3100 steps at work and 6200 steps outside work on workdays (e.g. on average around 9400 steps/day), which nearly coincident with the frequently proposed recommendation of accumulating 10000 steps/day (for health benefits from being physically active). However, it was reported previously, that individuals who meet the physical activity recommendations do not sit less than those who do not meet recommendations [20].
Health promotion activities, including those aimed at sedentary behavior reduction, should be encouraged for all sedentary occupations. By taking such actions, we could hope for a raised awareness of health benefits of regular physical activity engagement and harmfulness of being excessively sedentary among workers at risk. In addition, we believe that interventions for reducing occupational sitting are needed. While several intervention proposals have been seen for office workers (sit-to-stand tables, walking meetings, movement-oriented physical environment etc.), no proposals were found for crane operators. Designing interventions for reducing health hazard from being excessively sedentary in occupations such as crane operators (or in people working with other heavy equipment, or working in the transportation industry; where employees do not have freedom to stand up at will) should be the scope of future research.
It is also worth telling, that 8-hour work of crane operators, include two hours on crane (which represents two hour long sitting period) which follows two hours of rest, then the cycle is repeated once again. Cumulatively, crane operators have almost 4 hours of rest (when consider time to get on/out of the crane), which are also spent mostly sedentary. It seems that having a lot of rest time during work hours, do not reduce sedentary time drastically. Organizational interventions, in which work tasks that require more physical labor are implemented into the work activities of predominantly sedentary occupations, might be one of the possible solutions.

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PREVENTIVE QUALITY IMPROVEMENT BY ERGONOMIC DESIGN OF MANUAL ASSEMBLY OPERATIONS

C. Kern, R. Refflinghaus, T. Trostmann
Quality and Process Management, University of Kassel, Germany,
quality.office@uni-kassel.de

Abstract

Within the scope of manual assembly operations, human errors can be qualified as key cost drivers being addressed by preventive quality management as they lead to rejects and delays. In order to enable a contemporary work preparation, the module-based method "Methods Time and Quality Measurement" (MTQM) combines preventive quality planning with time related planning measures. MTQM utilizes human error prediction techniques on the basis of Performance Shaping Factors (PSF) to determine human error probability values. Among these PSFs, ergonomic influences on the human error probability have to be considered appropriately. Currently, these influences often refer to subjective assessments leading to insufficient reproducibility. Accordingly, this paper aims at using data already available in the companies, especially from screening-methods like EAWS, to improve the prediction accuracy and implementation costs of the method.

Keywords: *Human Error Probability, Performance Shaping Factors, ergonomic influences, Methods Time and Quality Measurement, screening-methods*

1. INTRODUCTION

Due to increasing globalisation and the associated outsourcing, assembly processes are becoming increasingly important in the context of industrial production [1]. Despite automation and digitalisation in the wake of Industry 4.0, the area of manual assembly processes and thus the aspect of human activities remains important [2]. For small quantities, high flexibility requirements as well as depending on the characteristics of the processed components, e.g. unstable components, manual assembly continues to play an important role [1]. In this context, human activities are always subject to an error probability [3]. Errors caused by human misconduct lead to increased costs in the production process resulting from necessary rework, rejects or delayed working processes [4].

The work task and the work organisation alongside with the area of ergonomics are the central factors influencing the probability of human errors and consequently human reliability [5]. Thus, ergonomics at the workplace keep being important concerning Industry 4.0 [6]. Within the scope of manual assembly, there is a direct relation between an ergonomic workplace design and the resulting number of rejects [1]. A typical example of this is a workplace at which a high amount of activities has to be carried out above the

head. Consequently, it is to be expected that actions at the end of the working day will not be carried out as properly as in the beginning of the working day due to physical fatigue. This leads to the quality issues mentioned before. In terms of possible errors, a distinction is made between errors by omission and execution errors, including time errors, quality errors, sequence errors and confusion errors [7]. Accordingly, risk, reliability and security analyses are not complete without consideration of human failure [8]. Within such a system analysis, an analysis of human error probability therefore has its appropriate significance in addition to methods like the Failure Mode and Effect Analysis, Fault Tree Analysis or the Hazard and Operability Analysis [8].
As to the aspect of a preventive quality management, the reasons and causes of such errors, including ergonomic aspects, need to be identified and reduced right in the planning stage of the work system. In order to determine these reasons and causes, the characteristics of human activities and the associated influencing factors have to be considered. The critical examination of appropriate methods for the assessment of human reliability in the context of manual assembly is the objective of this paper. This includes pointing out the suitability and the relevant weak points of these methods with regard to a preventive quality management.

2. PAPER CONTENT AND TECHNICAL REQUIREMENTS

For the systematic assessment of human error probability, different methods have been developed in the course of time for or a wide variety of applications (VDI 4006 gives an appropriate overview [7]). These methods for quantitative assessment of human activities are summarized under the term "Human Reliability Assessment" (HRA) [7]. They are based on a detailed analysis of the task and the course of action by decomposing the task into partial aspects which have to be assessed [9]. Additionally, detailed information regarding the corresponding work system and its framework conditions as well as reliability-relevant influencing factors (Performance Shaping Factors (PSF)) have to be identified [7].
In respect of different methods for the assessment of human reliability, the current VDI guideline 4006 differentiates between task-related (e.g. ASEP, THERP, HEART, ESAT) and situation-related assessment methods (e.g. CAHR, CREAM, CESA, MERMOS) [7]. Wischniewski uses a similar classification, but additionally mentions time-based methods (e.g. HCR) and refers to methods like HEART, SLIM and ESAT as methods related to performance shaping factors [10]. Lolling also takes up time-based methods, but summarizes methods like THERP, ASEP and ESAT as "analytical methods" and HEART and SLIM as "expert-based methods" [11].
Figure ***5*** gives an appropriate overview about exemplary HRA methods and their categorisation.

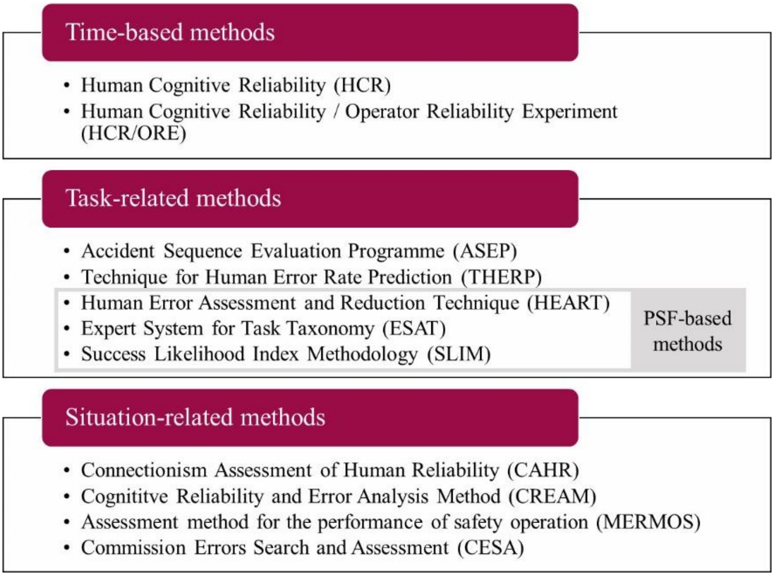

Figure 5: Extract and categorisation of HRA-methods

The necessity of applying situation-related assessment methods is determined by the task characteristics in the form of the indicators “temporal sequence” (e.g. sudden emergence of a failure scenario) and “system states in the situation” (e.g. masking of relevant information due to coincidence of system messages) [7]. Task-related methods are therefore suitable for cases where the task definition and the sequence of activities are known by the operator respectively employee in detail [7]. Consequently, in the context of manual assembly, task-related methods or rather methods regarding performance shaping factors are particularly relevant due to the prevailing framework conditions.
With regard to a preventive quality management, there is an insufficient consideration of the causes of the detected error probabilities in the current HRA procedures [12]. Furthermore, there is the problem of subjective assessments being necessary to determine the human error probability. These subjective assessments are based on e.g. expert estimates, operating experience or the assignment of influencing factors as well as predefined error probability values to task sequences [7]. Especially influencing factors are mostly determined subjectively without any reference to concrete assessment methods [7]. This subjectivity therefore influences the reproducibility of the corresponding methods [11] and thus the scattering of the identified error probabilities. In order to make this assessment within the methods more objective respectively systematic, the assessment of individual influencing factors such as the assessment of performance-influencing environmental factors as well as the routine or practise, work duration and work organisation, has already been optimised [10]. But there is still a wide variety of assessment variables whose influence can only be determined on the basis of experience values regarding the overall task or by assuming subject-specific expert knowledge. Among these assessment variables are also ergonomic influences on the human reliability resulting from physical and psychological fatigue, time pressure or the spatial texture of the workplace [13].

HRA-methods, initially developed for the area of power plants [12], have been adapted gradually to different operating conditions and ranges of applications in the cause of time. For example, Kim et al. have separated themselves from the core activities within power plants and have concentrated on the activities regarding transport and relocation of used combustion material [14]. Djaloeis has dealt with the human error probability in product development [15]. On the contrary, Linsenmaier focused on the field of human-machine interaction using the CAHR method as a basis of his research [16]. Furthermore, HRA methods have been adapted to the assessment of set-up tasks [10] and order picking activities [11]. In terms of manual assembly, Meister as well as Kern and Refflinghaus have devoted themselves to this particular research area. However, only the latter have developed a concrete method for quantitative assessment of human reliability, called MTQM (Methods Time and Quality Measurement) [17]. On the contrary, Meister focused on Resilience Engineering addressing the behaviour of actors in a socio-technical system [9].

Figure ***6*** shows the structure of the MTQM method. The reliability analysis in combination with the consideration of learning effects can be qualified as the quantifying link regarding the probability of occurrence between the determination of potential error factors and the assessment of the costs resulting from corresponding errors.

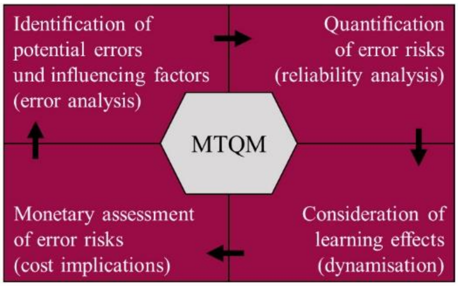

Figure 6: Procedure of the MTQM-Method
Source: Taken from Kern, C. and Refflinghaus, R., 2014 [18]

The reliability analysis therefore represents the core activity concerning the assessment of human reliability. It is based on the system of predetermined times MTM-UAS and MTM-1 as well as the HRA method ESAT. Figure 7 gives the procedure of the reliability analysis. At the beginning, there is a task description based on assembly-specific standard terms. Subsequently, predetermined times and pre-weightings are assigned to these standard terms. Finally, the objective of the method is to set up a stress vector, which considers all relevant task, personal, framework and system factors in the form of PSFs. With the help of the stress vector, the HEP (Human Error Prediction) value is determined via the reliability class (RC) of the assembly activity. This analysis enables a direct deduction of optimisation approaches with respect to individual task elements. [18; 17]
However, the problem here lies in the largely subjective assessment of the individual PSFs. As a result, the corresponding HEP value is highly dependent on the person conducting the assessment and can therefore be influenced pointedly. Furthermore, the necessity for discipline-specific knowledge to assess various PSFs intensifies the

problem. Examples of this are the PSFs regarding physical and mental fatigue, which are assessed entirely based on experience and subjective estimation [13]. Löwe and Sträter recognised that the provision of valid initial data is a significant influencing factor when assessing human reliability [12, 19]. Only the use of appropriate initial data can enable the identification of relevant influencing factors on human error probability, especially regarding ergonomic factors, and thereby the derivation of appropriate quality improvement measures.

Consequently, the effort required for the implementation of a HRA concerning manual assembly in an organisation is very extensive. A focused information collection has to take place and a detailed process description has to be recorded, which then has to be broken down into relevant partial aspects. Furthermore, the previously mentioned subjective assessment of performance shaping factors, especially regarding ergonomic factors, has to be conducted by carrying out workshops or expert surveys.

The classical structure of quality-related costs according to DIN 55350-11 shows that in the context of these costs, the costs for error prevention are one of the central aspects [20]. Consequently, there is a demand for the continual reduction of the implementation effort of corresponding analyses. This raises the question of how far MTQM can profit from data resulting from other analyses conducted in the companies. For example, the structure based on MTM-UAS and MTM-1 provides the opportunity to use data, which resulted from already conducted MTM analyses in the companies for the corresponding work system. This eliminates the need to derive a building-block-related task description and to determine the time values, which are relevant for the PSF assessment. A corresponding restructuring of the method is already taking place. Consequently, methods for the assessment of production ergonomics might also offer a similar potential regarding the PSF assessment. Using the data resulting from these methods could further reduce the implementation effort of the MTQM method as well as the forecast accuracy and could even positively influence the repeatability of the method. Furthermore, improved quality optimisation measures arise due to a more focused and more reliable determination of influencing factors, e.g. ergonomic factors, regarding error probabilities and their specification. With respect to the relevant areas of ergonomics, especially the area of physical strain offers the potential mentioned before due to the accepted technical and scientific assessment methods and standards existing in this area [21]. Examples of current methods to assess production ergonomics regarding physical strain are the key indicator method LMM-HHT or the Ergonomic Assembly Worksheet (EAWS). Further methods can be taken from [22]. These methods can be divided into low-level screening and conventional screening methods as well as expert, respectively detailed methods, and measurement methods. Regarding LMM-HHT, the following ergonomic influences on the human reliability can be derived from the calculation scheme of the method: body posture, execution time and frequency, loads to be handled and conditions of execution like freedom of movement [23].

In addition to the methods mentioned previously, methods based on a combined assessment of the required time and physical strain need to be considered. This opportunity results from the current development in the area of MTM building block systems regarding an integrated design of human work [2]. The method MTM-HWD, for example, represents a combination of the system of predetermined times MTM-1 and the ergonomic assessment method EAWS [24]. By conducting an MTM-HWD analysis, the user receives a time- and building-block-related description of the corresponding task, which is used to derive an ergonomic classification in accordance with EAWS. This

procedure therefore offers the opportunity to assess ergonomic-relevant influencing factors not only task-dependent, but also building-block-dependent in the course of the determination of the HEP value. This enables subsequently a focused derivation of optimisation measures.
Thus, relevant areas of the reliability analysis within the MTQM method, which can be influenced by ergonomic factors, ensue as illustrated in Figure 7.

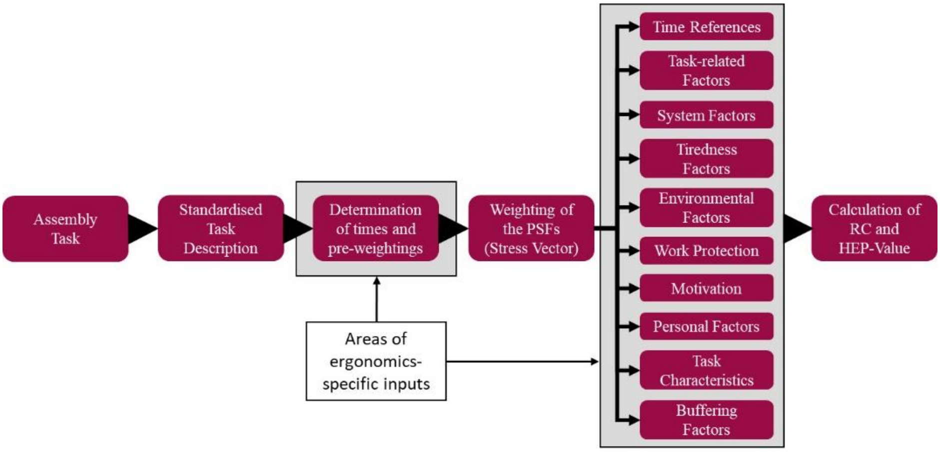

Figure 7: Procedure of the MTQM reliability analysis and areas of ergonomics-specific input
Source: own elaboration based on Kern, C. and Refflinghaus, R., 2016 **[13]**

3. CONCLUSION

This paper has pointed out the suitability and weak points of current HRA methods regarding a preventive quality management in the field of manual assembly. It becomes clear that current methods for the assessment of human reliability consider the influence of ergonomic factors just subjectively. Consequently, specific expert knowledge, respectively interviews are necessary to assess the relevant influencing factors. Moreover, no consideration of current guidelines and methods for the assessment of physical strain does take place within the methods. Therefore, a consistent, plausible, effortless and from the user independent assessment of human reliability is not possible. This leads to an insufficient applicability and significance of the methods in the scope of a preventive quality management. In the context of a preventive quality management, reasons and causes for failures, especially due to ergonomic influences, have to be identified and reduced as far as possible right at the planning stage of a work system. Thereby, the area of manual assembly is still essential, despite digitalisation and automation in the course of Industry 4.0. The building-block-based method MTQM addresses this scope of application. However, this method is also subject to the weaknesses mentioned before regarding subjective assessments. Failure causes can therefore not be considered reliably and effortlessly in the planning stage of assembly systems. This results in a direct influence on failure costs, costs for failure prevention and inspection costs, representing the central parts of quality costs. Using data of methods and analyses, which are already applied in the organisations, offers the potential to reduce the implementation effort and forecast accuracy of MTQM. If, for example, current methods for the assessment of production ergonomics regarding physical strain, e.g. the key indicator method or EAWS, are considered in this context, a more focused and more reliable cause analysis can be implemented.

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ANALYSIS OF THE WORKING LOAD IN THE TECHNOLOGICAL PROCESS OF SEWING

S. Kirin
Karlovac University of Applied Sciences, Department of Safetyand Protection,
Trg J.J. Strossamayera 9, Karlovac, CROATIA, snjezana.kirin@vuka.hr

Abstract

Considering the working conditions and demands placed before the workers in the area of clothing engineering, their working condition in the workplace can be evaluated using the Workplace Assessment Analysis (OADM). With the OADM method it is possible to detect flaws and failures created during the formation process of a workplace and also flaws in organising a production system. The experimental part of the work gives an example of a workplace assessment using the OADM method in the technological process of sewing in the workplace of performing a sewing operation of the shoulder stitch on children's T-shirt. The data collected by the survey point to a high level of motor coordination of body, hands and legs with forced positions of the head and the body as a consequence of a poor sitting position, misalignment of the working space dimensions, inappropriate working method and unfavourable conditions of the working environment.

Keywords*:* *OADM method, working load, technological sewing process*

1. INTRODUCTION

The worker is in the sitting position while performing technological sewing operations with the upper part of the body in the position of frontal flexion of the torso in sagittal plane with forward bend of the head and eye line on the needle plate of the sewing machine. In this position the worker uses the hands for handling workpieces and legs for operating the pedal of the sewing machine. Considering the performance method, this kind of a work process requires a high coordination level of body movements, both of the upper and lower limbs whilst performing simultaneous and combined movements. Due to the physio-mechanical properties reflected in the lacking rigidity, additional high-level flexibility of the fingers, hands and arm is required for handling the workpieces. Besides motor activities, visual focus is required to balance the workpiece and navigate it precisely during the entire work process. The same group of movements, as well as the operation itself, is performed during a short time interval and it is repeated during the working shift, depending on the size of the production series. Also, in compliance with the working requirements, this work process can be labelled as highly-repetitive [1-4].
This paper analyses the work and the working load during the technological process of sewing a T-shirt for children, using the OADM method.

2. OADM (*Workplace Assessment Analysis*) method

In the field of clothing engineering, the OADM method *(Ocenjevalna metoda delovnega mesta)* is used for assessing the worker's state at the workplace concerning the working conditions and requirements placed before the worker. The method was developed by J. Sušnik and co. in 1983. The OADM method is based on the settings for PAQ (Position Analysis Questionnaire) and AET (Arbeitswissenschaftliches Erhebungsverfahren zur Tätigkeitsanalyse), where some parts of the method are identical [5-9].

The OADM method enables detecting flaws and mistakes occurring during the design process of the work station, as well as flaws in the production system organisation. This is an interdisciplinary method analysing the workplace from the aspect of occupational psychophysiology, ecology, technological areas and organisation. The method also assesses the work station in terms of static, dynamic and thermal loads, required visual control and condition of the working environment.

The workplace is analysed using the developed questionnaire, which is the method's integral part. The questionnaire consists of 216 descriptions of workplace conditions, called working characteristics. The questionnaire also contains elaborate working characteristics with regards to:

- working system (position of the workplace within the structure of the working organisation, workpiece characteristics, mean of work in relation to the workpiece and the worker, work ambience characteristics, work environment and similar),
- work tasks (workpiece handling method, organisational structure, work complexity),
- working requirements and loads (visual acuity, concentration, communication, worker skill) and
- health safety (potential occupational injuries and occurrence of occupational illnesses).

The working characteristics are marked with a code in numbers and letters. The letters present the criterion based on which the assessment conducted.

Each of the working characteristics is assessed with one criterion or key. The criteria are divided in:

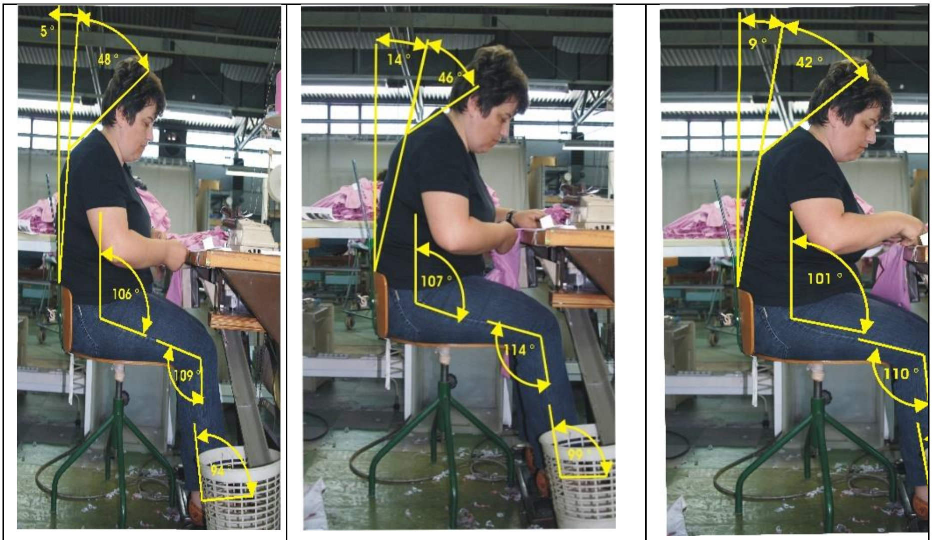
- alternative (A) – assessment of the characteristic' presence,
- importance (V) – assessment of the importance in relation to other conditions at the workplace,
- intensity (I) – assessment of the working characteristic intensity as such,
- duration (T) – assessment of the characteristic's time duration
- frequency (P) – assessment of the characteristic's repetition during a working day and
- features (K) – assessment varies and it is provided with the characteristic's description.

The criteria of importance, intensity, duration, frequency and features rank on a scale from 0-5, the alternative one ranks from 0 to 1.

The revision of the workplace is conducted by interviewing the workers or the interviewer's observation. Based on the collected data, the interviewer assesses individual working characteristics and proposes necessary measurements or ergonomic improvements where needed.

3. EXPERIMENTAL PART

Typical workstation for sewing shoulder stitches on children's T-shirt, in a realistic production process, was selected for determining worker load in the technological process of sewing.
The technological operation of shoulder stitch sewing was analysed using the questionnaire method and the OADM method, with all working system segments included: workpiece characteristics, characteristics of the work means, work environment and ambience, complexity of the work task, required worker ability and potential occupational injury.
During the technological operation of shoulder stitch sewing, typical manoeuvres of the worker were recorded (Figure 1) with Canon 350 D camera. The photographs were edited in Corel Draw 13 with Angular Dimension Tool.



a) workpiece straightening	b) machine-hand sewing	c) thread cutting

Figure 1: Ultimate working posture at workplace with a display of the kinematic chains: a) workpiece straightening, b) machine-hand sewing, c) thread cutting

4. RESULTS AND DISCUSSION

Using the OADM method, the analysis of the worker load in the technological operation of shoulder stitch sewing is shown in Table 1.

Table 1: Worker load according to the OADM method for the technological operation of shoulder stitch sewing

Working characteristics		Worker load	
Code	Description	Assessment	Description
 103 105 108	**Workpiece** medium size – arm manipulation mass up to 1 kg high flexibility	 T/4 T/4 T/4	continuous workpiece handling > 2/3 of the working hours
 122	**Work tool** Sewing machine	 T/4	continuous workpiece handling > 2/3 of the working hours
139 140 141	fingers used arm control legs control	P/4 P/4 P/4	repetitive using of arms and legs in operating the sewing machine > 2/3 of the working hours
 146 148 149 151	**Workplace** big working space desk seat pedal	 K/3 K/3 K/3 K/3	desk, seat and pedal of unadjusted height in relation to the worker
 152 153 157	**Working environment** illumination noise microclimate	 K/3 K/3 K/3	discrepancy present in the parameters of the working environment in relation to the recommended values
188 191	**Organisation elements** work control responsibility for task completion	K/2 K/5	worker responsibility
 216 217 219	**Working tasks** assembling sewing machine operating control	 V/5 V/5 V/5	responsibility for workpiece quality
 250- 253 256 257 259 260 274	**Working requirements and load** visual acuteness accommodation field of vision eye movements colour recognition working structure recognition workpiece shape recognition	 K/4 K/5 K/5 A/1 K/4 K/4 V/5	required worker capabilities during task performance
259 274	colour recognition workpiece shape recognition		required due to different colours and patterns
 311 318	**Motor system** non-physiological seating position forced neck and head position	 T/4 P/4	> 2/3 of the working hours
321 328 329 330 331	isometric arm load isometric leg load arm load leg load grasp with fingers of the left and right hand	P/3 P/3 P/3 P/3 P/3	arm load present very frequent use of arms, legs and hand
341 343 344 345	body coordination oculomotor coordination finger agility quick responding	I/3 I/3 I/4 I/4	workplace requires the mentioned working characteristics
356 357 364 374	**Illnesses** skeletal system muscles eyes skin	K/3 K/3 K/3 K/1	occupational illnesses

The results obtained using the OADM method show the worker handling the workpiece of high flexibility, with a mass below 1 kg and medium size of over 2/3 of the working

hours. During the technological operation of shoulder stitch sewing the worker uses a sewing machine which requires continuous use of arms and legs over 2/3 of the working hours. The workplace is equipped with a seat and a working surface with a sewing machine with discrepancies in relation to the worker's anthropometric proportions.
The state of the working environment (illumination, noise and microclimate) exceeds the limits of the prescribed norms, which was also confirmed with measuring. The workplace requires certain organisational abilities of the worker, *i.e.* controlling one's work and responsibility during technological operation performance. The worker is required to dispose with a high level of motor coordination of the body, arms and legs when handling the workpiece and operating the pedal of the sewing machine. The technological operation of shoulder stitch sewing requires extremely good ability of the sensory organs of eyes, particularly visual acuteness, visual accommodation and adaptation and colour distinction needed for workpiece manipulation. During the technological operation non-physiological sitting occurs as well as forced neck and head positions and isometric load to the fingers, arms and legs. Work performance requires quick response and finger agility. Since the worker suffers from load when performing the technological operation, possible illnesses may occur, i.e. musculoskeletal, eyes and skin.
The analysis of the recorded images and the determined kinematic chains of the worker's joint system show the head is tilted over the allowed 30º. The joint system torso/upper leg forms an angle of over 100º. The joint system upper leg/lower leg and the lower leg/feet fall within the prescribed limits.
To decrease worker load during the technological operation of shoulder stitch sewing, the workplace should be redesigned and a more favourable working method should be determined. The redesign of the workplace encompasses adapting its dimensions to the worker's anthropometric proportions. Furthermore, it is also necessary to provide additional illumination and install air-conditioning to regulate micro-climate parameters which would secure comfortable temperature and relative humidity.

5. CONCLUSION

Technological process of sewing is a complex system requiring good motor abilities of the worker, i.e. high agility and coordination of body, arms, legs, hands and fingers [10]. Based on the analysis using the OADM method, the results of the questionnaire for the technological operation of shoulder stitch sewing point to muscular load, forced body and head positions and non-physiological sitting as a consequence of unadjusted dimensions of the workplace (seat and height of the working surface) to the worker's anthropometric proportions, which can lead to occupational illnesses. The worker is handling the workpiece and the sewing machine for over 2/3 of the working hours during the performance of the technological operation. The work requires certain sensory abilities of the eyes (acuteness, accommodation, adaptation and distinguishing colours).
During the technological process of sewing, the head of the worker is bowed more than the prescribed 30º, and the joint system torso/upper leg forms an angle over the prescribed 95º. This shows that the height of the working surface and the height of the seat are not harmonised with the height of the worker. Therefore, a lower working surface in relation to the present state is recommended to achieve favourable kinematic chains of the joint systems and decrease the load to the worker.
Moreover, it is necessary to install additional illumination in the workplace as well as air-conditioning to regulate temperature and relative humidity in the work space.

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PATIENT-SPECIFIC MODELLING IN ORTHODONTIC TREATMENT

J. Leder Horina, T. Jurčević Lulić, D. Ćurko
Faculty of Mechanical Engineering and Naval Architecture, Zagreb, CROATIA,
jasna.leder.horina@fsb.hr, tanja.jurcevic@fsb.hr, daria.curko@fsb.hr

Abstract

Orthodontic treatment may improve mastication, phonation, and facial aesthetics, by ensuring proper alignment of the teeth with beneficial effects on the oral and general health and individual's comfort, having a positive role in improving the quality of life. In orthodontic treatment, the outcome is caused by the action of orthodontic forces, delivered against teeth ligaments and bones, resulting in teeth movement and modification of bone morphology. Orthodontic treatment also has, in addition to its benefits, associated risks and complications related to the placement of orthodontic devices and applied forces and moments. To optimize orthodontic treatment and predict outcomes of therapies, patient-specific models should be developed. According to patient's particularities, treatments must be individualized. The goal of this paper was to develop a computational model of human tissues in orthodontic treatment which is individualized to patient-specific data. The developed patient-specific model gives an individual approach to treatment and can optimize therapy in a way to foresee all possible outcomes of a treatment and make treatment faster and more efficient.

Keywords: *orthodontic treatment, patient-specific model*

1. INTRODUCTION

Orthodontia, also called orthodontics and dentofacial orthopedics, is a specialty field of dentistry that deals primarily with malpositioned teeth and the jaws: their diagnosis, prevention, and correction. Orthodontic treatment planning plays a big part in achieving the final goal of ensuring proper alignment of the teeth. Primarily, proper alignment of teeth has an influence on mastication, phonation, and facial aesthetics. Also, the influence of teeth alignment on oral and general health, as well as patient's self-confidence that has a direct role in life quality, should not be neglected.
Orthodontic treatment is achieved by orthodontic force action which is the result of orthodontic appliance placed on teeth. Orthodontic forces influence teeth, moving them in proper placement, directly affecting the bone morphology. Teeth movement is delivered against teeth ligaments and bones. Although orthodontic treatment has been developed and has many benefits, risks and complications related to the placement of orthodontic devices and applied forces and moments have been observed [1-3].

Better optimization and prediction of orthodontic treatment can be achieved with the development of patient-specific models. According to patient's particularities, treatments should be individualized. Patient-specific modeling is the development of computational models of human pathophysiology that are individualized to patient-specific data. Patient-specific models have more potential to improve diagnosis, optimize clinical treatment by predicting outcomes of therapies and surgical interventions, and inform the design of surgical training platforms [4]. Therefore, patient-specific models have found their interest group of researchers and clinicians. Common medical diagnostic practices that have been used, can lead to rough estimates of outcomes for a particular treatment plan [5]. The foundation of treatments is based upon the outcomes of clinical trials and experience of an orthodontist. However, these results may not apply directly to individual patients [6] because they are based on averages. As an alternative to traditional approach in orthodontic treatment, patient-specific models can be used to adjust and optimize an individual's therapy. Using this approach, mechanical, physical and anatomical characteristic of tissues involved in treatment are taken into account, and, by developing a computational model which includes all mentioned above, the influence of orthodontic forces that act as external loading on surrounding tissue, can be determined.
The advantages of computerized equipment within the orthodontic practice has been emphasized with the use of imaging [7] and computational models. Before cone beam computed tomography (CBCT), 3D models were obtained by using the standard Computer-aided Design (CAD) software. First, a tooth is extracted and cut in small slices in order to obtain the outer contour of the tooth. Afterwards, the contours are imported into CAD software to obtain the geometry [8]. The use of CBCT has been one of the most revolutionary medical informatics innovations in the field of dentistry of the past decade [9]. Thanks to its lower costs and lower dosage, compared with regular CT, it has made three-dimensional (3D) imaging a tangible reality for the dental field [7]. CBCT is providing CT images and, with proper imaging techniques, a three-dimensional (3D) model of a tooth and surrounding tissues can be made. The goal of imaging in medicine and dentistry has always been to display a "patient's truth" [10]. Until recently, the standard in orthodontic treatment was the use of two-dimensional (2D) diagnostic imaging, including traditional radiographs. Computational models that were used to verify mechanical changes in all tissues involved were also two-dimensional. The limitations of analyzing these imaging modalities are well known and include: magnification, geometric distortion, superimposition of structures, projective displacements (which may elongate or foreshorten an object's perceived dimensions), rotational errors and linear projective transformation [11]. Also, the results from 2D computational models are only partially accurate since they are not providing all the spatial mechanical changes that can occur. Even though 2D models are still in use in clinical practice and research providing some initial information about orthodontic treatment, the future research should be directed towards 3D models obtained from CT scans which also take into account the exact anatomy of a patient as well as bone density, which can have a crucial role in orthodontic treatment.
The focus of this paper was to develop a computational model of human tissues in orthodontic treatment, individualized to patient-specific data. The developed patient-specific model should give an individual approach to treatment and optimize therapy in a way to foresee all possible outcomes and to make the treatment faster and more efficient.

2. METHODS

Getting patient-specific model starts with CBCT imaging. CBCT has been considered the examination of choice in many instances since it provides high-resolution imaging, diagnostic reliability, and risk-benefit assessment [12]. CBCT offers 3D imaging, that is, the ability to work on patient's virtual body segment (the 3D images produced by CBCT machines) and recreate any set of 2D images from it, without needing to further irradiate the patient [7].
Results obtained by finite element (FE) analyses could be shown from the mechanical point of view, however, with careful interpretation, they give a good insight in biological behavior of orthodontic treatment. Many experiments that have been done on human tissues could explain mechanical behavior of a tissue or an organ. Therefore, the stresses and strains that occur in teeth, PDL and bone are quantified and the load limit that the bone or PDL can sustain before occurrence of unwanted biological reactions is known.

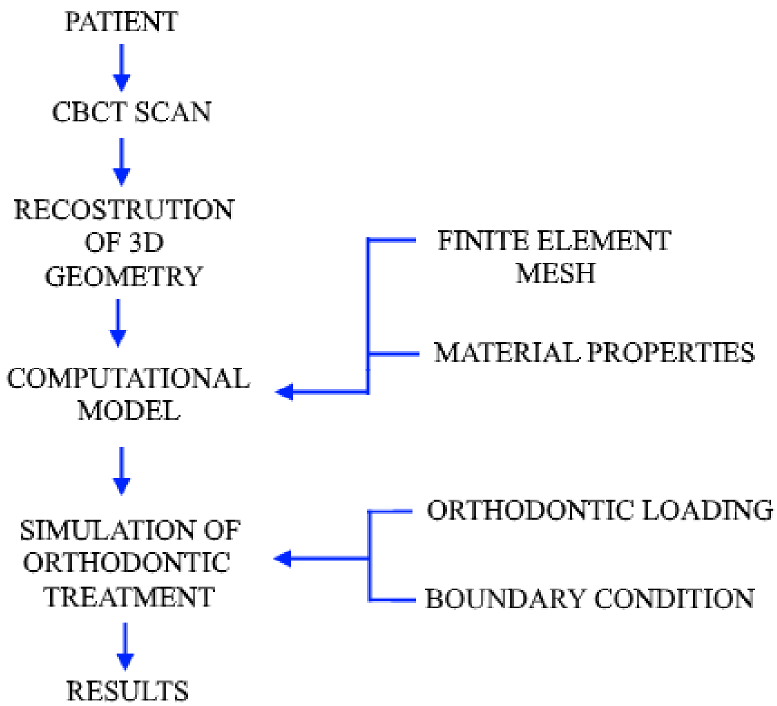

Figure 1: 3D patient-specific model reconstruction

The approach for 3D patient-specific model reconstruction and building a computational model from in-vivo CBCT scans for finite element simulation of the tooth, periodontal ligament (PDL), and bone, with its cortical and trabecular parts, is shown in Figure 1. First, a CBCT scan, made on Cone Beam CT scanner (SCANORA 3D, Soredex, Tuusula, Finland), of patient's maxilla and mandible was made in-vivo. Resolution of scanning was 200 microns isotropic, scanning time was about 20 s and radiation dose was around

47 μSv. The CT images consisted of 375 transversal sections with a slice thickness of 0.200 mm and a pixel width of 0.200 mm, which was large enough to reconstruct the tooth, the bone, and the PDL. CBCT provides images in DICOM format that can be imported into Mimics software (version 14.0, Materialise, Leuven, Belgium). Mimics software is used for reconstruction of 3D geometry from images. A global threshold was defined to isolate bone from soft tissues and the next step was to reduce noise and artifacts with automatic segmentation operations. The maxillary upper incisor was isolated with its surrounding PDL and the alveolar bone by using local thresholding on the CBCT images. For thresholding technique Hounsfield Unit (HU) limits were selected from the Mimics library. For the trabecular bone, thresholds were set at 226 HU (the lower limit) and 661 HU (the upper limit). Furthermore, cortical bone thresholds were set at 662 HU and 1988 HU, tooth treshholds at 1989 HU and 3071 HU, while the soft tissue treshholds were set at -70 HU and 225 HU. The periodontal space was defined as the space between the tooth and the bone after segmentation and the thickness was less than 1.5 mm. Boolean operations were carried out to achieve a perfect fit between the tooth, the PDL and the bone. 3D patient-specific geometry is seen in Figure 2.

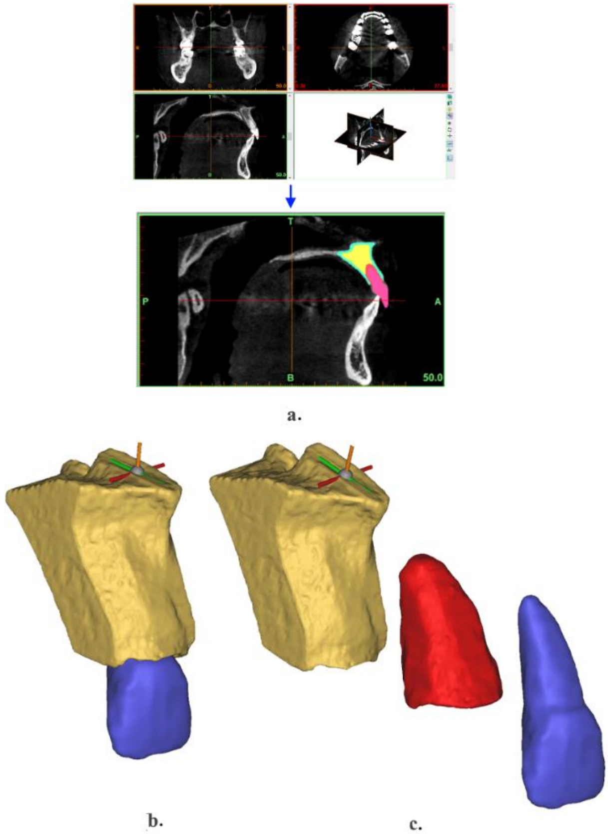

Figure 2: 3D patient-specific geometry obtained from CBCT images: a. CT images, b. whole 3D model, c. parts of model, bone, periodontal ligament

Next step is generating a computational model from obtained 3D geometry. The computational model based on numerical finite element method enables connection of virtual model and physical laws that describe orthodontic movement, which is the basis of orthodontic treatment. Finite element method (FEM) is a numerical method for solving problems of engineering and mathematical physics and it is eagerly accepted as a tool for predicting mechanical changes in orthodontics. The process of teeth movement due to orthodontic force and moments can be described as a mechanical problem since the result of force and moment actions can be calculated numerically. By connecting biological aspect of orthodontic movement into a computational model, the treatment becomes biomechanical. In orthodontic treatment, FEM can be used for predicting the final position of teeth, calculating strain and stress in all tissues involved in treatment, as well as changes in bone density, taking into account the time needed to accomplish proper alignment of the teeth. To obtain the computational model, the first 3D model should be discretized by finite element mesh (Figure 3a.). After all the components are meshed separately, they are connected using a 'glue contact' option. Next step is defining material properties which quantify mechanical behavior of a material and are obtained experimentally. Material properties should be predetermined in software for each part of the model, as well as loading and boundary conditions. Figure 3a. shows material properties of each part of the model, where each color shows different material property. Figure 3b. shows boundary conditions used to simulate orthodontic treatment. All displacements of the cortical elements were constrained on the mesial and distal side, as well as at the upper edge of the lingual and labial side of the bone, representing the support of these sides by the rest of the mandible. From a mechanical point of view, emphasis should be put on defining loading and boundary conditions. In this part of developing a patient-specific model, clinical experience comes to the fore since the proper selection of the load placement, as well as the definition of the boundary conditions, play a crucial role in the results. Orthodontic force and/or moment is applied to the model in such a way to describe desired tooth movement, which can be a translation, rotation or tipping, and leads to proper alignment of teeth. Loading is seen in Figure 3b. After all the above, the features are set and finite element analyses can be carried out.

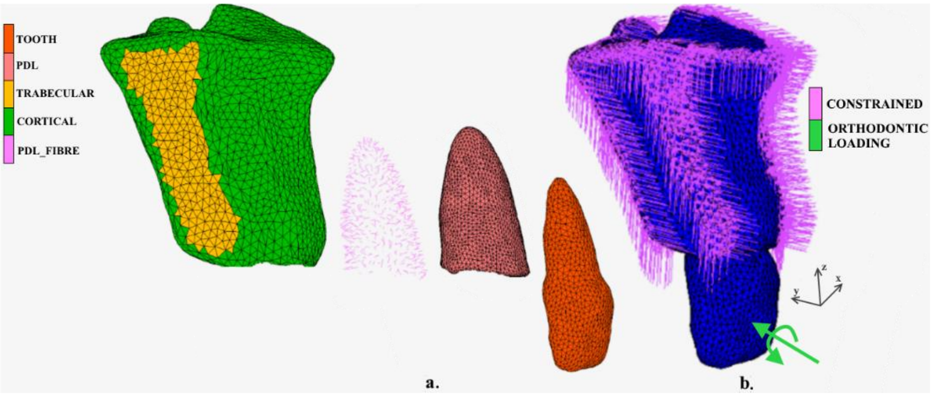

Figure 3: 3D computational model: a. finite element mesh of parts of the model, b. boundary conditions used to simulate the patient-specific computational model

3. RESULTS AND DISCUSSION

The approach presented in this paper offers orthodontists simulation of orthodontic treatment through changes in orthodontic loading, before the actual treatment. Changes can be made in loading magnitude and in loading position. This way, stress and strain that occur can be calculated and compared to the ones obtained from experiments. If stresses or strains are too high, causing an undesired biological response, the orthodontic load should be changed. On the other hand, a computational model can show that an orthodontic load should be a higher value, and in that way speed up the whole treatment. Usually, finite element analyses are limited to only one specific case due to the overly amount of manual work required to generate a 3D mesh [13]. Therefore, the development of a general model that will be able to automatically generate a mesh of patient-specific data would be the next step in the development of a 3D virtual patient-specific model.

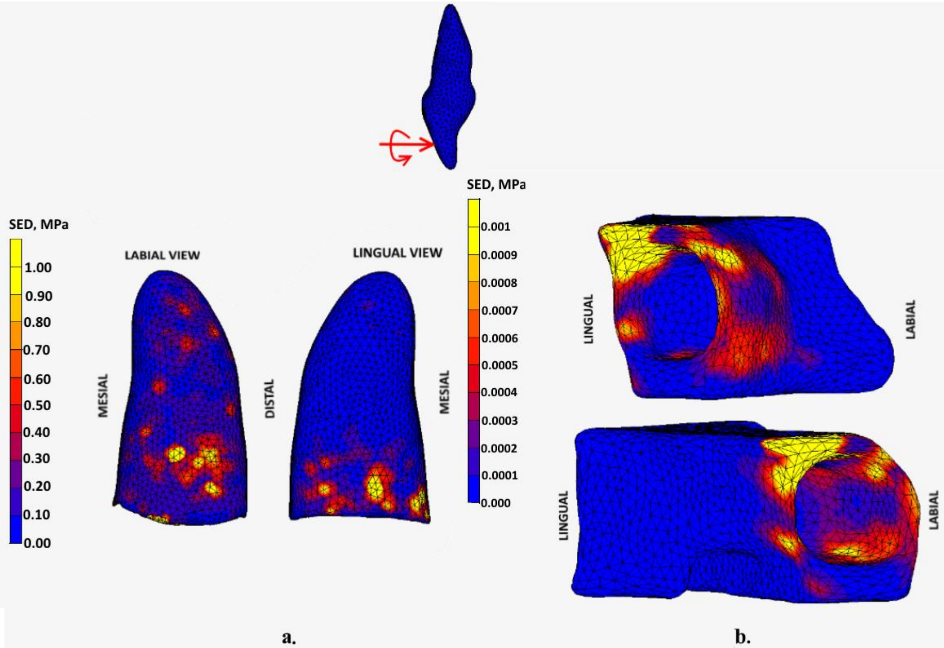

Figure 4: Simulation of an initial stage of orthodontic treatment: a. SED in PDL, b. SED in bone

The methodology presented in this paper is based on images of a patient to whom orthodontic treatment was recommended. Finite element analysis was performed to stimulate orthodontic movement of controlled tipping, where tooth tilts in direction of the orthodontic force. Results that occur due to orthodontic loading are showing strain energy density (SED) in bone, which is an indicator of bone remodeling and tooth displacement, (Figure 4). Figure 4a. is showing SED distribution in PDL, where higher values are showing the area where PDL will be compressed, indicating the direction in which the tooth will move. In Figure 4b., higher SED values in bone denote the occurrence of bone remodeling in the area, allowing tooth's movement into the desired position. Compared to the stress' that were obtained experimentally, one can see that the loading used in this analysis was high enough to cause initial orthodontic movement.

3. CONCLUSION

With the development of technology imaging, scientists are much closer to the truthful anatomical form of patient's body parts. A complete patient-specific model, with its exact anatomy, including teeth and surrounding tissues, as well as the influence of orthodontic loading, is an immensely useful tool for orthodontic treatment. With this information, a patient-specific model could be used not only for diagnosis, as it is today, but also for further applications, such as treatment simulation. Patient-specific model gives 3D spatial information without additional radiation of the patient, as a result of imaging, and also reduces the cost of treatment. The approach presented in this paper is representative to connect orthodontic treatment with patient data and computational models that are the future in orthodontics.

The main advantage of developing a patient-specific model is that it gives an individual approach to treatment so it can optimize therapy in a way to predict all possible outcomes of a treatment, making it faster and more efficient. In that way, orthodontic treatment will be closer to patients, while for an orthodontist it will be easier to decide how to approach patient's teeth alignment, having a direct influence on patient's comfort and quality of life.

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INDOOR AIR QUALITY ABOARD ITALIAN HIGH-SPEED TRAINS

P. Lenzuni[1], M. del Gaudio[2], D. Freda[3]
[1] Italian Workers' Compensation Authority, Florence, ITALY, p.lenzuni@inail.it
[2] Italian Workers' Compensation Authority, Avellino, ITALY, m.delgaudio@inail.it
[3] Italian Workers' Compensation Authority, Rome, ITALY, d.freda@inail.it

Abstract

High-speed train coaches are peculiar environments characterized by the possible co-existence of thermal, acoustic and luminous discomfort. The most widespread source of complaints is however indoor air quality (IAQ) which is also the most difficult element to keep under control, because of the heavy crowding in the coaches. Our results show very large concentrations of CO_2, with peak values up to 2500 – 2800 ppm that determine large fractions of dissatisfied and significantly impair the subjects' ability to carry out mentally demanding tasks. The typical time evolution of CO_2 in a coach shows large fluctuations, which are inconsistent with constant ventilation, and imply the existence of variable inflows during the trip. Some indications on the size and timing of such variations are presented. Possible solutions based on CO_2 real-time monitoring are proposed, aimed at lowering the concentration peaks and attenuating existing fluctuations.

Keywords: *IAQ, CO_2, Acceptability, High-speed trains*

1. INTRODUCTION

Due a favorable combination of cost, convenience and reliability, high-speed trains have become extremely popular in Italy in the last fifteen to twenty years. From the viewpoint of passenger comfort, high-speed trains are challenging environments because of at least three elements: 1) they represent prototypical environments characterized by multifactorial discomfort due to the thermal, acoustic, luminous conditions as well as to a less-than-ideal air quality (hereafter IAQ); many different factors must accordingly be taken into account simultaneously; 2) the density of subjects is often large, especially in the early morning and late afternoon, which further complicates matters; 3) from a very basic cost-to-benefit perspective, it is obvious that the demand from passengers of at least moderate comfort conditions, must somehow be met.

On the other side, it should also be considered that a high-speed coach is a very static environment, where the density of subjects, along with their locations, postures and activities can be taken as constants during the trip, which simplifies comfort planning, and assessment. High-speed trains have sealed windows, so that they must rely on well-designed and well-operated ventilation systems in order to provide acceptable IAQ to passengers. Contaminants aboard trains are both of anthropogenic (bio-effluents exhaled

by passengers) as well as non-anthropogenic nature (substances released by the plastic materials and detergents). Because the density of passengers is often quite large, and the majority of trains is relatively new (2 to 10 years old), it is expected that the most serious pollution has anthropogenic nature. While CO_2 has been proven not to be a problem in itself [1], even at fairly large concentrations (up to 3000 ppm), it is nevertheless a very useful quantity as a tracer of other substances released by the human body, which are largely responsible for the poor IAQ perceived by the occupants of crowded indoor environments. Poor IAQ is not only unpleasant, but it is also known to be detrimental to the performance of even simple tasks [2, 3, 4]. Numerous studies have been performed of the concentration of CO_2 aboard high-speed trains [5, 6, 7, 8]. However they do not focus on the detailed time evolution of CO_2, which prevents any understanding of the way the ventilation system is actually operated.
This study consists of three parts: in the first part, measurements of the time evolution of CO_2 aboard high-speed trains are presented. In the second part, model predictions of the CO_2 concentration are calculated, and by matching predictions to measurements, air inflow rates are estimated. In the third part, the acceptability of measured CO_2 concentrations is discussed in the light of existing technical standards. Finally, possible solutions based on CO_2 real-time monitoring are proposed, which are aimed at lowering the concentration peaks and attenuating existing fluctuations.

2. METHODS

Measurements have been carried out on different trains, operated by both Italian high-speed railway companies. Standard coaches have between 70 and 80 seats. Air conditioning is centrally operated. Air inflow takes place along the sides of the coach, just below the windows, while extraction occurs near the floor level.
The surveyed high-speed lines include a) Bologna – Florence, b) Florence – Rome, c) Rome – Naples. The associated travel times range between 35 and 95 minutes. Lines b) and c) include a large number of short (< 1 km) or intermediate length (1 to 5 km) tunnels. Line a) is characterized by two very long tunnels, which combine for about 90% of the entire line length. Table 1 provides a synthesis of measurements, including details on line, duration, number of passengers and largest measured CO_2 concentration.

Table 1: Summary of measurements

Meas. #	Line	Duration (minutes)	Passengers	Largest CO_2 concentration (ppm)
1	c)	80	57	2000
2	c)	75	55	2800
3	c)	80	37	1600
4	c)	85	28	1700
5	c)	85	40	1700
6	c)	70	60	1700
7	c)	75	20	900
8	b)	95	45	1200
9	a)	40	50	2100
10	a)	35	50	2140

Measurements 1 to 9 have been performed using a ToxiRae PGM-1850 CO_2 meter with a resolution of 100 ppm. Measurement 10 has been performed using a P-P CO2000 CO_2 meter, with a higher resolution of 10 ppm. The acquisition rate has been set at 1 every 5 minutes for the former, 1 every 2 minutes for the latter. Nominal accuracy is ± 50 ppm for both meters. Accuracy has been checked by repeatedly carrying out measurements in rural areas where pollution is minimal and the expected CO_2 concentration is around 400 ppm. Sensor readouts have been accordingly corrected based on these calibration results.

3. RESULTS

Figure 1 shows four prototypical time evolutions of the concentration of CO_2.

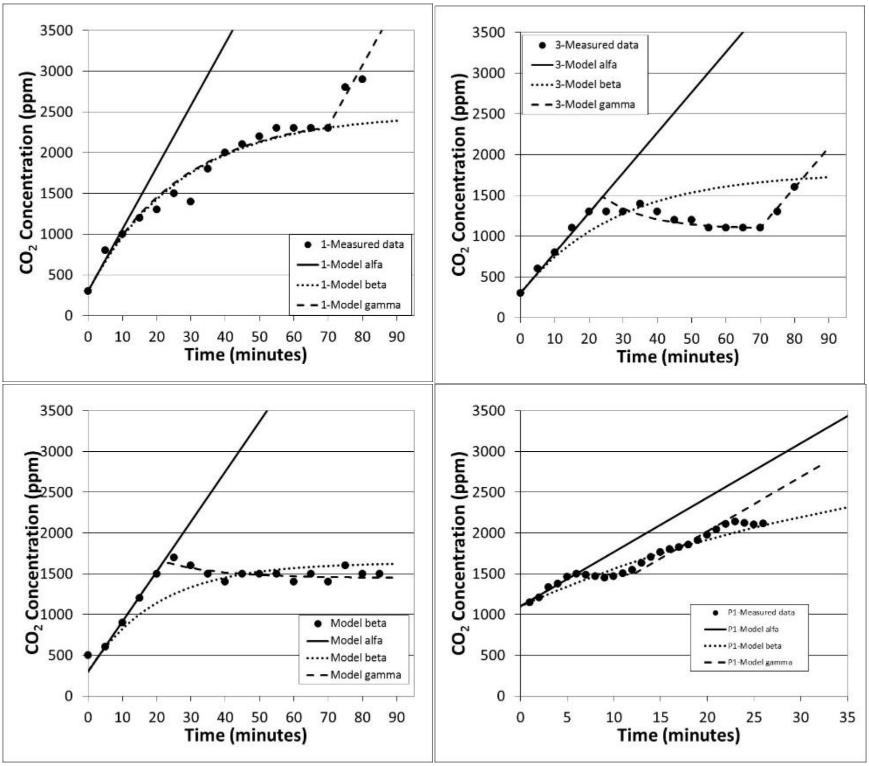

Figure 1: Time evolution of CO_2 concentration. a) measurement # 1, b) measurement #3, c) measurement # 5, d) measurement #10

Figure 1a shows a steady growth of the concentration with an asymptotic trend that extends throughout most of the trip, followed by a sudden jump in the last ten minutes of the trip. Figure 1b shows a linear growth dur-ing the initial part of the trip (around 20 minutes). This is followed by a stage where CO_2 concentration stabilizes first, and then slowly declines. Here again a sudden jump appears in the last ten minutes of the trip. Fig-ure 1c is similar to Figure 1b, but there is no indication of CO_2 declining at any stage and no discontinuity in the last minutes of the trip. Figure 1d shows a steady growth of the CO_2 concentration that continues for the entire trip duration. This latter measurement has been performed on line a) where two very long tunnels account for about 90% of the trip duration. Figure 1d shows that very limited ventilation is provided when the train is in the tunnel, which leads to a significant CO_2 buildup. The same behavior is observed in measurement # 9 also carried out on the same line. This might be due to technical difficulties in supplying large quantities of fresh air while the train is inside long tunnels.

4. DISCUSSION

4.1 Predictive models

Measurements have been carried out on non-stop trains, which keeps the number of passengers in a car roughly constant. Also constant has been assumed to be the metabolic activity of passengers, set equal to 0.95 met, which is the value given in Table B.3 of ISO 8996 [9] for seated subjects. With this metabolic activity, the rate of inflow of CO_2 in the environment is $R(CO_2)$ = 14.7 l/h per person [10].
Three simple predictive models have been tested in order to gain insight into the actual operating scheme and effectiveness of the ventilation system.
Model α assumes zero air inflow (Q = 0). Model α has no free parameters and exhibits a linear growth of CO_2 concentration in time

$$CO_2 = (CO_2)_{start} + \left[\frac{N_S R(CO_2)}{V}\right] \times t \qquad (1)$$

where N_S is the number of subjects in the coach, V is the effective coach volume and $R(CO_2)$ is the emission of CO_2 by each subject, which in its turn is linearly proportional to his/her metabolic activity.
Model β assumes a single, constant air inflow rate (Q = constant) for the entire duration of the trip. The air in-flow rate is the only free parameter of the model. The time evolution of CO_2 according to model β is

$$CO_2 = \frac{A}{B} - \left[\frac{A}{B} - (CO_2)_{start}\right] \times e^{-\frac{B}{t}} \qquad (2)$$

where

$$A = \frac{N_S R(CO_2)}{V} + \frac{Q \times (CO_2)_{ext}}{V} \qquad B = \frac{Q}{V} \qquad (3)$$

Model γ assumes that the air inflow rate is either zero or a constant value. This model has three free parameters: the non-zero air inflow rate Q and the two times, t_1 when the airflow rate becomes non-zero and t_2 when the airflow gets back to zero. The time evolution of CO_2 has been calculated using a combination of equation (1) in the absence of air inflow and equations (2) and (3) with non-zero air inflow.
Each of these models has been fitted to the CO_2 concentration data collected during each measurement. Table 2 summarizes the model parameters Q (m^3/h), t_1 and t_2 (minutes) which give the best fit to data. Model α usually provides very poor overall fits to

experimental data, although it is occasionally adequate for limited fractions of the trip duration. Model β also is usually inadequate, with slightly better performance when applied to measurements #7, 8 and 9. Model γ performs appreciably better and is often quite accurate. The quality of fits to the experimental data, using model γ, has been objectively assessed using the reduced chi-square ($\chi_\nu 2$) statistics, also shown in Table 2.

Table 2: Summary of best-fitting model parameters

Meas. #	Model α	Model β	Model γ	
	Q (m^3/h)	Q (m^3/h)	Q/t_1/t_2 (m^3/h)/(min)/(min)	$\chi_\nu 2$
1	0	370	373/3/69	1.81
2	0	225	318/31/70	1.81
3	0	530	687/23/70	0.38
4	0	490	656/30/70	1.04
5	0	425	584/22/85	0.66
6	0	660	785/13/70	3.03
7	0	775	820/5/65	1.33
8	0	850	847/1/95	0.72
9	0	95	95/1/40	0.83
10	0	250	722/6/11	1.54

Best fitting models (α, β and γ) are also graphically shown in Figure 1, using lines of different styles super-posed on experimental data (filled dots). The visual comparison between measured values on one side and model predictions on the other clarifies that models α and β are just too simplistic to provide an acceptable description on the time evolution of CO_2 concentration. The fact that model γ can actually reproduce at least the general trend of measurements implies that the ventilation system is actually operated based on some sort of either manual or automatic active feedback mechanism. A more extensive experimental campaign is in progress in order to gain a deeper insight into this issue.

4.2 Acceptability of CO_2 levels

Table 2 shows that the largest CO_2 concentrations reached during the trips range from 1000 ppm up to almost 3000 ppm. In four out of the ten trips the maximum level has exceeded 2000 ppm and in two of such cases the level has been above 2200 ppm for an extended period of time.

In order to gauge the acceptability of such levels, it is fundamental to select the appropriate limit value. Unfortunately, there is currently no threshold value in international standards dealing with the CO_2 concentration aboard trains. A limit value of 2500 ppm (hourly average) is quoted by the Hong Kong guidelines for managing IAQ on railways [11]. It is unclear however whether it makes sense to apply this value in the european context. The vast majority of existing limits for CO_2 in different countries, both in social and in occupational contexts, are 10 to 20 years old [12], which casts serious doubts on their current adequacy, in the light of contemporary (high) comfort expectancies and urge for energy-saving strategies.

The recent European standard EN 16798-2 [13] includes in its Table C.8, here replicated in Table 3, four limit values of CO_2 concentration associated with four different categories. The standard is conceived so that it can be used both for design and for assessment. Despite the fact that the limit CO_2 values are officially quoted as “default design CO_2 concentrations”, they appear to be applicable also in the stage of quality assessment.

Table 3: Limit CO_2 concentrations in environments with different requirements

Category	Definition	CO_2 concentration above outdoors (ppm)
I	Should be selected for occupants with special needs (children, elderly, handicapped).	550
II	The normal level used for design and operation.	800
III	Provides an acceptable environment. Some risk of reduced performance of the occupants.	1350
IV	Should only be used for a short time of the year or in spaces with very short time of occupancy.	1350

Source: Limit CO_2 values taken from EN 16798-2, Table C.8; category definitions taken from EN 16798-2, Table 3 [13]

EN 16798-2 nominally deals only with buildings. However, from the point of view of IAQ perception it is hard to see any difference between a building an a train coach: both should be designed and operated so that people can live and/or work therein for extended periods of time, with near optimal performance and acceptable global comfort conditions. Based on these considerations it appears not only reasonable but also legitimate to apply the values of Table 3 inside the high-speed train coaches that form the target of this investigation. Because category III is identified by EN 16798-2 as the appropriate category for environments where occupants have “low expectations”, the associated differential (indoor-outdoor) concentration of 1350 ppm has been selected as the relevant limit value for standard class high-speed train coaches. This is indeed a fairly relaxed limit, and future reconsideration of train coach comfort might well opt for the more stringent category II limit. Because the typical outdoor CO_2 concentration in rural areas is about 400 ppm, this corresponds to an effective indoor CO_2 limit concentration of 1750 ppm. Table 2 shows that even this relaxed limit value has been exceeded in four out of the ten cases reported in this study, which implies that poor IAQ is by no means an exception aboard high-speed trains. This is unfortunate since many people use the train journey to study/work, and the quality of their learning performance is likely to be negatively impacted [2 – 4]. Qualitatively, it also possible that this might contribute to a less than ideal performance during the day.

The results of this study are in line with the results of a similar work carried out on long-distance buses [14] where even larger concentrations were found. Although high-speed trains and long-distance buses have widely different characteristics in terms of technology, design and operating costs, and ultimately expected level of comfort, both often fail to provide an even acceptable comfort to passengers in terms of IAQ.

5. RECOMMENDED ACTIONS AND CONCLUSIONS

High-speed trains are challenging environments for creating and maintaining comfort conditions, due to the very large density of subjects. However, because of two favorable characteristics, the constant density of subjects in a coach and the constant metabolic activity of subjects, they are amenable to relatively simple ventilation strategies. The most simple-minded approach would be to keep the air inflow rate set at a constant level for the entire trip duration. Because this level should be a function of the number of passengers, and the latter is not known a priori, this might be a somewhat impractical solution. An alternative and more viable option is a CO_2-based ventilation strategy. The system would then operate like a traditional heating system on the combination of a lower and a higher set point. The air inflow rate would increase when CO_2 sensors indicate level near the threshold of acceptability (the high set point, 1750 ppm), and would decrease when the environmental CO_2 concentration drops below the low set point (an indicative value might be around 1200 – 1400 ppm). As a final remark, it is recommended that the ventilation system is not switched-off during stops, which appears to occur now. The natural ventilation induced by door opening and by the inflow/outflow of passengers from the coaches determines wildly fluctuating and unpredictable ventilation rates with low average values, usually leading to significant CO_2 buildup.

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KITCHEN ASSISTANTS' WORK ANALYSIS AS A CONTRIBUTION TO A UNIVERSITY RESTAURANT PROJECT

V. Lipovaya[1], F. J. C. M. Duarte[1], F. P. A. Lima[2], P. G. F. Costa[1,3], A. A. Volosiuk[4]

[1]Production Engineering Program, Coppe, Federal University of Rio de Janeiro (PEP | Coppe | UFRJ), Rio de Janeiro, BRAZIL, victorialipovaya@globo.com, fjcmduarte@gmail.com, patriciagfc@gmail.com
[2]School of Engineering, Federal University of Minas Gerais, Belo Horizonte, BRAZIL, frapalima@gmail.com,
[3]EVS (UMR 56000), Lumière Lyon 2 University, Lyon, FRANCE, patriciagfc@gmail.com
[4]Inter-Regional Ergonomics Association (IREA), Saint Petersburg, RUSSIA, aa.volosiuk@gmail.com

Abstract

This article argues that work activity analysis contributes to the project design. It explores the strategies that operators create to facilitate the accomplishment of their tasks at their workplaces. The analysis of three food units of a new Brazilian University Restaurant project allowed the ergonomists (i) to understand some aspects of the activities that were not foreseen or perceived at the initial stages, (ii) to give visibility to the human potential, bringing the workers' know-how to the project meetings and (iii) to reveal the shortcomings of the initial project. The results showed that by changing the original way of portioning from fixed to a flexible one, the overall outcomes of the project were increased: the chores became more adaptable, the kitchen assistants started to feel less anxious, the level of tension and fatigue at the counter was reduced.

Keywords*:* *university restaurant project, kitchen assistants' ergonomic work analysis, project dialogue meetings, project initial concepts review*

1. THE ORIGINS OF THE DISTINCTION BETWEEN THE MODEL AND ITS OPERATION

Activity-centered ergonomics [1] highlights the need for designers to examine a work system from the activity point of view, as a sociotechnical system. In general, the operational level is rarely considered in defining the concepts of future projects [2]. Thus, the future operators do not have their opinion heard during the conception process of their activities for the future projects [3]. This leads to damaging consequences.
Ergonomic intervention practices show that all phases of the projects design process can influence directly or indirectly the future work [4]. Some of the practices reveal certain

negative characteristics of industrial projects [5, 6] and indicate the disregard of real work and future work as one of their possible causes.
Particularly, projects have the risk of remaining technocentrated with prevalence of the technical and economic dimensions in the conception of their work systems, while the social and collective dimensions of work stay devaluated [7]. The last two dimensions are an integrated part of any organization. However, because the technocentered vision seeks in a deterministic way a consensus among the actors involved in the project, the social context is often overlooked, which increases the chance of unwanted effects for the activities.
The purpose of this article is to show how the work analysis helps to develop a project design process, as it allows to improve working conditions and reduce negative effects on workers' health. From the work activity point of view, the article presents a critical vision of the project and its conception. For this, the method of the Ergonomic Work Analysis (EWA) [8] was adopted. The field research in real situation allowed the analyzed workers to actively participate in the performed analysis.
Finally, the article presents the results of the case study of a pioneer Brazilian University Restaurant (UR) project in Rio de Janeiro. The main objectives of the study were to contribute to the improvement of cafeteria units already in operation and give recommendations for the future ones. The study revealed the origins of the distinction between the UR project and its actual operation; as a result of the ergonomic intervention, the initial concept was reassessed and fixed portioning became more flexible.

2. THE VISION OF THE PROJECT AND ITS DESIGN FROM THE WORK ACTIVITY POINT OF VIEW

In general, project design refers to a particular context in which a group of experts defines a priori the main characteristics of a future situation [9]. In this scenario, the individual and collective activities of the designers and the actors responsible for the conception process lead to the transformation of the project, but sometimes there is no clear distinction between the activity of the project conception and the actual operation of the conceived model [9]. Then, it can be implicitly assumed that the operation will stay the way it was designed, neglecting the inherent variabilities of real situations.
The present approach views a **project as an incomplete and unfinished work** [10]. It, thus, emphasizes the need for continuous and dialogical exchanges between designers and actual work situations [11], as well as the interaction between the professional worlds [12] of those who conceive models and the workers who use them.
As a discipline of action, the role of activity-centered ergonomics is not only to generate knowledge about work situations, but also to act in the evaluation of the conception results [13]. By the ergonomic intervention, which helps to reveal the invisible work of the workers, that is by the revealed activity, the ergonomists can show the negative effects of the distinction between the "perfect" model designed without considering the actual operation and the real work. And they can introduce these elements to promote the dialogue between the actors of the project process, including operators.
When activities are still in design process, one cannot foresee all potential consequences of the work system on them. However, it is possible to anticipate some margins of maneuver necessary in carrying out the activities [12]. In such cases, ergonomists can bring the activity point of view to the design dialogue through the reference existing

situations, the provision of the situation of characteristic action (SCA) or simulations [14]. When activities already exist, ergonomists can use EWA to point out the distinction between what was set for the workers to perform (the task) and how they perform the work (the activity) [8].
What is advocated is the mobilization of the activity point of view in the diverse phases of the project process, whether using the revealed activity to build the dialogue between the different organization points of view or as a source of information and support for the project design, in particular for the problems construction. After all, the activity point of view advances the understanding of the complexity of work situations [2].
What ergonomists seek is to show the results of the activity analysis to the different actors involved in the project meetings, explaining its systematic dimension. Ergonomists can support the interactive dialogue and allow different professional worlds to balance their different logics [15] by highlighting how activity articulates a significant number of elements in action which represent constraints that are often caused by decisions made at the design stage and require some adaptation.
Since the implementation of the designed project cannot be completely foreseen, it is possible that some constraints can arise during this phase. However, it is believed that to promote a healthy debate and a constructive conflict between the heterogeneous actors involved in the project process it should be shown how the activity performs its integrating function or becomes a dialogical interface between these points of view which naturally diverge [16]. Thus, the activity logic can be a link between different actors of the project that encourages articulation of usually conflicting logics, aiming to give coherence to them.

3. METHOD

The research had two main stages: the EWA [8] and the monitoring of the UR project meetings. The first stage began with an invitation given to the ergonomist. One of the UR directors asked for contributions to the improvement of the general functioning and the working conditions of two units that were already functioning and had entered into an implementation process of a new productive system standardization.
The second stage began with another invitation from the director for the ergonomist to attend a series of meetings for the UR project redesign. The main focus was to debate the existing problems related to the two cafeterias and to find together with the workers some possible solutions. Another drive was to develop the recommendations for the new third unit.
The demand for EWA began to be structured from the reports of this director about the increase of the level of turnover in these two units. After the first visits to these cafeterias, it was noted that most of the kitchen assistants complained about physical fatigue and mental wear, in particular, at the serving counter during the meal distribution.
Based on the analysis of the existing data and the verbalizations made by the kitchen assistants, it was decided that the systematic work analysis would be carried out in the first operational unit, the oldest one, and, primarily, at the serving counter indicated by these workers as the most problematic workstation. This decision was made in a consensual way between the UR director and these workers.
Systematic observations and structured interviews were recorded in notes in the field notebook, in video and audio recordings. The focus of the observation and analysis was the strategies created by the kitchen assistants during the portioning of different

ingredients of the salad that were transported in salad bowls. Subsequently, these data were used for auto-confronting interviews [17] and to produce the activity description forms [18]. These data helped to identify and understand the variability in the work of kitchen assistants at the serving counter.

The explanations of the workers analyzed helped to understand the divergent logics and conflicts between the different actors involved in the productive process. In clarifying the strategies created by them to facilitate the execution of their tasks, it was also possible to reveal the distinct logics of the actors involved in this project conception, which permitted the functioning of this cafeteria unit as a whole.

Finally, a general diagnosis of the situation was elaborated and recommendations were generated to improve the working conditions at the serving counter, to redesign the operational units' production system and also to improve the new cafeteria.

These results were validated and discussed with the kitchen assistants throughout the analysis. During this research stage, meetings were held with the UR project responsible director and EWA's results were presented and discussed with her. Subsequently she used them to promote the dialogue during the UR project redesign meetings. She especially presented the kitchen assistants' strategies to all the actors involved in both the design of the project (the UR project nutritionist team) and its execution (the board, the nutritionist team, the kitchen assistants of an outsourced company).

4. RESULTS AND DISCUSSION

One of the main features of the new UR project is the distribution of the transported ready-cooked meals in large quantities (3.500 lunch and 900 dinner) from the outsourced company's industrial kitchen (42 km) to all UR project cafeterias. The UR director and the nutritionist team are responsible for overall control and oversight of the production process carried out by a team of nutritionists, kitchen assistants and personnel of the outsourced company which worked in these two cafeterias of the university campus.

The main stages of the production process are: (i) preparation, held at the headquarters of the contracted company; (ii) transportation, carried out by the outsourced company's trucks; (iii) receipt and control; (iv) completion and regeneration; (v) storage of ready and regenerated meals; (vi) qualitative analysis and other controls; (vii) distribution at the service counter; (viii) hygiene, cleaning and sanitizing of kitchen utensils and the environment; (ix) garbage collection; (x) dispatch of the isothermal boxes used to transport the meals. These last eight steps are carried out in the cafeterias.

The requirements for the quality of the transported ready-cooked meals (short-term food shelflife, time and temperature control of raw material, etc.) were one of the main determinants of the production process (maximum 3 hours for the distribution of meals), as well as the problems that arose during the different stages of production (truck delays, impossibility to replace most of the menu items on time, etc.).

For example, the menu prepared by the UR nutritionists could not repeat the same recipe more than twice a month. Therefore, the menu had to be defined one month in advance, so that it could be passed on to the contracted company. These and other constrains of the distribution system model limited the possibilities of anticipation of the problems and the margins of maneuver for both the groups of nutritionists and of the kitchen assistants at the serving counter so that they could respond to the variability of the real situations.

Daily, before the cafeteria opening for the public service, passwords were distributed to the users of the restaurants. The number of meals distributed per day was limited. For contractual reasons, the outsourced company was paid per distributed meal, but distribution could be made only if all menu items were available and their quality was approved by UR nutritionists. This was one of the main contractual rules, because if a meal or an ingredient prescribed by the nutritionists was missing, the outsourced company could be fined by the UR team. The size of the distributed portion was calculated based on the concept of fixed portioning for an average student.

The results of the analysis showed that despite the prescriptions and contractual rules, the amount of meals received in the UR did not always coincide with the planned and ordered quantity, which resulted in ingredients shortages on certain days and leftovers on others. Thereby, sometimes the kitchen assistants had to regulate the number of served meals by adjusting the meal portions.

One of the hypotheses on the possible origin of the complaints about the physical fatigue and the mental wear at the serving counter was related to this regulation on portioning the different menu ingredients. The objective of the systematic analysis was to show why it was painful trying to carry out the fixed portioning during the meal distribution.

The systematic analysis of the work done at the service counter showed that these workers had to make the regulation between the demand (number of meals planned through the distributed passwords) and the supply (number of students actually served, calculated based on the number of meals sold). This strategy required the mobilization of knowledge, experiences, resolution of conflicts, etc., as will be better described below.

4.1. Regulatory strategies as a way of balance between the rigidity of the production system and the variabilities of the collective food service

The EWA results revealed that during the portioning at the serving counter, the kitchen assistants tried to give coherence to the different elements and conflicting logics of three main groups involved in the production process: (i) the UR team whose main objectives were to promote food culture, meet the requirements of safety and nutrition [19] and to monitor the quality and quantity of meals supplied by the outsourced company; (ii) the outsourced company whose main goal was to sell as many meals as possible; (iii) UR users who wanted to be served quickly, pay a low price and eat tasty and quality food.

Generally, these distinct logics entered into a conflicting interaction with each other and with the other elements of the production system when they met at the serving counter. In addition, the concepts of fixed portioning and the profile of the average student did not match the variable profile of the UR users.

One of the strategies created by the kitchen assistants was to convince the users to take some undesired ingredients. Thus, when they realized that some ingredient might be lacking, the kitchen assistants began to retain certain raw materials, serving smaller portions than planned by nutritionists, altering the fixed portioning measure pattern, but meeting the demand of students and their company.

It can be said that through this change in the fixed portioning measure pattern, the workers made the balancing between fixed supply [planned meals] and variable demand [the number of students served/meals sold], a classic problem of Production Planning and Control (PPC). However, this balancing was a source of tension and stress because it was vetoed by the UR's nutritionist team.

4.2. The main transformations of the initial concepts of the UR project

The EWA results which were presented by the ergonomist and discussed with the UR director were subsequently presented by the last one at the project redesign meetings. This information was the basis for building a dialogue between the main actors involved in the production process and in the design process. The revealed activity of the kitchen assistants gave the chance to all these participants to acknowledge the existing problems from this point of view, as well as to present their own perspective, and thus to promote a debate in search of the improvements of the productive system.

Starting from these meetings and the recognition of the strategies of regulation of the kitchen assistants, aiming at the improvement of the PPC, the UR team began to carry out a statistical research of the number of leftovers and the minimum level of its acceptability. Therefore, it was decided that if the leftover ingredient reached up to 30%, the nutritionists of the contracted team had to change the techniques of preparation or even substitute less desirable ingredients for users on the menu.

In addition, the UR director decided to replace fixed portioning with more flexible one, meaning that the kitchen assistants could increase or decrease the amount of ingredients by about 15%, depending on the user's requests. It intended to reduce the shortages and leftovers of the ingredients. The workers also proposed to make an individual portioning of rice and beans, that is a free demand. But this last request was not authorized. So, as a result of the meetings, the kitchen assistants were allowed to carry out the more flexible portioning and not to serve certain undesirable ingredients of the menu.

In practice, the results of the changes were: the reduction of conflicts between the kitchen assistants, users and nutritionists, and the reduction of food waste. The decision to change the fixed portioning measure to a more flexible one allowed the workers to continue using their regulation strategies, which gave them a certain degree of autonomy at the serving counter and made the regulation less painful. They also felt less control and supervision at the counter and, therefore, less conflicts, tension, fatigue, mental wear and emotional exhaustion during the portioning. By being able to negotiate the possible solutions to the unforeseen problems that arose in their workplace, it can be said that the workers finished the design of the UR project in its operation, i.e., in its use [20].

After the end of this research, the workers achieved another goal. The portion of rice and beans became free demand. Thus, each user could request as much as he wanted. These successful modifications reinforce that workers' participation in the interactive project design dialogue should be viewed not as an option but as a necessity. By giving importance to the status of the operator and their activity in the design process, it helps to improve the initial concepts of the project and the operation of the system in general.

5. CONCLUSION

Through the activity analysis, we tried to show the inconsistency of the technicist environments in relation to the workers' objectives, which then, in the operation, presents itself as a significant factor in the working conditions deterioration. The work analysis showed that the role of human's activity should not be underestimated and that it could be useful to measure the distinction between the prescribed work and the real work [8]. The results of the study in the UR demonstrated how the kitchen assistants, as project

final operators, continually modified the design results through their interaction [20], changing its initial concepts. Considering the UR director's decision to make the fixed portioning more flexible, it can be said that the project process design also continues during its operation, i.e. in use [12, 20]. After all, in the initial design process the problems cannot be fully solved nor can they be fully predicted, and, thus, the users continue to modify the initial design results (artifacts, products, designed processes) and to seek solutions to problems that arise during the operation.
The EWA results of the kitchen assistants' activity at the serving counter and their participation in the UR redesign project meetings contributed to assessing and modifying the initial project concept. As a consequence, there was a decrease in stress, conflicts at the counter, physical fatigue and mental exhaustion of these workers. This scenario proves that a project cannot be seen as a complete construct, since it is a continuous and multilogical social process in which the actors involved must negotiate their differences and develop their complete concepts in face-to-face exchanges [21].

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METHOD DEVELOPMENT OF ONBOARDING PHASE OF SNAPCHAT APPLICATION WITH USABILIY TEST AND AFFINITY DIAGRAM METHOD

E. Lógó, A. I. Kovács, A. Paulusz
Budapest University of Technology and Economics Department of Ergonomics and Psychology Hungary, H-1117 emma@erg.bme.hu

Abstract

User Onboarding process is very important topic on the field of software ergonomics, because the attention span of an average person has decreased from twelve to eight seconds for past 20 years, and users have behave impatient with software products. In our research we analyzed Snapchat application, detected the onboarding phase with usability testing. 16 task was supposed to do Subjects (3 male and 3 female; 3 of them was iOS and 3 Android user), who had never used Snapchat application before the test. We collected approximately 400 user experience card with the usability test and cards were sorted by an expert team with Affinity Diagram Method. Expert team contained designer, engineer, ergonomist and economist members, and the end of the sorting they have identified 5 main user experience group with 19 sub-group, and have formulated developments towards better user experiences during onboarding phase of Snapchat.

Keywords: *Software ergonomics, Onboarding phase, Application, Usability testing, Affinity Diagram Method*

1. INTRODUCTION

With the growth of Internet penetration, smartphones, as well as the applications and the various forms of social media available on them have become an integral part of our everyday life. Social media applications are the main communication channel of the 21st century person where they can create content with their connections, and share, like, send messages, and where they spend a significant part of their time. For this reason, a large number of professionals work on keeping the user satisfied, which means using these applications more and more [1]. The initial onboarding stage, in which the application is installed and first used, is decisive as to how frequently the application will be used and what quality it will be. This is the reason why we will focus on this process in the study of our selected application, and we have conducted examinations with six subjects regarding this. We processed and assessed the results of the study with the Affinity Diagram, because this method helps find the key points and provides a good visual representation of the main issues, as well. This transparency made the assessment process as well as suggesting areas for improvement easier, as well. We selected Snapchat application because, although it has a large number of users worldwide, we were not able to find any analysis regarding usability tests or onboarding in professional literature or in other publications.

2. THEORETHICAL BACKGROUD

We will introduce the background of the study in three sub-chapters. First, we will introduce Snapchat application itself and its major functions, as these are in connection with the onboarding phase of the application which we will examine later. Afterwards, we will cover the introduction of the onboarding phase in brief, which has a wide spectrum of professional literature related to usability testing. Finally, in the third section, we will introduce the Affinity Diagram method with which we have processed the raw data from the usability testing.

2.1. Snapchat

The application today we know as Snapchat was launched by three Stanford university students. Their purpose was no other than to integrate picture-based communication in our everyday life. Not only perfect events, occurrences, situations were to be recorded, but also the most spontaneous moments of our lives. These pictures, or even videos, then subsequently should be shared with as many of our friends as possible, without consequences. By having no consequences, I mean the core function in the application that automatically deletes photos. This is probably one of the reasons why it became so popular with the youth. The images, videos we send to others will not remain visible for eternity, the receiving party has a time frame of up to 10 seconds to view them. Once this time is up, the content received cannot be viewed again (though, there is one loophole, the replay function that allows the content to be seen one more time in the day). The pictures and videos we have created can be saved to our device easily. In brief: Snapchat is a video- and picture messaging social media application that can be downloaded to smartphones and which essentially allows a one-time playing or viewing for a period of a few seconds only, after which the message is lost. [2] We can send our daily experiences and adventures to our friends, which they will receive as some sort of a status update, and it is not the composition of the picture that matters but the message that is conveyed, and the, in most cases, entertaining imagery. A subtitle can be attached to each picture or video in no longer than one sentence. Despite the fact that it is originally a picture-sharing application, users send more videos than pictures, to be more precise, 10 trillion videos are viewed a day on Snapchat. In 2014, the company confirmed that they had 100 million active users worldwide. This figure was 160 million in the first half of 2017 [3]. This almost equals the number of active Instagram users. One user spends half hour with Snapchat on average, and an active user launches the application 18 times a day on average. In addition, Snapchat is one of the most popular applications among the youth. A significant number of the users is under 35. Recently, however, half of the newly-registered users have been above 25 [4]. In the followings, we will show some core expressions that are necessary to understand the application and which help to get our bearings

• Snap: A video or picture that we send or receive.
• MyStory: This is a function with which we can share a picture/video on our public profile and the shared content will be available for 24 hours.
• Screenshot: When another user saves a screenshot of the content we sent, the sender will receive a notification of this happening.
• Filter: An added function that alters the original picture. Filter is an overlay function that can be added to pictures (before or after they are created), it uses virtual reality features. Such are the filters that alter or distort for example our faces.
• Stickers: An illustration that can be added to the picture once it has been created by selecting the stickers icon.
• Timer: Timer. This shows the person who receives our picture how long (how many seconds) they have to view it.
• Discover: By swiping left two times on the main screen we find the Discover function. Here we can read various articles, usually from popular magazines and blogs.
• Snapscore: The points that the user can collect for the pictures/videos they sent.
• Snapcode: It is essentially a QR-code with which we can also friend somebody.
• Tutorial: This is in fact the interactive help that shows some of the initial steps in the application. This makes it easier for the user to use the application for real.

2.2. Onboarding

Onboarding is a short interval in which the user becomes familiar with an application, trying it for the first time and understanding its main functions. When designing the onboarding process, the preliminary knowledge of the user needs to be considered, how much they know of the application, have they ever used it, what advertisements, messages they have met in terms of marketing. [5] The onboarding process needs to find answers to the following questions [6]:
• What functions does the application have and which are the ones that the users can find especially interesting?
• What are the initial steps that the user needs to do?
• How can it be guaranteed that the core value, the purpose of the product is clear for the user?
• Where can the user find help or assistance if there is something they are not aware of?
Successful onboarding means that the user will use the application on a regular basis.

2.3. Affinity Diagram

Affinity Diagram is a tool with which large numbers of data (e.g. ideas, opinions) can be collected and arranged. The use of this method is recommended for the thorough analysis of large quantities of ungrouped information, for example, if a manufacturer would like to identify its customers and their demands, grouping the available sets of data with Affinity Diagrams can be really helpful [7] [8] [9]. From another angle, this method is also suitable for nudging those applying it towards a new way of thinking, because when it is being used, people will react rather spontaneously and instantaneously, instead of thoroughly thinking through, or chewing on the situation. Conventional thinking patterns can be broken this way, giving space to more creative ideas. According to common practice, Affinity Diagram is not worth using if the list of data has less than 15 items.

The “Affinity” process is carried out by a group or a team, therefore more options can be seen from more angles. The method works best if the number of participants is not more than 5-6 people [10]. The process is more efficient if it is done in silence and the members of the group carry out the categorizing without talking, out of their own will. This is a novel experience for most people, which has two positive outcomes: it facilitates out-of-the-box thinking and prevents fighting over semantics. This way it can be prevented that Affinity becomes dominated by one person. To succeed, it is important that everybody react instinctively instead of being thoughtful, it is worth reacting swiftly to the problem at hand when making a selection to facilitate the process. Disputes can be handled easily: if somebody does not like where one data is placed, they can move to where they prefer. This allows the creation of an environment where it is acceptable that people with differing views do not agree on everything. If consensus cannot be reached, it is worth doubling the amount of information, the same data can be placed in more groups.
In our case, the Affinity group consisted of 4 persons, we selected members with designer, marketing and ergonomics backgrounds.

3. METHOD

In the first phase of the examination, we carried out conventional usability studies in the onboarding phase. We will present the process and the results rather briefly, as in our study we focused on the methodology used for processing the results that followed it. We involved 6 subjects in the usability study, and with the help of the thinking aloud protocol, between a short preliminary questionnaire and a post-interview, they went through the registration process and performed some tasks to familiarize themselves with the application. It is important that we selected users who are completely inexperienced in using Snapchat, and they had to install the application on their own devices so that testing be done in a familiar hardware environment, only focusing on the usability of the application.

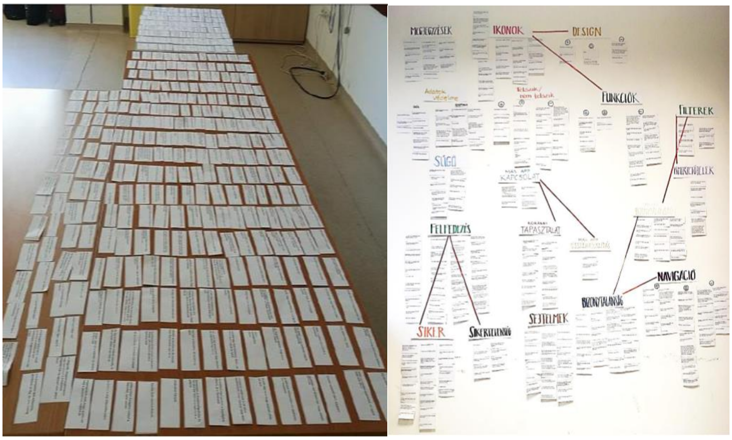

Figure 1: (Left) 400 statements were created (Right) The Affinity Diagram after we finished
Source: Own Photos

Half of the subjects were male and half were female, and similarly, 50% of them were using iOS and Android operating systems. During the examination we recorded screenshots and voice as well, for later analysis.

We listened to the recordings that the voice recorder made and noted down the sentences that we found important and relevant for the study. Every note was given a serial number and in the end more than 400 statements were created as result of the examination. This set of statements were used to create the Affinity Diagram.

When creating the Affinity Diagram, the first steps were difficult and uncertain, but once the members of the experts' team created one or two smaller groups of statements, the process became apparently easier. Simultaneously as the sets groups were being developed, thinking began about the connections between these groups and these were marked with connecting lines. Eventually 19 groups were created, many of which had both positive, neutral or negative sides, too, since the remarks were not always general in their nature. Such divided groups were navigation, function and design. After the complete Affinity Diagram was reviewed, we were able to summarize the statements under the headings in the following way (seen on Figure 1):

REMARKS: many recognized the counter displaying the visibility time of the pictures and snaps received, and also its function.

ICONS: the meaning of colors and shapes is not clear, they did not make a lasting impression in the testers. They did not remember which appeared where and what they meant, except for the chat window, because it is marked with similar icons in other mobile applications, too. The Stories function is misleading. The "Took a screenshot" icon was recognized in only half of the cases, others noted that they noticed a notification but it disappeared so quickly (it was visible for such a short time) that they were unable to read it.

DESIGN: in principle it raises attention, subjects liked the unique yellow design, the subtitling text field is well-thought out, but the application is not so clearly arranged.

DATA PROTECTION: the SMS-based validating system, the username offered, and the 8-character password seem safe. On the other hand, many were skeptical about having to allow everything (GPS, contacts, camera, microphone etc.), without these permissions some of the functions of the application do not even function, for example certain filters cannot be used unless positioning is permitted.

LIKE/NOT LIKE: (Like) The application is popular, trendy, interesting, entertaining, colorful, funny, has a "feeling to it", original, a little difficult, but people like challenges. (Not like) Meaningless, unnecessary, not needed, chaotic. It was not designed for our test subjects or for their age group, it is complicated and not everything is straightforward, but after using it some time you can get the hang of it and it can be easier for those who use many applications. It is not used in a circle of friends, they do not feel the need to use it. It was mentioned by many as a negative point that the application is too big.

FUNCTIONS: Almost everybody learned the basic functions (sending photos and videos, overlaying text on pictures), but it was commonly agreed that the user interface is complicated and another 1-2 days would be necessary to learn to use it safely. It was mentioned by many as a deficiency that there is no notification of being marked as friend. Many did not find the "back" option.

FILTERS: They are funny, there are always some new, it is fun to play with them, "mind-numbing entertainment".

DISTINCTIVE MARKS: Sending “weird” pictures to each other, you can put masks on yourself. There is a filter that is so widespread, so “mainstream” that is no longer fashionable, people are ashamed to use it. Most of them recognized one filter immediately because they had seen it so often on the Internet.
FILTER UNCERTAINTY: Most of them found the function but it was not clear what a filter actually was.
HELP: Since the start screen is the place where pictures and videos can be made, everybody starts using this first, however, they only learn a few basic functions. They realize only later that the application has sent them a video on how to use it, because it is on another screen. The help assists with some very basic functions, but there is a time delay between introducing the basic functions and the actual usage of the application.
CONNECTION TO OTHER APPLICATIONS: It is compared to Facebook, which is ranked higher than the tested application. Many recognized, though, that Facebook took over some functions from Snapchat.
COMPARISON TO OTHER APPLICATIONS: It was also compared with Facebook, because of the 24-hour photo and video sharing function and because of the chat function.
EARLIER EXPERIENCES: Here, more of them mentioned other applications, e.g. Instagram, Messenger, Viber. According to the tester, this application also needs a tutorial, a presentation, an assistant that would lead through its use. It was also compared to other camera applications (or photography sections of other applications) when photos and videos were being made, for example the switch between photo and video. They would have assumed that the application would recommend closer acquaintances, they missed this feature, it could increase the chance of returning to it.
DISCOVERY: Everything that meant a new discovery for the testers in the application was collected here. They found where to send a message (not just photo or video), the settings function and the search, as well. Some selected to whom to send the photo to before it was made, some did it after it was made, and the same was true for the Stories function, too.
SUCCESS: Adding pictures and videos proved to be simple, the help made the essence of Stories understandable, using the Timer was also simple. The blue bubble was also recognized as the chat window, finding friends and saving own pictures (made by the tester) was successful. Those who noticed and understood the “Took a screenshot” notification appreciated being told that somebody made a screenshot of the pictures they sent them.
FAILURE: It was experienced by many as a failure that they were not able to view the pictures or videos they had already sent again. Being able to see the “Took a screenshot” notification for such a short time also invoked similar feelings, as well as the fact that it was illegible and incomprehensible.
ASSUMPTIONS: None of the testers was aware of what Snapcore was. They were only able to guess at the meaning of the colors in the application. It was also not obvious which the main screen was, or if there was a Replay function and how it could be used. Many assumed that groups could be created. The concept of timer was understood differently, they believed it referred to the time before the picture was taken and not the visibility of the image. They did not know whether the gallery was the gallery of the phone or the own gallery of the application.
UNCERTAINTY: We mainly listed general questions here, for example, what is this, what happened, how did it happen, what does this screen do. Many asked if the timer

needs to be set for each picture separately, if the snaps sent can be viewed again, and there was some incomprehension related to icons, too.

NAVIGATION: The list of friends and the password change was straightforward. It was regarded positive that the Snapchat logo, the ghost, could be seen on the registration screen, and the subjects were able to associate the most important things to this sign, they knew that they would find the settings at this logo, as well. It was regarded as negative that when looking for the "back" icon mentioned earlier some of them accidentally left the application, and that they found some functions only when they performed the same series of steps again. At first there was much uncertainty, navigation was really incomprehensible, trying every option was purely based on chance. The structure is not logical, neither is what, where and how to touch and swipe - up, down, right or left - to find one particular function.

After this we prepared the Affinity Diagram. We created 5 main headings and organized the groups we made earlier under these which you can see in the figure below:

USABILITY	GETTING INFORMATION	UNCERTAINTY	OPINIONS	SUCCESS
icons	distinctive marks	data protection	remarks	success
design	help	filter uncertainty	like/not like	
functions	connection to other applications	failure		
filters	comparison to other applications	assumptions		
	earlier experiences	uncertainty		
		navigation		

Figure 2: The headings and contents after finished Affinity Diagram
Source: Own compilation

4. CONCLUSION

During the study we examined the onboarding phase: to what extent is it successful among new users, and what are the areas in the application that need to be improved further. We identified and uncovered the following relevant problematic areas in the application:

1) The lack of tutorial within the application,
2) The complexity of navigation,
3) Not obvious icons.

It is true that in planning the current onboarding phase of Snapchat the "Show and do not explain" principle was an important factor, but despite this, we believe it is important to have an optional help in the process which would assist in overviewing the navigation options, too.

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METHODOLOGY FOR ERGONOMIC PC MOUSE DESIGN AND EVALUATION OF MUSCLE ACTIVITY

M. L. Lourenço[1,2], D. A. Coelho[2,3]
[1] Technical Scientific Unit of Engineering and Technology and Research Unit for Inland Development, Polytechnic Institute of Guarda, Guarda, PORTUGAL, mlopes@ipg.pt
[2] CMAST - Centre for Mechanical and Aerospace Science and Technologies, Universidade da Beira Interior, Covilhã, PORTUGAL
[3] Human Technology Group, Department of Electromechanical Engineering, Universidade da Beira Interior, Covilhã, PORTUGAL, dac@ubi.pt, denis.a.coelho@gmail.com

Abstract

A structured research methodology was adopted in the design and experimental work, presented in the first author's doctoral thesis, aiming ergonomic development and assessment of computer handheld pointing devices: a positivist empirical study for artefact building and evaluation, contributing to test and expand existing theory. PC mouse usage leads to generally low static muscle activation levels, deemed a high risk for musculoskeletal health. The rationale for selection of the forearm muscles monitored is shown as well as signal processing. Selected results of surface electromyography data collected from 20 subjects performing standardized tasks in interaction with a prototype of a new slanted device and a traditional PC mouse are reported. Analysis of electromyography signals was performed via Amplitude Probability Distribution Function (APDF) for baseline, common and peak levels of percentage of maximum voluntary contraction (MVC).

Keywords: *ergonomics, research design, PC mouse evaluation, S-EMG, product development*

1. INTRODUCTION AND AIMS

The research process carried out by Lourenço [1] in the design and experimental work presented in his doctoral thesis, supervised by the second author, involved interlaced research methodologies in the development and ergonomic evaluation of new computer handheld pointing device shapes. In looking for answers to the research questions, distinct research methods were implemented, including literature review, product development, data collection instrument development, laboratory experiments and field experiments. These research methods were implemented through a variety of research techniques, such as observation of artefacts use, prototyping, use of evaluation scales and the use of measuring devices. Positivism, recognizing only that which can be scientifically verified, or which is capable of logical or mathematical proof, is the underlying philosophy behind the proposed research methodology; thus, the structured process adopted enables study replicability. Sanders et al. [2] describe the general steps of any research process using an onion metaphor, which progresses in successive steps from a peripheral layer towards the core. Using this process in the improvement of the PC mouse led to product development of new PC mouse shapes [3] and comparative evaluation against existing benchmark models. Thus, the proposed methodology, presented in detail elsewhere [1, 4], deals with product design and specific experimental design integrating usability assessment [1, 5, 6, 7] and muscle activity assessment [8].

This paper also focuses the assessment of specific muscles' activity of the subjects' right forearm in computer mouse usage. The comparative tests are based on standardized tasks [1, 5, 7] to achieve replicability in usability evaluation and specific muscle activity assessment. Computer mouse usage implies static muscle activation levels, which despite being low in general, are believed to represent a high risk for musculoskeletal health. Søgaard et al. [9] define 'low level' static effort as a condition associated to muscular work in which the muscle is activated at such a low order of contraction that it allows the work to be maintained over a long period of time. Use of computer handheld pointing devices that causes pronation of the forearm, such as the conventional PC mouse, may reveal the occurrence of this type of static muscular activity, which may eventually indicate potential risk for musculoskeletal disorders. Surface electromyography (S-EMG) measures the activity levels of muscles during activity, such as the use of the device [10]. The aim of this paper is presenting a research methodology for ergonomic PC mouse design with evaluation of forearm muscle activity. Selected results of S-EMG data collected from 20 subjects (10 male), performing standardized tasks [5, 7, 11] interacting with distinct PC mouse shape [1, 8] are shown. Analysis of electromyographic signals from 4 forearm muscles was performed via Amplitude Probability Distribution Function (APDF) calculation for the 10th, 50th and 90th percentiles of percentage of maximum voluntary contraction (MVC).

2. METHOD AND RESULTS

2.1. Research methodology for ergonomic pc mouse design

The proposed research methodology was framed within positivism and classified as an empirical study for artefact building and artefact evaluation, which contributes to testing existing theory but also to expand it, based on the taxonomy of research approaches proposed by Järvinen [12, 13]. Applying the taxonomy of research approaches proposed by Järvinen [12, 13], some research questions emerge. In the theory-testing approach, a certain theory under interest may result from literature review, or it can be developed and refined for the study. In this regard the research question may be "do observations confirm or falsify the theory?". Additionally, the research question "is it possible to build a certain artefact?" applies to the artefacts-building approach. On the other hand, within the artefacts-evaluating approach and in what concerns PC mouse usage, a suitable research question may be "how much muscular effort is required from the user engaging in activity with this device (artefact)?". Thus, the experimental work carried out combines the artefacts-building and artefacts-evaluation approaches within the theory-testing approach (Figure 1). Proceeding to product development and comparative evaluation of handheld pointing devices, using a newly developed shape as well as an existing one, under the theory-testing approach, expansion of existing theory arises because of the interlaced research methodologies applied here.

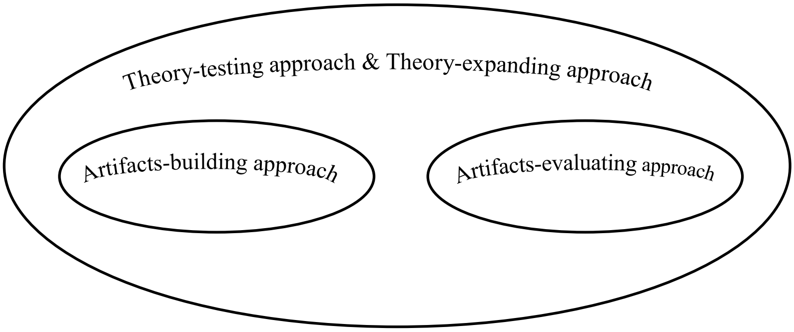


Figure 1: Implemented research methodology (based on taxonomy of research approaches proposed by Järvinen [12])

The development process of new shapes (PC mice) is based on specialized literature recommendations, mostly in the form of applicable standards [14, 15, 16, 17]. The main requirements indicate that the device should promote a more neutral forearm posture by the user, ensuring accurate control and effortless grip. Thus, new computer mouse shapes should avoid forearm pronation, achieving efficiency and effectiveness and requiring the lowest possible muscular activity to operate the device. The detailed development process of the new PC models goes beyond the scope of this paper; nevertheless, the complete specification list and a flowchart of the operational model adopted for that purpose can be found in Lourenço et al. [3]. The operational model is adapted from Lewis and Bonollo [18] and Hales [19]. The new prototypes were intended to be tested along with other devices sold with the 'ergonomic' seal, as well as to be compared with a standard shape from a benchmark PC mouse. The comparative tests are based on standardized tasks [5, 7, 11], to achieve replicability in both usability evaluation and specific muscle activity assessment. Figure 2 shows the prototype of a new PC mouse that arose from the product development process briefly characterized in the present paper and explained in detail by Lourenço et al. [3]. This prototype and a standard (traditional) model, depicted in Figure 3, both using the same hardware, were comparatively assessed through several tests for usability and forearm muscular activity evaluation.

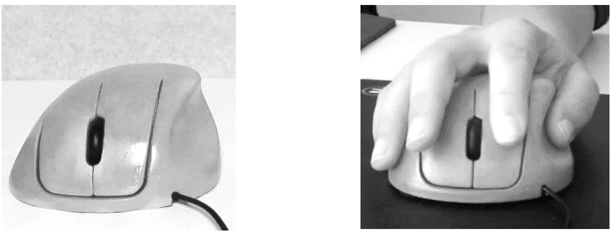


Figure 2: Prototype of the new PC mouse shape (slanted shape: ch) - res. 1000 dpi
(dimensions: 120x90x49 mm, total mass: 128 g)

Figure 3: Standard PC mouse shape (benchmark symmetric model: mi) - res. 1000 dpi
(dimensions: 106x56x30 mm, total mass: 78 g)

2.2. Method for evaluation of forearm muscle activity

According to Sjøgaard et al. [9], some of the muscular activity typically accepted as dynamic could be the bearer of risks associated with static efforts, probably arising from the fact that muscular contraction is continuously maintained. The same study lists a set of activities, including PC mouse usage, where static 'low level' and long duration contractions usually occur. Thus, to account for the level of activity of a muscle but also for the effect of time duration of the muscle contraction during PC mouse usage, analysis of the electromyographic signals was performed via Amplitude Probability Distribution Function (APDF) calculation. The APDF was calculated for the 10th, 50th and 90th percentiles, representing baseline, common and peak levels of percentage of maximum voluntary contraction value (MVC). Electromyographic recording was performed with a Bagnoli 4 channel system using DE-2.1 Single Differential Electrodes, placed on specific standardized locations of the participants' forearm. The surface electrodes were attached to the skin through proper double-sided adhesive tape. The EMG signals were normalized from a set of three attempted maximum voluntary contractions, per muscle and for each one of the 20 participants in the experiment, each voluntary contraction lasting 3 seconds, followed by 60 seconds of rest in between trials [20]. The MVC value used to normalize the data resulted from the maximum observed value of the three trials. All the measures were taken in order to minimize or eliminate any 'noise' effect. Data collection was performed using a sample rate of 1000/s per channel and with channel amplification between x1000 and x10000. EMGworks 4.1.1 Acquisition software was used. Each selected muscle was monitored during 60 seconds and the instantaneous EMG signal was scanned by a RMS function moving window applied every 0.125 ms. Data pre-treatment was performed using EMGworks 4.1.1 Analysis software. The subjects performed standard graphical tasks [5, 7, 11] using each of the PC mice in the following order: pointing at large targets, pointing at medium targets, pointing at small targets, dragging targets with the left button of the mouse, dragging targets with the middle button and steering targets inside a tunnel, finally the subjects performed a scroll up task.

2.2.1 Muscle selection

Computer mouse usage has been related to musculoskeletal disorders of the upper limb and several studies have been performed involving evaluation of muscle activity using S-EMG. Most of these studies include the monitoring of the electromyographic activity of the *Extensor Digitorum Communis* (EDC or ED), *Extensor Carpi Radialis* (ECR) and the *Extensor Carpi Ulnaris* (ECU) muscles [8]. The above-mentioned muscles assume special relevance in the generation of postures considered inadequate and potentially harmful and that are likely to be adopted during the use of the PC mouse. Generally, these postures involve wrist extension and, or, extension of the medial fingers, radial deviation and ulnar deviation of the hand or wrist [16]. Wrist extension can be monitored through electromyographic activity of the ED, ECR, and ECU muscles; additionally, extension of the medial fingers occurs through ED activity, with slight or even no activity of the ECR and ECU muscles [21]. Moreover, wrist radial deviation can be monitored through electromyographic activity of the ECR muscle and wrist ulnar deviation can be monitored through electromyographic activity of the ECU muscle [21]. For the current study and in addition to these three selected muscles one more muscle was included. In this sense, the personal counselling given by Professor David M. Rempel [22] was fundamental to consolidate the knowledge learned from literature and from expert advice, after weighing all the available information. Thus, the *Abductor Pollicis Brevis* (APB) muscle had been indicated and included; but it was found, after a few pilot trials, that the sensor applied on the thenar protuberance of the hand was being dragged on the contact surfaces, such as the mouse and the mousepad. Knowing that the APB activity is related to the motion of the thumb, this muscle was then replaced by the *Abductor Pollicis Longus* (APL) muscle, allowing a more suitable surface electrode placement on the subjects' forearm. Replacement of the APB muscle by the APL muscle lead to undervaluing monitoring of the pinch grasp posture of the hand when grasping the mouse. However, abduction of the thumb is also recorded by either of these muscles. The surface electrodes used to collect the electromyographic signals from the ED, ECR and ECU muscles were placed following Perotto's guidelines [23]; concerning the APL muscle, the sensor was placed according to Criswell' guidelines [21]. Figure 4 shows the electrodes location on the right forearm of a participant during a prototype mouse test. The detailed surface electrode placement can be found in Lourenço and Coelho [8].

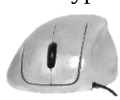
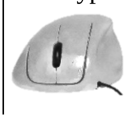
Figure 4: Prototype PC mouse being tested by a participant performing the standard graphical tasks [5, 7, 11]

2.2.2. S-EMG muscle activity monitoring method and results

The individual EMG data from ECR, ECU, ED and APL muscles (normalized with MVC values) for the twenty subjects were submitted to a transformation process to determine the Amplitude Probability Distribution Function (APDF) of the electromyographic signal. According to Hagberg [24], the probability of a certain level of amplitude of muscle contraction over time is the probability of the myoelectric activity being less than or equal to that level of contraction. This probability may be expressed as the fraction of the total duration at which the amplitude of the signal is less than or equal to that level. If this fraction is estimated from a sufficiently large number of levels, a good estimation of

APDF is achieved. In the present study the APDF values were calculated by using 960 points collected from 60 s of measuring the electromyographic (RMS) signal. These discrete values were obtained through sampling the signal at intervals of 0.0625 s, using EMGworks 4.1.1 Analysis software. A procedure of APDF calculation for the 10th (APDF10), 50th (APDF50) and 90th (APDF90) percentiles of each monitored muscle, per individual task and device was carried out. APDF10 has been recognized as related with baseline activity, APDF50 as median activity level and APDF90 as peak activity [25]. Table 1 depicts the mean values of APDF10, 50 and 90, as well the standard deviation, averaged from seven standardized graphical tasks performed by twenty subjects using the conventional PC mouse and the prototype tested. These mean APDF values vary, approximately, between 7% MVC and 22% MVC. The highest values refer to the ECU and ED muscles for all three evaluation parameters (APDF), suggesting muscular load related to ulnar deviation performing the graphical tasks of pointing, dragging, steering and scrolling operations. The peak muscular activity indicator (APDF90) exceeds 20% of the MVC for the ED muscle, suggesting this somewhat high load is related to the extension of the medial fingers, most probably due to the extension of the fingers that operate the mouse buttons. Interestingly, contraction dynamics increases for the ED and ECU muscles when moving from the standard to the prototype mouse. Given the slanted design there is a marginal reduction in APDF for ECR across the three levels for the prototype (pronation reducing) compared to the standard device.

Table 1: Mean APDF values (and standard deviation) of muscular activity as a percentage of MVC for ED, ECR, ECU and APL muscles, for the standard PC mouse and the prototype tested

	Standard	Prototype	Standard	Prototype	Standard	Prototype
						
Muscle	Mean APDF10 (SD)		Mean APDF50 (SD)		Mean APDF90 (SD)	
ED	13.18% (5.34%)	12.95% (6.55%)	16.19% (5.38%)	16.48% (6.91%)	20.62% (6.61%)	21.75% (8.36%)
ECR	9.83% (5.85%)	9.80% (6.01%)	10.49% (5.81%)	10.42% (6.02%)	11.44% (5.82%)	11.32% (6.11%)
ECU	13.75% (6.41%)	14.45% (6.82%)	15.37% (6.81%)	16.60% (7.92%)	17.99% (7.59%)	19.71% (9.72%)
APL	6.96% (5.33%)	7.22% (6.29%)	8.80% (6.14%)	9.13% (6.89%)	11.33% (7.47%)	11.96% (8.15%)

Source: Authors' experimental data

3. DISCUSSION

The development of the new geometry (PC mouse) was based on a set of requirements, including the reduction of forearm pronation and muscular 'effort' and the improvement of the handling (use) of the device in connection with increased accuracy (effectiveness). The prototype is slanted (reduction of forearm pronation), with a global geometry and a lateral cavity for improving palmar and thumb support, respectively. This new three-dimensional shape also aims reducing muscle 'effort' to satisfy requirements and answer research questions. The decrease sought was only marginally found for muscle ECR. Thus, these observations do not seem to confirm theory, although they do not undermine it, either. Thus, the study contributes to the expansion of theory. It is thought that, in addition to its three-dimensional shape, its size may also influence the use of the device, as suggested in usability assessment of computer handheld pointing devices [26]. In fact, the standard model tested (Figure 3) presents much smaller dimensions than the prototype of the new geometry (Figure 2). Thus, in future studies, the expanded theory should be tested by comparatively testing, for example, the same geometries but with identical dimensions. The results also raise interest on future studies focusing on the dynamics of muscular contraction, which seems different for some of the muscles monitored across the two devices.

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DETERMINISTIC DEVELOPMENT OF A VIBRATIONAL INTERFACE

S. Lutherdt[1], S. Bredenstein[1], F. Roß[2], H. Witte[1]
[1] Biomechatronics Group, Faculty of Mechanical Engineering,
Technische Universität Ilmenau, Ilmenau, GERMANY
{stefan.lutherdt, simon.bredenstein, hartmut.witte}@tu-ilmenau.de
[2] Dept. of Automation Engineering, Faculty of Informatics and Automation
Technische Universität Ilmenau, Ilmenau, GERMANY
fred.ross@tu-ilmenau.de

Abstract

As a part of a greater project funded by German government it was a goal to develop an information interface for elderly using vibrations. The whole development process based on a user-centered design concept which is explained within the paper. During the analysing process stages of user and task contexts it was determined, that for different contexts also different interfaces are necessary, usable and acceptable. So two different interfaces for two exemplary use cases were developed and tested by applying the NuGASt concept. First result was a vibrational shoe sole for highly-aged elderly in care facilities to give information aids for navigational tasks. Position of vibrational actuatators is determined by allocation of mechanoreceptors under the foot sole. Second is a vibrational interface for wearing at the lower arm in working areas or for sport. For this we determined the position of actuators during several user tests with different parameters.

Keywords: *user-centered design, vibrational interface, NuGASt concept, development process, user participation*

1. INTRODUCTION

It is well-accepted that it could be helpful to give information to users not only through visual or auditory channel, but also by tactile or haptic sensations (like vibrations). Such vibration-coupled information are especially meaningful for users with sensor deficits (blinds or visual impaired, deaf people) as well as for users in special situations or environments [1]. For blinds this technology is well-researched and realized in technical solutions. Many blinds had used or own a device with vibrational feedback or vibration-bound information. By vibrational stimuli it is also feasible to give a perception of graphics and scripts [2].
Another approach and application area is gaming world and technology. Their already exist a lot of gamepads and other controllers with vibrational feedback systems. But all of them give that feedback unspecific, without a real information content. To overcome this lack various researchers try to develop a new generation of vibration devices, like

belts or vests. With these virtual objects and environments in games as well as real world scenarios could be represented more realistic, with a perception of textures by friction and forces [3].

In current state of the art vibration is only used to point attraction to things that happen in the moment, like smartphones (incoming calls or messages, press a button and so on), gamepads (f. e. to feel collisions or to accompany with tantalizing and thrilling situations), but there is no further and no explicit information. An approach to widen this information deficit is given by the company (and device with the same name) ARAIG (which means "as real as it gets") in 2013. They developed a vest with vibration actuators and multiple sensors inside which can deliver information about surroundings, other acting figures/gamers or impacts of own or other actions during the game (see https://araig.com/). After that a couple of other similar concepts were launched (f.e. Teslasuit, KOR-FX, HAPTIKA or AxonVR), and also Google next to others took attention on this area (see exemplary the US-patents US14586281, US13819049 and US13819086, thematically focused on vibrational actuated gaming suits).

Not least in automotive vibration alerts became very common to point drivers' attention to unwanted actions as well as to hazardous situations. The advantage of using vibrations for these purposes is that signal lights often could not be seen (or recognized), because the visual sensor system could be overload with information [1]. Additional the use of haptic (vibration) signals lead to shorter perception and reaction times [4]. Exemplary for such systems can be named the Citreon AFIL (alert for unwanted lane departure, see [5]) and active foot throttle from Bosch (shown in [6]).

Summarizing these findings and as a result of own former researches, we planned to develop a vibrational interface for different users or user groups in several user contexts. This interface should be designed to give information by tactile, vibrational stimuli to their users in addition to or as a substitute of other information channels.

2. BASIC CONCEPT AND APPROACH OF DEVELOPMENT

2.1 User involvement

It is common well-known and accepted as requirement for any developments in human-machine-interaction, that every user is unique and differ from others, and thus everyone has specific requirements especially to usability of interfaces. Although often is the main attitude in research and development projects to obtain one solution for all users, maybe driven by economic guidelines or handicaps. But by this a couple of users or user groups with special requirements could not be addressed, and as a result the final solution will not reach a high level of acceptance by (some of) future users. Already NIELSEN meant in 1995 that in most of traditional style guides only parts of overall acceptance (consisting of social and practical acceptance) are represented [7]. And of course, acceptance of users will rule the success of any development.

Otherwise additional requirements are given by different tasks and use contexts. These requirements have to be fulfilled as well as the user requirements. To solve this design task with balancing between technical and user related requirements a specific development process is necessary. A suitable concept with an early involvement of future potential into the development is given with NuGASt[1], shown in [8]. The core of this concept is a development process structured like problem solving approach in German technical rules VDI 2221 and 2206 [9, 10]. Applicability and efficiency of this approach also from a psychological view was shown in a couple of works, like in [11]. This approach was added by several feedback loops (executing is not mandatory, only when it is necessary). In the process structure also were included parts of user involvement, some of them are mandatory (e.g. to determine user requirements), and others are optionally when needed. The fig. 1 shows schematic structure of this suggested development process.

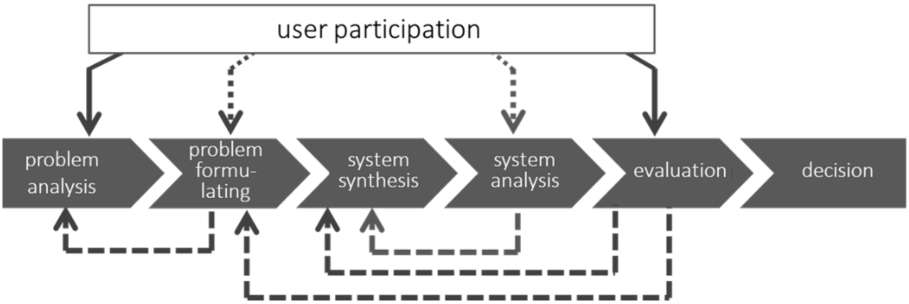


Figure 1: Schematic development process with early user participation (solid lines: mandatory in process;
dotted/dashed lines: possible, additional during the process)
Source: Taken from Lutherdt, S., 2017 [8]

2.2. Procedure and stages of development

The development process of this concept is sectioned into five stages. For the first ("problem analysis") and the fiths stage ("evaluation") is an user participation necessary, for second ("problem formulating") and forth ("system analysis") users also can be involved if it is helpful and feasible. The system synthesis and decision about the development and reaching the goals is reserved for the developers.

During our execution of first stage it became obviously, that the problem of development of a vibrational user interface for information delivery can only be solved by splitting into different solutions. These solutions depend on needs and expectations of future users as well as on the different tasks and contexts. Overall the scheduled surrounding of use, environmental and other conditions of use will determine the development. All this lead to the first finding: it is necessary to develop a special interface for each user (or user group) and each task or scenario. That means for our further development process, that all stages have to be done multiple times, at least twice the number of the desired tasks and scenarios. This quantity is required from the iterative structure of development process, most of the stages have to be executed in sloops. The number of iterative steps belongs to complexity of the designed system, but also to soft-skills of the development

[1] NuGASt: German acronym which means „user-related design of assistance systems and their user interfaces"

team. To pass the process in an efficient and therewith brief way it depends on experience and knowledge of the developers to perform the parts of user participation (besides all other needed engineering competencies), and it depends also on a good-weighted selection of probands and test persons.
For the next steps within the development process we decided to design three exemplary systems to show the feasibility and usability of vibrational interfaces in different surroundings, for different user groups and for different tasks. These three examples should be a vibrational wristband (or similar band for lower arm) for workers in noisy surroundings, a vibrational shoe sole for navigation tasks (or to support the orientation in unknown environments, and a strap and belt system to ware on the upper torso for divers (under the diving suit).

2.3. Executing the development process

The execution of all stages of described development process will be shown exemplarily at one of the developed interfaces, the vibrational wristband. From the others will only show the resulting interfaces.
The "problem analysis" (first stage) started with an intensive search of similar concepts and survey of psychophysical basis of perception, especially of vibrational stimuli. The tactile perception which is responsible for awareness off vibrational stimuli is facilitated by mechanoreceptors in our skin. Findings of own experiment as well as from other researcher had shown, that best perceived vibration frequency is between 150 Hz and 300 Hz (see fig. 2), depending on the special body where the stimuli were applicated [12, 13, 14, 15]. An overview and first entrance to understanding of tactile perception and physiology of their receptors is given by Bear [16].

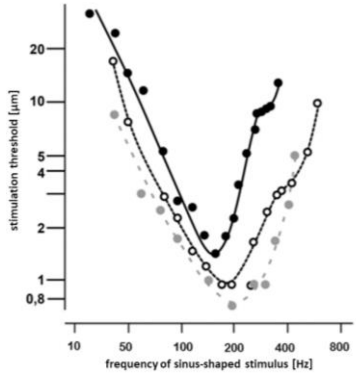


Figure 2: illustration of dependency between frequency and stimulation threshold for vibrational stimuli of three different Vater-Pacini-corpuscles
Source: own image after Gekle, M., 2010 [12] p. 302, taken from Lutherdt, S., 2017 [8]

To use vibrations as a medium of information it is also necessary to be capable of discrimination of spatial distribution of the given vibrational stimuli. This is required to have options of building vibrational patterns which coding the information. This capability of spatial discrimination depends on the stimulated body area. Like shown in fig. 3 and fig. 4, both the distribution of mechanoreceptors in the skin and the two-point threshold[2] differs from one body area to another.

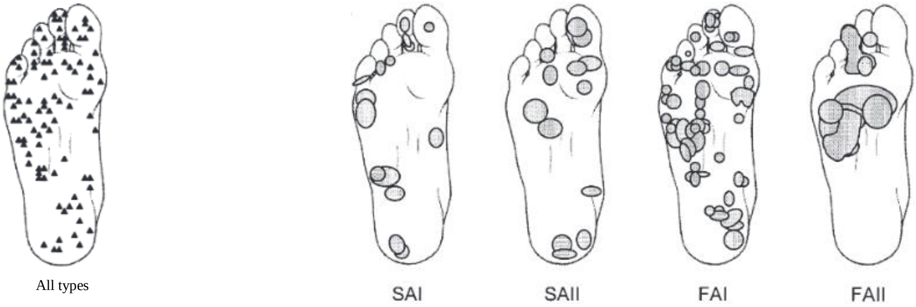


Figure 3: Distribution of mechanoreceptors under the foot sole
Source: Taken from Kennedy, P. M. et al., 2002 [17]

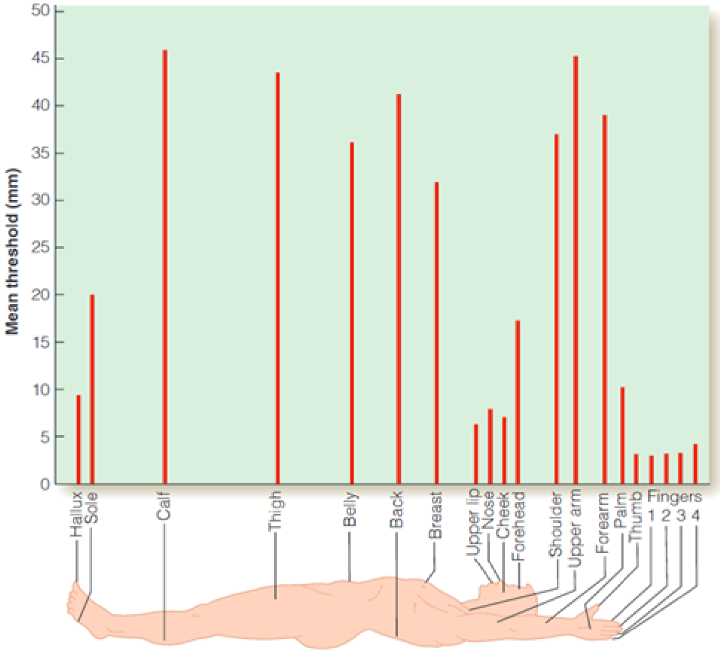


Figure 3: Illustration of sensibility of mechanoreceptors at different body areas (by means of two-point
threshold at these areas)
Source: Taken from Weinstein, S., 1968 [18] (in Goldstein, B.E., 2010 [19])

[2] Capability to discriminate between two different tactile stimuli at skin surface

In synopsis of these findings it is necessary for the vibration generating technical system (which means at least the designed interface) to place it at optimal position as well as to have actuators which are vibrating within the given frequency band. To determine these positions and to choose the right actuators as well as to verify the general acceptance of such vibrational interfaces user tests were planned and executed. Therefor a first test interface was built and used during the tests. It gives options to vary the positions of actuators at the forearm around its circumference. It is also possible to change the actuators to test different types of these actuators. Depending on availability, applicability and safety restrictions only electrical actuators (ERM-motors[3] and LRA[4]-type) were used. Cause of low voltage they are harmless for users in case of error, and otherwise due to low energy consumption they can be used for long-term or mobile applications.
Results of the executed user tests were as follows: the best performance (percentage of recognition) of all tested configurations had have cylindric ERM-motors with direct skin contact. The highest recognition rates could be reached near articulations with over 60 % (near wrist) and over 50 % (near elbow) of highest rated perceptions of 7 probands with 20 test runs each (see fig. 5).

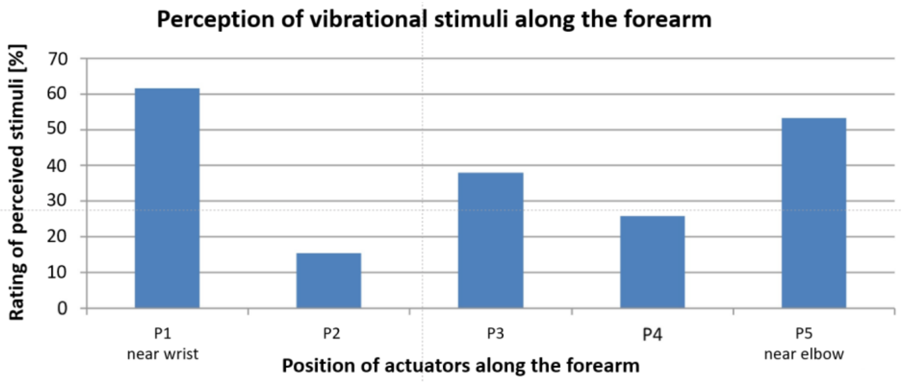


Figure 5: recognition of vibrational stimuli along forearm from distal to proximal
Source: own data

The tests of different positions around circumference of forearm showed, that best rates could be reached at upside, followed by both interior and exterior side, and worst results at underside (see fig. 6). Some of the probands also mentioned feelings of discomfort when stimulating the underside.

[3] ERM-motor: eccentric rotating mass motor
[4] LRA: linear resonance actuator

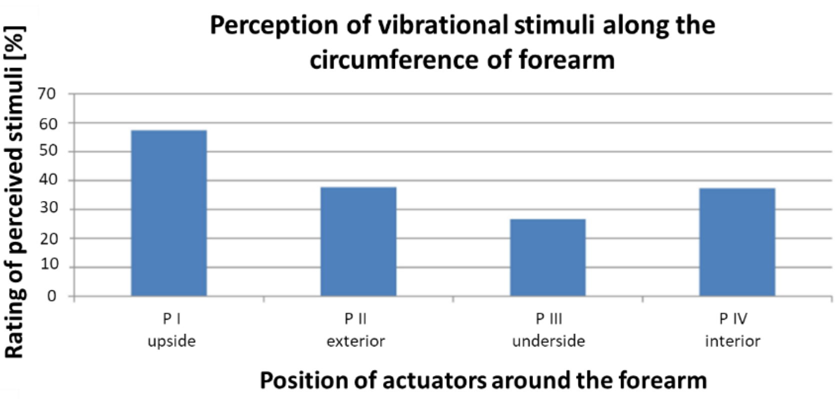
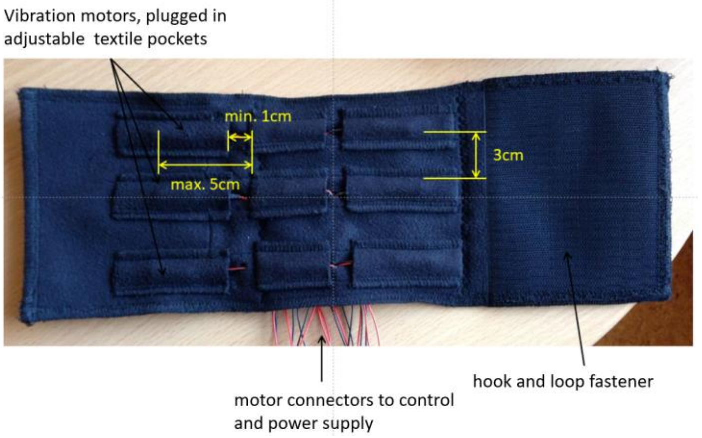


Figure 6: Recognition of vibrational stimuli at forearm depending on position around the circumference
Source: own data

With these results and findings, a requirement catalogue was deployed in stage two of development process: "problem formulating". Some of the main requirements were, that the new interface must have at least three actuators in longitudinal direction and three around the circumference at each of these positions. The actuators should be from ERM-type in cylindric shape, and the wristband must be adjustable to different arm diameters. To enhance the wearing comfort wristband should be made from elastic, breathable textile.

In realization of these requirements a first prototype of interface shown in fig. 7.a and 7.b was built (stage "system synthesis"). The interface is controlled by a micro-controller (Arduino® Nano) with transistors as motor drivers. Power supply is given from LiPo-accumulators. To increase the recognition rate an additional stimulation concept was implemented, called "spatial moving vibrations". Similar patterns already were tested by other researchers (see [20, 21]). These spatial moving vibrations are realized by spatial and time-synchronous changing of a stimulated position. Parameters for this to really recognize vibrations as "moving" are duration of stimulus (DOS) and stimulus onset asynchrony (SOA) like described in [20] and [21].



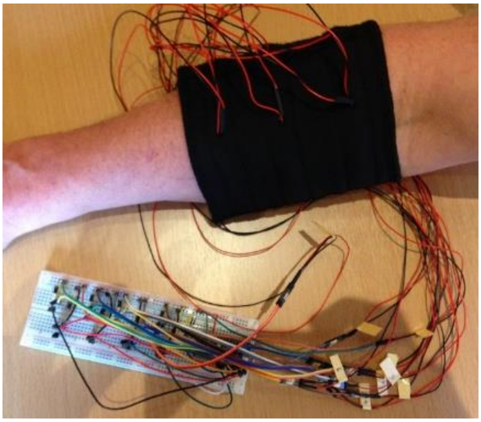


Figure 7.a: prototype of vibrational interface with nine actuators

Figure 7.b: applied interface on forearm of a proband

Source: both own images

During the next stage ("system analysis") a formal validation of interface prototype was performed, again with involvement of potential users. Focus of the tests laid on the spatial moving vibrations. With prototype interface three versions were realized, which differ in parameter SOA. Probands had to recognize the moves and their directions. Results of these tests are shown in fig. 8 and summarized in table 1.

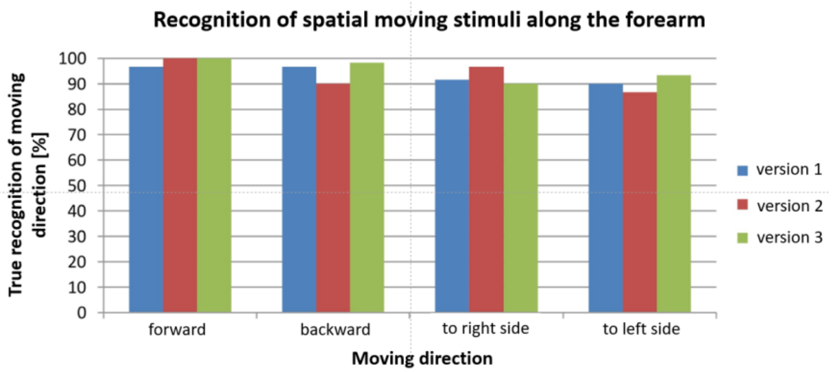


Figure 8: Results of user tests to recognize the direction of spatial moving patterns (own data)

Table 1: Summarizing correct recognitions of spatial moving vibrations

		spatial moving vibration		
		version 1	version2	version 3
True recognized moving directions [%]	forward	97	100	100
	backward	97	90	98
	to right side	92	97	90
	To left side	90	87	93

Source: own data

3. CONCLUSIONS

Stage of systems analysis directly descend to evaluation. As a result, generally can be concluded, that both a vibrational interface in common as well as with spatial moving patterns are feasible and helpful for users in different situations and user contexts. The high rate of correct recognitions of spatial moving vibrations shows a great potential of such patterns to support users' perception.

Another finding is, that a deterministic development of such interfaces is successful executable with the development concept NuGASt. Also, two other vibrational interfaces were design using this concept. In fig. 9 is shown the strap and belt system to support divers in unknown surroundings (under water) with poor visibility. This interface gives information to the diver about the direction of desired underwater moving (up or down, left or right, and in between these concerning the upper hemisphere above the diver). Tests also in water (in public swimming pool down to 4 m depth) were successful executed. Diver's opinion about the system was positively, 100 % of the commands were recognized and executed correctly.

Figure 9: Prototype of vibrational interface for diver supporting systems, left wearing at torso of probands in a lab, right user tests in public swimming pool (under diving dry suit)
Source: own images

One other interface developed prototype using NuGASt concept is shown in fig. 10. This shoe sole with five vibrational actuators supports their users to orientate in unknown surroundings. The interface is also controlled by an Arduino® microcontroller with link to a PC-based navigation system. Distribution of vibroactuators within the sole is derived from spatial distribution of mechanoreceptors in the foot sole (see fig. 3). An additional pressure sensor detects heel strike and toe off, because during stance phase foot sole is not receptively for vibrational stimuli [14, 15]. User tests with different groups (students, elderly in home care facilities) to evaluate the interface showed that it is possible, acceptable and comprehensible to give information by that sensor modality.

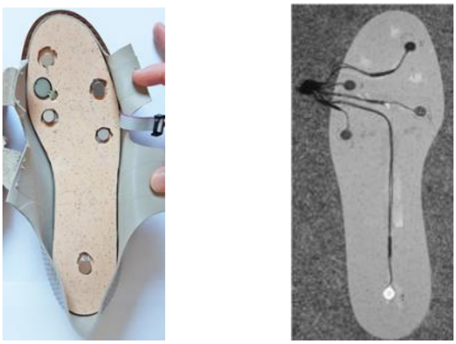


Figure 10: Test sandal (left) and removed shoe sole with integrated vibration motors (back side)
Source: own images, taken from Lutherdt, S et al., 2016 [22]

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COGNITIVE ERGONOMICS AND BIG DATA ANALYTICS IN THE DISEASES PREVENTION FOR REAL TIME FINANCIAL RISK ANALYSIS TO OPTIMIZE QUALITY OF LIFE AND PROTECT THE BALKAN ECONOMIES

C. S. Mammas, A. S.Mamma
State Scholarship Foundation, Fellowships of Excellence for Postgraduate Studies in Greece-Siemens Program 2014-16, Athens, Hellas, csmammas@med.uoa.gr

Abstract

Big data collected prospectively on a real time mode from the Hellenic Peripheries' records on 07.11.2017 have the potential on time and accurately to detect high risks currently faced by governmental authorities. These health-safety and financial risk issues are sourcing from ageing population, diabetes, cancerous and infectious diseases, epidemics, financial and refugee and migration crisis interrelated with decision-making and massive purchases of highly expensive biomedical products (Diagnostic machinery, vaccines, and tests etc.). The results of the Big Data driven experimentation about the cost of diseases prevention for 3.5 million public and private workers in Hellas showed: 1.High usability and reliability either by hyper-computer or by human-computer based computational analysis (http://www.ekt.gr/el/events/all/20671), 2.That a surveillance system for financial risk analysis integrated with cognitive ergonomics in the human-system diseases prevention design, can be reliably driven from Big Data analytics for early detection of risks for improved interventions and work training to save the Balkan economies.

Keywords: *Diseases Prevention, Remote Diagnosis and Decision Making, Cognitive Ergonomics,* *Big Data analytics, Financial Risk Analysis*

1. INTRODUCTION

It has been commonplace in the Hellenic society and in all the western countries that medicine has come to fruition rather than science. In its real depth, modern medicine is more a market-place- in which the purpose of the economic profit is more important than the pursuit of the benefit of the patient or the need for patient-centered relations [1,2]. Indeed, the health sector has become very economical world-wide. Money and complexity have come into play. The Health sector is now depends purely on economic and legal criteria and this leads to a new trend that of financially controlled health. In this new market-place, hospitals have given up their ever-high priority for the care of the patients - not to talk about the care of the poor patients - and have turned into speculative businesses that are more interested in consuming services and biomedical products [3]. However, the most decisive fact even for powerful states and for supranational entities is that the overall health costs, have been rising at rates higher than inflation over the past two decades. If these rates continued at the time, according to the renowned economist at Princeton University in the US, Uwe Reinhardt, after about 80 years the overall health costs would approach the gross national product. In fact, every-day problems in medicine such as how much a patient will stay in the ICU, whether to give a graft to one or to another patient, whether or not to undergo a more or less costly oncologic treatment or intervention, ceased to be a purely medical subject and have become very economical. This is because the biomedical technology costs a lot and so does the health [4]. Indeed, as Pellegrino and Thomas pointed out, "when economics and business are the ones that guide the professions, then the interest and the functioning of the market are the only incentives for professional activity". However, transforming the health sector into pure business is not yet another form of change of the form of medicine, but an unprecedented change of its identity defined as a mutation in the health sector even since 1998 [3]. Today's medicine is increasingly removing its interest from health, patients, doctors, illnesses or, moreover, philanthropic medicine. Its modern language passes more easily and more often to financial terms such as suppliers, products, consumers, consumption, profits and investments, contracts and services!''...Today, there are two additional terms: ''international stock exchanges "and ''global markets''[3,4]. On the other hand the most decisive factor in the alteration of the so called classical medicine is the unprecedented growth and the global dominance of biomedical technology industry [2,3,4,5]. In fact, the professor and academician D. Trichopoulos had emphasized since the early 80s the significant of advances in the field of bio-medical technology that have changed the medical sector after the First World War and with greater certainty after the Second World War, bringing about the corresponding great advances in the health sector. However he concluded that the major diseases of modern pathology (such as cancer, chronic infections, heart disease, cerebral vascular disease, etc.), even since the 80s in fact have remained uncured in all countries. This disproportionate ineffectiveness in the treatment of the aforementioned diseases in relation to the abovementioned advanced biomedical technology described as "Health Crisis"[6,7].

The problems of this new post-World War II Health Crisis characterized by: 1.Health inefficiency in both the well-known pathology and the newly-formed diseases (such as AIDS, new epidemics, etc.). 2. The progressively decreasing performance of the rapidly rising costs in the Health sector, 3. An exacerbated crisis of trust in the doctors' relations with the community, 4. The pursuit of the economic health., and ultimately in the 70s, 5.The prevalence of business in the Health sector [4,6,8]. As a result, the advancement of biomechanical technology has dragged the medical body into mechanistic medicine, seeking and / or promoting the prevalence of technology so that it is trapped in strange "circuits" (including the financial and the business ones). In fact, the symptoms of the " Health Crisis " have been marked in the most developed countries in the world, since 1970 [6]. Accordingly, the newly-formed disease to be dealt with by developed and robust biomedical technology eventually remained stagnant due to the ineffectiveness of the second, while the main phenomenon that clearly documented was the dramatic increase in health expenditure and, on the other hand, a decreasing return on the capitals invested in the Health Sector, but supplemented by bio-medical technology [6]. However, this novel and threatening phenomenon, which was dangerous for even the large economies of big States in the world and further analysis to treat its standard causes has been a priority: i.e.The prevalence of bio-medical technology products and the increase in the financial costs for their purchase without "cost-benefit" analyses and without productivity cost reductions, the low levels of education and training of the physicians and especially the unprecedented increase in corruption in medicine, the new-emerging diseases due to refugee crises and to the increased migration rates from war places and/or from poor or developing countries) [3,4,5,6,8,9]. These countries face even financial disasters with all their consequences (over-lending, inability to repay their financial obligations, etc.) that ultimately end up in the loss of their national sovereignty. This trend concerns Greece as early as the mid-2000-10, when more than 5 billion euros were consumed each year (an astronomical amount for Greece and its citizens) in the Health sector for only the pharmaceutical expenditure, with zero impact at the same time on the health map in the fields of prevention, cancer, transplantation and trauma, but with a maximum result in the massive, indecisive and uncontrolled purchases of biomedical products (Siemens scandal in Greece in the period of 2000-10) and (Novartis-Roche scandal in 2005-18) [3.4.8]. At the same time migration of the Hellenes young people has escaped from the country as they do the companies to confront the tough consequences of the financial Memorandum of Greece since 2010, decreasing the population and weakening its work-force, and its competitiveness [9]. Thus, the entry of poor, illiterate and unqualified immigrants who uncontrollably come in the country has drastically exacerbated all semantic poverty indicators in Hellas [9,10]. Their impact is also exacerbated by the rise in the population of the economically overpriced and non-productive local society or the country as a whole. The prevention of illnesses, therefore, of those who are considered healthy, but unemployed and poor immigrants or refugees has been covered by the scarce capitals which however concentrated on massive purchases of expensive biomedical products for examinations or preventive measures loading new high expenditures in a financially controlled- by a Memorandum- country since 2010. In other words, the Health sector has been the geo-political and geo-strategic weapon for Greece by the part of its enemies and even friends in the EU, with which it finally deprived from its national sovereignty, while on the other hand all of its assets will be under international control for 99 years since 2016 [9,10]!

2. PAPER CONTENT AND TECHNICAL REQUIREMENTS

This paper presents the concept of the long standing ergonomics methods that can be driven from Big Data, and succeed in providing insight into human performance in the field of real time financial risk analysis in medical prevention consisting a Cognitive Ergonomics (CE) modelling. Then a real time experimentation access reliability prediction, failure mode and effect analysis as well as identifies the critical parts of a surveillance system for financial risk analysis integrated with cognitive ergonomics in the human-system diseases prevention design driven from Big Data analytics for early detection of risks and for improved interventions and to prevent systematic destruction of the Balkan economies [14]. CE defined by the International Ergonomics Association "is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. [12]. Successful, ergonomic intervention in the area of cognitive tasks requires a thorough understanding not only of the demands of the work situation, but also of user strategies in performing cognitive tasks and of limitations in human cognition. Emphasis lies on how to design human-machine interfaces and cognitive artefacts so that human performance is sustained in work environments where information may be difficult to predict, multiple simultaneous goals may be in conflict, and performance may be time constrained [12]. Big Data are simply sets of data that are too large and complex to manipulate by standard methods. Integrated streaming analytics and Big Data are two technologies inexorably linked: The process is consisted of the identification of important streaming analytics to evaluate, and then streaming analytics [12,13,14]. On the other hand the Cloud computing is a powerful technology to perform massive-scale and complex computing on real time. It eliminates the need to maintain expensive computing hardware, dedicated space, and software. Massive growth in the scale of data or Big Data generated through cloud computing has been technologically established. Addressing Big Data is a challenging and time-demanding task that requires a large computational infrastructure such as hyper-computers [11,12,13]. The experimental hypothesis is therefore whether real time Big Data analytics and computing linked with Cloud technology for real time streaming performed with a mobile computational unit (realized by our experimental digital medical device Prometheus I pn 1008239 equipped with the special software for concrete financial computations) is comparable- in terms of feasibility and reliability- with the ideal modern hyper-computers for massive real time cost-effect analysis. The latter refers to the computation- on a weekly base by the users- of the expenses for preventive examinations of the total workforce of a country (i.e. The workforce of the peripheries of Hellas on 07.11.2017) [14,16]. On the basis of the provisional results for the whole country, 10,787,690 permanent residents were recorded in 2011, of which 5,303,690 were males (49,2%) and 5,484,000 were females (50,8%). The total work force was 3.727.633 of which the 2.214.053 were males (59.3%) and the 1.513.580 were females (40.7%) [18].

2.1. Designing for Human factors: The remote public health education

By experimental simulation, the ergonomic impact on remote macro and micro examinations and instant computation evaluated on a digital medical device Prometheus I (patent number (pn) 1008239, (http://www.livemedia.gr/video/171480) as the experimentation material in terms of the ergonomics of remote public health education. Simulating experimentation included Prometheus I (pn 1008239) digital device capabilities: Medical record process, Examinations results, Capture/ imaging, DICOM and PACS, Real-time tele-conference, Chat and whiteboard Application sharing, Tele-secretary facilities, Tele-Mentoring facilities, Telecommunication net Virtual Slide integration, Cloud and Big Data Analytics [15,16], taking into consideration that a modern Hyper-computer's equipped with accelerating accessories and new technologies is the perfect choice for integrated Big Data analytics and computing and CE (Feasibility=100%, Reliability=100%) [13,14,16,17]. The corresponding workforce in Hellas in 2011 was the target population for the real time Big Data analytics and computing [18].

2.2. Designing for Human factors: Pre-symptomatic group control: Health education, primary and secondary prevention of diseases

It is well known that in the control of asymptomatic individuals, the blood and the biochemical tests, the urine analysis and all other examinations should be performed when the healthy citizen belongs to a clinical category with an increased risk of developing important pathological conditions that can be detected based on pathological results of these tests. An example of instructions for controlling asymptomatic individuals comes from the Health Program of the University of the Ohio State of the USA. Therefore, no other examinations should be requested and, in particular for no substantial reason in healthy citizens [6] (Table 1). In this protocol the measurement of transaminases, alkaline phosphatase and bilirubin is important for the examination of liver function [6]. It is recommended to examine serum ferritin and iron. In pre-symptomatic testing, it is acceptable and useful to examine urine by simply examining general urine [6].

Table 1: The Ohio State Pre-symptomatic Cancer Prevention Protocol

Type of cancer	Examination	Indication
Cervical	Pap-test	Females>18y every year and sexually active girls every year
Prostate	Digit Examination	Males>=40y every year
Breast	Palpation by a specialist	Females 20-40y every three years, >40y every year
	Mammography	Females 35-39y once 40-49 every 1-2y >50y every year
Ovaries	U/S and Blood tests	Non-indicated
Large Intestine	Rectum Digit Examination	Males and Females >=40y every year
	Fecal Occult Blood	Males and females >=50y every year
	Sigmoidoscopy	Males and Females >=50y every 3-5years
Lung	Chest X-ray	Non-indicated

2.3. Designing for Human factors: CE integrated with Big Data

With regard to general health education and prevention with an emphasis on Cancer Prevention our technology and method consisted of the Week of Panhellenic Health Education and Prevention which addressed to a 1.000.000 public workers in N=500 central administrative points and their branches of all types of public working or national administrative divisions in Hellas from 20.02.2017 to 26.02.2017 (National Documentation Centre (*http://www.ekt.gr/el/events/all/20671)*.

2.4. Designing for Human factors: Real time Big-Data analytics

The medical process was based on the Ohio State Prevention Protocol in the US, with which we had first completed the remote, specialized, holistic and personalized health education in February 2017 for the whole work-force of the country while the cost of performing all the proposed preventive examinations was then calculated real time from the War Museum of Athens- which was the experimental point for our computations- on 7.11.2017 and based on the population, on the work-force sub-population of Greece in all regions- the so called Peripheries- according to the gender (males and females), the age (18 to 65 years of age) classifications and the EOPYY prices as counted in 2011. The real time Big Data financial analysis with the technology and method of the digital medical device Prometheus I (pn 1008239) completed with the real time computation of the annual total cost of the proposed examinations in each Periphery taking into consideration that the used digital medical device receipted instantly the total number of each participant prevention financial analysis oriented data from the Peripheries by using the Cloud technology to feed the mobile unit and use the digital data for real time computations (Figure 1.)**.**

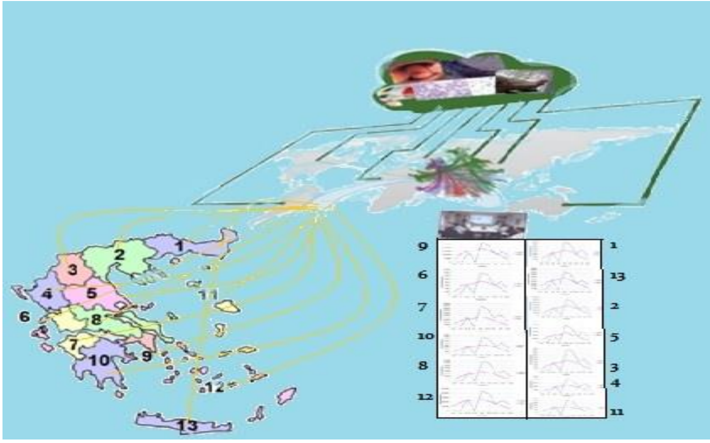

Figure 1: According to the experimental protocol the partners were allocated to 13 peripheries of Greece from which the preventive examinations performance and cost formed as structured Big Data and sent to the cloud from which the medical device Prometheus I (pn 1008239) accumulated the Big Data for real time computation of the financial indicators (total cost, cost paid by the citizens, cost paid by the state). The results depicted instantly in a table and in a graph for each Big Data cost analysis and for each periphery (*Periphery of: 7=Western Greece, 3=Western Macedonia, 11=the North Aegean, 10=Peloponnese, 9=Attica, 8=Central Greece, 6=Ionian Islands, 5=Thessaly, Eastern Region, 1=Macedonia and Thrace, 2=Central Macedonia, 4=Epirus, 12=the South Aegean, 13=Crete).

The experiment simulated the proposed prevention examination program completion and Big Data analytics for real time computation of expenditures of all Peripheries in Hellas on a weekly base. Experimental results analysis in a real time mode using the digital medical device Prometheus I (pn 1008239) showed high feasibility for the direct computational analysis of Big-data referring to the computation of the cost of the performed preventive examinations of the workforce of Hellas by periphery (Table 2.). On the other hand the accuracy of the computational analysis was really high given that a software for mathematical analysis had been incorporated in Prometheus I (pn 1008239) and calculated instantly the Big Data projected in the Cloud (Figure 1, Table 2.). The time for preparation of the digital data and their projection in the Cloud in a structured form on 07.11.2017 for real-time analysis and computation of the three type of costs) was about one hour. Correspondingly, the process for the final computations of all the costs of the preventive examinations of the workforce of each Periphery -according to the Ohio State Disease Prevention Protocol and using the digital medical Prometheus I (pn 1008239)- lasted for an additional half an hour (Figure 1.). The results showed that the computed costs are really high and need to lessen while the Hellenic State spends much more money for advertisement and for other supportive services in the field of Health Prevention than in the examinations themselves! The abovementioned computational analysis results can be used by the Peripheries and the Ministry of Health public services to intervene locally or nationally on time so as to correct several problems referring to the participation in the prevention program by the individuals of the workforce or to correct mistakes or destructive pricing policies of the biomedical products on a weekly base [19]. On the other hand they may be used as accurate and real time tools on a weekly base to make decisions about the biomedical technology products expenses and pricing for the benefit of the population and the state [19]. The main drawback of this experimental study is that the integration with Big-Data computational analysis on 07.11.2107 based on 2011 prices.

Table 2.: Cost of the Performed Preventive Examinations of the Workforce in the Peripheries of Hellas* as Computed Instantly on 07.11.2017

* Fig.1	Total cost (in Euros)	Cost paid by the individuals (in Euros)	Cost paid by the State (in Euros)
9.	198.507.587,33	27.291.534,46	171.216.052,87
6.	10.188.440,73	1.413.063,69	8.775.377,04
7.	27.839.454,15	3.898.490,72	23.940.963,43
10.	26.813.933,77	3.748.939,68	23.064.994,09
8.	23.443.674,07	3.281.953,68	20.161.720,39
12.	15.902.535,48	2.195.120,72	13.707.414,76
1.	25.396.707,68	3.535.431,16	21.861.276,52
13.	30.396.789,66	4.195.764,16	26.201.025,50
2.	83.829.563,66	11.640.358,33	72.189.205,33
5.	31.618.416,53	4.415.018,14	27.203.398,39
3.	11.737.444,32	1.646.304,47	10.091.139,85
4.	14.662.261,50	2.044.019,28	12.618.242,22
11.	8.624.122,03	1.199.365,30	7.424.756,73

*Periphery of: 7=Western Greece, 3=Western Macedonia, 11=the North Aegean, 10=Peloponnese, 9=Attica, 8=Central Greece, 6=Ionian Islands, 5=Thessaly, Eastern Region, 1=Macedonia and Thrace, 2=Central Macedonia, 4=Epirus, 12=the South Aegean, 13=Crete.

However, our feasibility and reliability comparative analysis referred mainly to the evaluation of our mobile unit technology and the method. Another drawback was that there was non-parallel comparative process with a Hyper-computer. However the reliability and accuracy of a modern Hyper-computer considered by definition as ideal.

3. CONCLUSION

Thus a frequent and instant computation of crucial financial indexes which reflect the real time risk analysis and decision making on a weekly base using mobile computational units not only for Hellas but for all countries in the Balkans seems to be feasible and reliable. The present and the future of finance in general is digital and a digital financial business must be continuously aware of real-time conditions to predict and act on opportunity and threat in the moment. The so called ‘’streaming analytics’’ power a new generation of algorithmic, predictive, and prescriptive systems, are driving the digital financial services evolution and proving a source for disruptive innovation. Streaming analytics are tools that make it easy inject analytics into streaming data with temporal computations of math on windows of data and the ability to spot patterns among flowing points of data. But today, an even more common use for streaming analytics is for continuous computing: continuous risk management; continuous customer engagement; continuous client awareness; continuous market monitoring. These now-common use cases aren’t so much about real-time automated action, they are about a continuous, real-time,360-degree view of the financial ecosystem, and the ability to act on real-time conditions, often by humans using mobile computational units, not only by automated hyper-computers action. In fact modern technological integrations such as the intersection of knowledge, CE methods and Big Data analytics create an important new framework for driving new insights and continually and on real time compute the frequency of preventive examinations performed on a national level weekly and at the same time the expenditures for biomedical products in the Health sector for making evidenced decisions. As analyzed the lack of the latter may cause even a geopolitical destruction to the level of a loss even of the sovereignty of a state.

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COGNITIVE ERGONOMICS AND BIG DATA ANALYTICS FOR THE REMOTE EVALUATION OF THE GRAFTS AND FOR REAL TIME FINANCIAL RISK ANALYSIS IN ORGAN TRANSPLANTATION TO PROTECT THE BALKAN ECONOMIES

C. S. Mammas, A. S.Mamma
State Scholarship Foundation, Fellowships of Excellence for Postgraduate Studies in Greece-Siemens Program 2014-16, Athens, Hellas, csmammas@med.uoa.gr

Abstract

Big data collected on a real time mode from ESOT's records on 07.11.2017 have the potential to compute crucial risks, sourcing from the damaged organs interrelated with the human-system design of the procurement phase of Organ Transplantation (OT). In a prospective real time experimentation using Big Data analytics, computed the cost of damaged organs in OT in Europe and compared the reliability of hyper-computer vs human-computer based computational analysis for 189.721 transplants from 2011 to 2016, showing: 1.High usability and reliability either by hyper-computer or by human-computer based computational analysis (https://prbite.wordpress.com/) for early detection of risks sourced from damaged organs (Accuracy for liver, renal, pancreas, uterus, heart and lung grafts ranged from:90.9%-97.6%),2.That a surveillance system integrated with cognitive ergonomics in the remote evaluation of the grafts for a continuous financial risk analysis :a.Can be reliably driven from Big Data, b.Drive to evidenced interventions and work training, c.Improve the quality of life and d.Save the fragile Balkan economies.

Keywords: *Organ Transplantation, Remote Evaluation of the Grafts and Decision Making, Cognitive Ergonomics, Big Data analytics, Financial Risk Analysis*

1. INTRODUCTION

It has been commonplace in the Hellenic society and in all the western countries that medicine has come to fruition rather than science. In its real depth, modern medicine is more a market-place- in which the purpose of the economic profit is more important than the pursuit of the benefit of the patient or the need for patient-centered relations [1,2]. Indeed, the health sector has become very economical world-wide. Money and complexity have come into play. The Health sector is now depends purely on economic and legal criteria and this leads to a new trend that of financially controlled health. In this new market-place, hospitals have given up their ever-high priority for the care of the patients - not to talk about the care of the poor patients - and have turned into speculative businesses that are more interested in consuming services and biomedical products [3]. However, the most decisive fact even for powerful states and for supranational entities is that the overall health costs, have been rising at rates higher than inflation over the past two decades. If these rates continued at the time, according to the renowned economist at

Princeton University in the US, Uwe Reinhardt, after about 80 years the overall health costs would approach the gross national product. In fact, every-day problems in medicine such as how much a patient will stay in the ICU, whether to give a graft to one or to another patient, whether or not to undergo a more or less costly oncologic treatment or intervention, ceased to be a purely medical subject and have become very economical. This is because the biomedical technology costs a lot and so does the health [4]. Indeed, as Pellegrino and Thomas pointed out, "when economics and business are the ones that guide the professions, then the interest and the functioning of the market are the only incentives for professional activity". However, transforming the health sector into pure business is not yet another form of change of the form of medicine, but an unprecedented change of its identity defined as a mutation in the health sector even since 1998 [3]. On the other hand the most decisive factor in the alteration of the so called classical medicine is the unprecedented growth and the global dominance of biomedical technology industry [2,3,4,5]. In fact, the professor and academician D.Trichopoulos had emphasized since the early 80s the significant of advances in the field of bio-medical technology that have changed the medical sector after the First World War and with greater certainty after the Second World War, bringing about the corresponding great advances in the health sector. However he concluded that the major diseases of modern pathology (such as cancer, chronic infections, heart disease, cerebral vascular disease, etc.), even since the 80s in fact have remained uncured in all countries. This disproportionate ineffectiveness in the treatment of the aforementioned diseases in relation to the abovementioned advanced biomedical technology described as "Health Crisis"[6,7]. The problems of this new post-World War II Health Crisis characterized by: 1.Health inefficiency in both the well-known pathology and the newly-formed diseases (such as AIDS, new epidemics, etc.). 2. The progressively decreasing performance of the rapidly rising costs in the Health sector, 3. An exacerbated crisis of trust in the doctors' relations with the community, 4. The pursuit of the economic health, and ultimately in the 70s, 5.The prevalence of business in the Health sector [4,6,8]. In fact, the symptoms of the " Health Crisis " have been marked in the most developed countries in the world, since 1970 [6]. Accordingly, the newly-formed situation dealt with by developing robust biomedical technology which eventually remained stagnant due to the ineffectiveness, while the main phenomenon that clearly documented was the dramatic increase in health expenditure and, on the other hand, a decreasing return of the capitals invested in the Health Sector for the development of bio-medical technology [6]. However, this novel and threatening phenomenon, which was dangerous for even the large economies of big States in the world and further analysis to treat its standard causes has been a priority: i.e.The prevalence of bio-medical technology products and the increase in the financial costs for their purchase without "cost-benefit" analyses and without productivity cost reductions, the low levels of education and training of the physicians and especially the unprecedented increase in corruption in medicine, the new-emerging diseases due to refugee crises and to the increased migration rates from war places and/or from poor or developing countries) [3,4,5,6,8,9]. These countries face even financial disasters with all their consequences (over-lending, inability to repay their financial obligations, etc.) that ultimately end up in the loss of their national sovereignty. This trend concerns Greece as early as the mid-2000-10, when more than 5 billion euros were consumed each year (an astronomical amount for Greece and its citizens) in the Health sector for only the pharmaceutical expenditure, with zero impact at the same time on the health map in the fields of prevention, cancer, transplantation and trauma, but with a maximum result in the massive, indecisive and uncontrolled purchases of biomedical products (Siemens scandal in Greece in the period of 2000-10) and (Novartis-Roche scandal in 2005-18) [3.4.8]. At the same time migration of the Hellenes young people has escaped from the country as they do the companies to confront the tough consequences of the financial Memorandum of Greece since 2010, decreasing the population and weakening its work-force, and its competitiveness [9]. Their impact is also exacerbated by the rise in the population of the economically overpriced and non-productive local society or the country as a whole. In other words, the Health sector has been the geo-political and geo-strategic weapon for Greece by the part of its enemies and even friends in the EU, with which it finally deprived from its national sovereignty, while on the other hand all its assets will be under international control for 99 years [9,10]! Traditionally, Organ Transplantation (OT) focuses on the technical knowledge, skills and abilities to complete specific tasks as they relate to specialty responsibilities**.** Over the past seven years the major data that have contributed to its growth are related to the Professor's P. Friend lecture according to which the 8% of the liver (LG), the 14% of the pancreas (PG), the 11% of the renal (RG), and the 10% of the lung grafts (LnG) (the same percentage is expected for the Heart (HG)) arrived at the recipient hospitals in the UK in 2010 and after benching considered damaged, improper for transplantation or needed an intervention [11]. The percentages considered high and considering the high cost of the implicated biomedical technology products and the surgical services in all phases of OT it is expected to have tremendous healthcare, socio-economic, working and social consequences which are expected to multiply in less organized and technologically powerless countries which however allow the high cost transplant therapies. As an example we refer to the reference of the President of the Hellenic National Organization of Transplantation (HNOT) in 2017 according to which there is a total amount of 35 million euros debt of the HNOT (and consequently of the Hellenic state) to other European National Transplant Organizations for transplant services for about 300 patients from 2008 to 2016. Although the amount is analogically extremely high for Hellas for just the surgical services from other countries it is expected to multiply if we take into consideration the average cost of the total expenses paid for each transplantation (Heart Only, Single Lung, Double Lung, Heart-Lung, Liver, Kidney, Pancreas) including immunosuppression therapy in US Dollars in 2011 prices (Table 1.) the abovementioned 300 patients are expected to have cost to the Hellenic economy from 2008 to 2016 in average 161 million and 298 thousand Dollars! The amount seems tremendously high for Hellas if we take into consideration that in the same period the rate of transplantations decreased dramatically in the country because of the financial crisis since 2010. What is the solution to this problem and what other countries in Balkans can do to avoid such perspectives. What is the technology of choice to protect the states from these high risk socioeconomic environments? Big Data analytics and cloud computing seems to be the technology of choice to support the fragile states with evidences on the right time that will drive to the right decisions and allow successful interventions not only in the clinical system of OT for the remote evaluation of the grafts and decision making, but also in the management of biomedical technology implicated and in it with instant cost-effect analysis given that the high cost of OT threatens even powerful states with a financial bankrupt and the fragile Balkan ones with a loss of their sovereignty, as happened in Greece since 2010 while since 2016 its assets is already under international control for 99 years [9,10,12]!

Table 1: Estimated U.S. Average 2011 Billed Charges Per Transplant (in Dollars)

Transplant	30 Days Pre-transplant	Procure-ment	Hospital Transplant Admission	Physician During Transplant	180 Days Post-transplant Admission	Immuno-suppressants	Total
Heart Only	$47,200	$80,400	$634,300	$67,700	$137,800	$30,300	$997,700
Single Lung	$10,300	$73,100	$302,900	$33,500	$117,700	$23,700	$561,200
Liver	$25,400	$71,000	$316,900	$46,600	$93,900	$23,300	$577,100
Kidney	$17,000	$67,200	$91,200	$18,500	$50,800	$18,200	$262,900
Pancreas	$17,000	$65,000	$108,900	$17,800	$61,400	$19,300	$289,400

2. PAPER CONTENT AND TECHNICAL REQUIREMENTS

The concept of Big Data analysis and computing for optimizing quality in OT has been examined in several uses and challenges and the results have shown how OT is uniquely suited to the pursue of Big Data analysis and computing. This is because in OT there are waiting lists, allocation of organs processes, organ offers, healthy organs which can be transplanted, damaged organs that have to be discarded etc., which all can be data elements for Big Data analysis and computing. Then there are a lot of data that can be studied. Studying those data in the field is semantic because in OT more than other clinical field there are scared allocated resources and optimal decisions have to be made. Consequently, a lot of data analysis can inform those decisions and inform the clinical practice as well [12].

This paper presents the concept of the long standing ergonomics methods that can be driven from Big Data, and succeed in providing insight into human performance in the field of real time financial risk analysis in OT and mainly in the procurement phase and the damaged organs consisting a Cognitive Ergonomics (CE) modelling [12,13]. Then a real time experimentation access reliability prediction, failure mode and effect analysis as well as identifies the critical parts of a surveillance system for financial risk analysis integrated with CE in the human-system remote evaluation of the grafts and real time analytics and computing of the costs in OT design driven from Big Data analytics for early detection of financial risks and for improved interventions and to prevent systematic damages to the fragile Balkan economies [14]. The CE defined by the International Ergonomics Association "is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. [13].

Big Data are simply sets of data that are too large and complex to manipulate by standard methods. Integrated streaming analytics and Big Data are two technologies inexorably linked: The process is consisted of the identification of important streaming analytics to evaluate, and then streaming analytics [14.15,16].

On the other hand the Cloud computing is a powerful technology to perform massive-scale and complex computing on real time. It eliminates the need to maintain expensive computing hardware, dedicated space, and software. Massive growth in the scale of data or Big Data generated through cloud computing has been technologically established.

Addressing Big Data is a challenging and time-demanding task that requires a large computational infrastructure such as hyper-computers [12,13,14].
The experimental hypothesis is therefore whether real time Big Data analytics and computing linked with Cloud technology for real time remote evaluation of the grafts and decision making can be integrated with streaming performed with a mobile computational unit (realized by our experimental digital medical device Prometheus (pn 2003016), equipped with the special software for concrete financial computations) is comparable- in terms of feasibility and reliability- with the ideal modern hyper-computers for massive real time cost-effect analysis. The latter refers to the real time computation- on a weekly base as proposed - of the cost of the procurement phase for 189.721 transplants from 2011 to 2016 in the European countries integrated with the real time computation of the rate of damaged organs as performed on 07.11.2017 [11,17,18].

2.1. Designing for Human factors: The technology for remote evaluation of the grafts in OT

Experimentation included a:The development of an Experimental type of Prometheus (pn 2003016), the Exp.-TS (Table 1**.)** [18,19]**,** b: TC among DH, National Transplant Organization (NTO) and RH based coordinators and completion and transference of the medical record of the deceased donor on the electronic space of Prometheus (pn 2003016), c: Prometheus (pn 2003016) based retrospective and Real Time Projection (RTP) and applying tele-communications (TC) in the Coordination Process (CP), Tele-radiology (TRE),Tele-pathology (TPE), Tele-cytology (TCE), Tele-microbiology (TME), Tele-genetic biology TGBE) for the remote evaluation of the grafts between the Donor Hospital (DH) and the Recipient Hospital (RH) on the clinical trial on 28.06.2016 assessed the diagnostic accuracy of injury-trauma, infection or cancer of the grafts [20,21]**.**
Simulating experimentation included Prometheus (pn 2003016) digital device capabilities: Medical record process, Examinations results, Capture/ imaging, DICOM and PACS, Real-time tele-conference, Chat and whiteboard Application sharing, Tele-secretary facilities, Tele-Mentoring facilities, Telecommunication net Virtual Slide integration, Cloud and Big Data Analytics [18], taking into consideration that a modern Hyper-computer's equipped with accelerating accessories and new technologies is the perfect choice for integrated Big Data analytics and computing and CE (Feasibility=100%, Reliability=100%) [18,20,21]. The corresponding transplantations in Europe from 2011 to 2016 was the material for real time Big Data analytics and computing using Prometheus (pn 2003016) on 17.11.2017 [22,23,24,25,26,27].

2.2.Designing for Human factors: CE integrated with Big Data for the remote evaluation of the grafts and decision making in OT as it had been performed on 28.06.2016

With regard to the clinical method as well as the process and ergonomics and the clinical standards of the remote, specialized, multidisciplinary and personalized evaluation of the Grafts and decision making by using the digital medical device Prometheus (pn 2003016) this was applied in the clinical trial between the Aretaieion University Hospital of Athens and the Hippocrateion University Hospital of Thessaloniki on 28.06.2016 (IKY Excellence -SIEMENS program).

In this trial the team members and individuals registered in the following site www.prbite.wordpress.com and actively implemented the best practices, high technology and geographic and timing strategies for pre- and post-grafting remote evaluation of the grafts and decision support and making, to reduce the damaged and diseased organs and improve outcomes in Liver (LT), Pancreas (PT), Renal (RT), Heart (HT), Lung (LnT) and UT transplant by pre-transplant operative planning. In fact the integrated TC, CP, TRE, TPE, TCE, TME and TGBE of solid abdominal and thoracic organs i.e. PG, LG, RG, HG, LnG and UG for minimization of the damaged organs in OT and for pre- grafting and/or pre-transplant planning has shown high sensitivity, specificity and accuracy (ranging from 90% to 98%) in the remote diagnosis of infectious, inflammatory, neoplastic lesions.

The results smoothed the path for initiating the clinical and training standards for the real time Big Data analytics and computing of clinical and financial indexes referring to the quality of OT with a priority to the rate of damaged organs and their cost for further decision making and on time interventions [21,28].

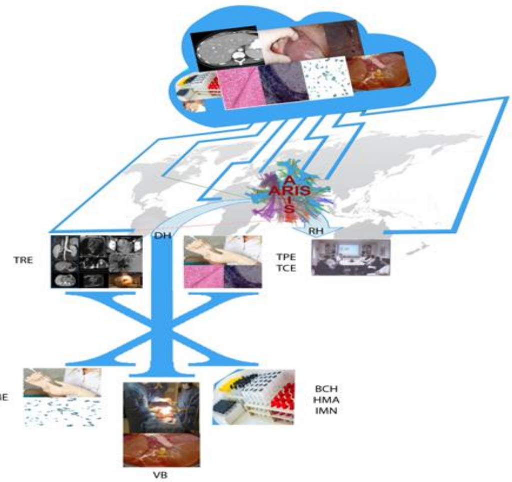

Figure 1. According to the simulating experimental protocol for the clinical remote evaluation of the graft as applied on 28.06.2016 the transplant coordinators, the grafting and transplant surgeons and the specialists doctors divided in two main experimental groups which allocated in the Donor Hospital (DH) (Aretaieion University Hospital of Athens) and in the Recipient Hospital (RH) (Hippocrateion University Hospital of Thessaloniki) while five additional points referred to the cooperated departments where specialists cooperated prospectively or retrospectively for remote diagnostics and consultation (**Point 1**=Aretaieion University Hospital of Athens, Department of Pathology as DH, **Point 2**=Hippocrateion University Hospital of Thessaloniki as RH, Department of Immunology for CP, **Point 3**=Medical School of Athens, Department of Pathology for TPE, **Point 4**=Eugenideion University Hospital of Athens, Department of Radiology for TRE, **Point 5**=Hippocrateion University Hospital of Thessaloniki, Department of Microbiology for TME, **Point 6=**A Department of Cardiology in the RH, **Point 7**=A Department of Cytology simulated the department of cytology in the RH for TCE.

2.3. Designing for Human factors: Real time Big-Data analytics and computing of the OT cases and expenses focusing on the damaged organs computation and cost analysis as performed on 07.11.2017

The experimental process on 07.11.2017 based on the GODT publications from 2011 to 2016. The real time Big Data financial analysis with the technology and method of the digital medical device Prometheus (pn 2003016) completed with the real time computation of the optimum damaged organs rate according to the estimation indexes in Britain in 2010 and their costs taking into consideration that the used digital medical device received on real time the total number of transplantation that would take place in a form of structured data from the National Transplant Organizations in Europe and/or from the ESOT using the Cloud technology. The damaged organs and the total amount losses because of them also computed on a real time Big Data analytics simulating the real process from the War Museum of Athens on 07.11.2017 (Figure 2.)**.** The experiment simulated the proposed prevention examination program completion and Big Data analytics for real time computation of expenditures of all Peripheries in Hellas on a weekly base. Experimental results analysis in a real time mode using the digital medical device Prometheus (pn 2003016) showed high feasibility for the direct computational analysis of Big-data referring to the cost of transplantation per organ, to the estimation and comparison of the referred damaged organs and to their cost (Tables 2.,3.). On the other hand the accuracy of the computational analysis was really high given that a software for mathematical analysis had been incorporated in Prometheus (pn 2003016) and calculated instantly the Big Data projected in the Cloud (Figure 1, Tables 2.,3.). The time for preparation of the digital data and their projection in the Cloud in a structured form on 07.11.2017 for real-time analysis and computation of the two type of costs was less than half an hour.

Correspondingly, the process for the final computations of the costs of interest in this particular experimentation (Total cost per OT and losses because of the damaged organs)- using the digital medical Prometheus (pn 2003016)- lasted for an additional half an hour (Figure 2.,Tables 2.,3.).The abovementioned computational analysis results can be used by the Ministry of Health services or the National Transplant Organizations to intervene locally or nationally on time so as to correct several problems referring to the rate of damaged organs in OT, to organ donation and to the cost of OT in the country or to correct mistakes or destructive pricing policies of the biomedical products on time [9,10,11,18,28].

On the other hand they may be used as accurate and real time tools on a weekly base to make decisions about the biomedical technology products in OT expenses and pricing for the benefit of the population and the state [1,3,11]. The main drawback of this experimental study is that integration Big-Data computational analysis on 07.11.2107 based on the 2011 prices in US Dollars. However, our feasibility and reliability comparative analysis referred mainly to the evaluation of our mobile unit technology and the method. Another drawback was that there was non-parallel comparative process with a Hyper-computer. However the reliability and accuracy of a modern Hyper-computer considered by definition as the ideal [12,14].

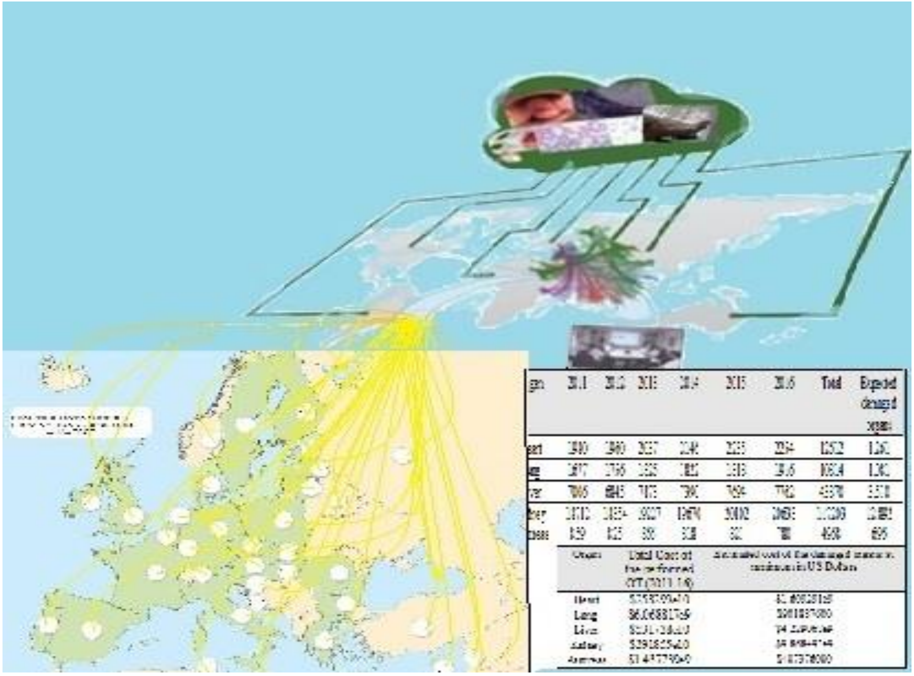

Figure 2: According to the experimental protocol the partners were allocated to all European and other cooperated countries -from which the transplantations number of cases and the damaged organs number of cases formed as structured Big Data would be sent to the Cloud from which the medical device Prometheus user based on the war museum of Athens on 07.11.2017 accumulated them for real time Big Data analytics and computation of the financial indicators (total cost and amount losses because of the damaged organs postponement of the transplantation process). The results depicted instantly on tables and graphs for each year, and for each Big Data cost analytics for each graft type (Hear, Lung, Liver, Pancreas, Kidneys).

Table 2.Actual organ donations performed OT in the European Union from 2011 to 2016 as accumulated and computed by real time Big Data analytics on 07.11.2017

Organ	2011	2012	2013	2014	2015	2016	Total	Expected damaged organs
Heart	1980	1960	2037	2146	2235	2254	12612	1.261
Lung	1677	1756	1825	1822	1818	1916	10814	1.081
Liver	7006	6845	7173	7390	7694	7762	43870	3.510
Kidney	18712	18854	19227	19670	20102	20638	17203	12.892
Pancreas	859	825	865	818	821	780	4968	696

Source: GODT 2011-16.

Table 3.: Total expenditures in OT- and losses in case of damaged organs in Dollars in Europe from 2011-16 as computed by real time Big Data analytics on 07.11.2017

Organ	Total Cost of the performed OT (2011-16)	Estimated cost of the damaged organs in the performed OT (2011-16) at a minimum in US Dollars
Heart	$258299e10	$1.609291e9
Lung	$6.068817e9	$901887600
Liver	$531738e10	$4.229068e9
Kidney	$391855e10	$9.868493e9
Pancreas	$1.437739e9	$407376000

3. CONCLUSION

The reliability of Prometheus (pn 2003016) digital mobile unit based on computational analysis for 189.721 transplants from 2011 to 2016, showed: 1.High usability and reliability for early detection of risks sourced from damaged organs (Accuracy for liver, renal, pancreas, uterus, heart and lung grafts ranged from:90.9%-97.6%), 2.That a surveillance system integrated with cognitive ergonomics in the remote evaluation of the grafts for a continuous financial risk analysis :a.Can be reliably driven from Big Data, b.Drive to evidenced interventions and work training, c.Improve the quality of life and d. Save the fragile Balkan economies from tremendously high expenses in the OT sector of medicine.

Thus a frequent and instant computation of crucial financial indexes which reflect the real time risk analysis and decision making on a weekly base using mobile computational units not only for Europe but for all countries in the Balkans seems to be feasible and reliable. In fact modern technological integrations such as the intersection of knowledge, CE methods and Big Data analytics create an important new framework for driving new insights and continually and on real time refer the frequency of transplantations cases and the number of damaged organs in OT performed on a national or a Balkan and European level weekly and at the same time compute the concurrent expenditures for making evidenced decisions.

As analyzed the amounts spent or wasted are tremendously high and the lack of evidenced decision in OT may cause even a geopolitical destruction to the level of a loss even of the sovereignty of a state. Also a Balkan Organization of Transplantation for a peripheral Organ Transplantation Coordination would be equally substantial.

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INTERIOR NOISE ANALYSIS OF TRANSPORT HELICOPTER Mi-8 MTV-1

M. Maradin[1], D. Jerinić[1], T. Bucak[2]
[1]Ministry of Defense, Croatian Air Force, King Petar Krešimir IV Square, 10000 Zagreb, Republic of Croatia,mmaradeen@gmail.com, dominik.jerinic01@gmail.com
[2]University of Zagreb, Faculty of Transport and Traffic Sciences, Vukelićeva 4, 10000 Zagreb, Republic of Croatia, tbucak@fpz.hr

Abstract

This paper contains an overview and analysis of transport helicopter Mi-8 MTV-1interior noise parameters measured both on ground and in-flight during typical helicopter flight regimes: engine start-up, taxing, hovering, transition, climbing, external loading, minimum and maximum airspeed, single engine operation, steady level flight, descending and approaching. The research aims to estimate the ergonomic aspect of noise impact on transport helicopter pilot's hearing. Assessed data show cabin noise levels mostly above recommended under all flight phases.

Keywords*:* *helicopter interior noise, Mi-8*

1. INTRODUCTION

Interior (a.k.a. cockpit or cabin) noise is one of the main factors that affects pilot/crew attention, situational awareness and judgment possibilities [1]. For a longer period, noise can lead to hearing loss which affects medical criteria and endangers flight safety. During the years of personal flying experience on Mi-8 helicopter while undergoing all phases of flight and engine regimes, various levels of noise impact has been observed. The following experiment replicates in situ the segments of almost all possible flight operations in normal conditions, along with equivalent cabin noise footprints captured and presented.

2. AIRCRAFT NOISE SOURCES

Aircraft, as a man-made machine, has several noise sources. The main sources are aircraft engines and airstream along the aircraft fuselage. Due to aircraft operations, it can be divided into take-off and landing noise, hovering noise and ground or maintenance noise. During all helicopter operations, the engine regime is constant and set to 100% of maximum power. The difference in noise level is created by main and tail rotor blade angle ("pitch") changing [2]. Figure 1 shows noise footprint of Airbus H145 helicopter presenting spatial differences in noise levels during flight. It is important to mention that

Airbus H145 helicopter has the opposite main rotor rotation direction comparing to Mi-8 MTV-1.

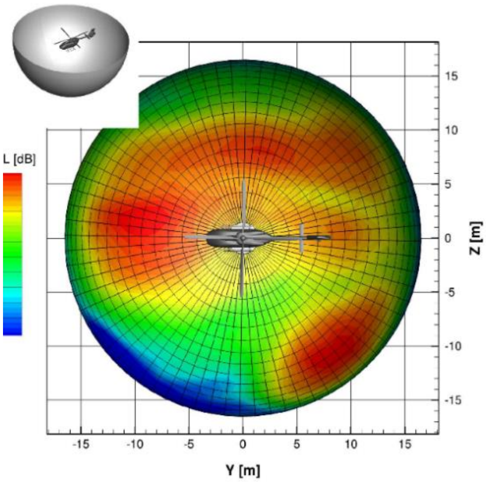

Figure 1: Helicopter noise spreading into environment
Source: [3]

3. MEASUREMENT OF INTERIOR NOISE OF TRANSPORT HELICOPTER Mi-8 MTV-1

3.1. Characteristics of transport helicopter Mi-8 MTV-1

Mi-8 MTV-1 is a Russian transport helicopter made for passenger and cargo transport, emergency medical transport, search and rescue missions, firefighting and special operations on difficult terrain access. It has one main five-blade rotor and tail three-blade rotor. Some tactical-operational characteristics of Mi-8 MTV-1 transport helicopter are presented in Table 1.

Table 1: Technical-operational characteristics of Mi-8 MTV-1 transport helicopter

Description	Value
Crew	two pilots + flight technician
Engine	2 x TV3-117VM
Engine power	1470 kW (2000 HP) each
Basic empty mass	7142 kg
Nominal take-off mass	11100 kg
Maximum take-off mass	13000 kg
Maximum cargo mass inside cargo cabin	4000 kg
Maximum external load mass	3000 kg
Maximum LPG lift mass	150 kg
Length without rotors	18,424 m

Length with rotors	25,352 m
Height without tail rotor running	4,756 m
Height with tail rotor running	5,521 m
Main rotor diameter	21,294 m
Tail rotor diameter	3,908 m
Main rotor area	356,1 m^2
Fuselage width	2,5 m
Total fuel with additional fuel tanks	3550 l
Cruising speed	220-240 km/h
Maximum speed	250 km/h
Minimum horizontal speed	60 km/h
Maximum celling	6000 m

Mi-8 MTV-1 transport helicopter of the Croatian Air Force is presented on Figure 2.

Figure 2: Mi-8 MTV-1 transport helicopter of the Croatian Air Force
Source: [4]

3.2. Measurement method and equipment

Interior noise measurement of Mi-8 MTV-1 transport helicopter was performed in the vicinity of Split Intl. Airport. The measurement was performed with Class 1 Sound Analyzer placed between pilot and copilot at the head level due to ISO 5129 standard. Engine regime was set to 100% of power. During the measurement, conducted flight regimes were: start-up, taxing, hovering, transition, climbing, external load flight, minimum/maximum speed, single engine flight, steady level flight, descending and approaching.

3.3. The results and analysis

Following tables and figures present LA_{eq} noise values expressed in dBA. Table 2 and Figure 3 show interior noise values assessed during abovementioned flight regimes.

Table 2: Equivalent noise levels of Mi-8 MTV-1 transport helicopter

Regime number	Flight regimes	LAeq (dBA)
1	AI-9 APU start-up	84,8
2	1st engine start-up	94,7
3	2nd engine start-up	94,1
4	Right correction, all equipment running	98,6
5	Taxing, concrete	92,6
6	Hovering, concrete, all openings opened	93,1
7	Hovering, concrete, all openings closed	90,2
8	Hovering, grass, all openings opened	92
9	Hovering, water, all openings opened	93
10	Transition, water, all openings opened	90
11	Climbing, IAS=160 km/h, ROC=5m/s	89,7
12	Hovering, two tones external load	95
13	Minimum speed, IAS=70 km/h	91
14	Maximum speed, IAS=250 km/h	97,7
15	Single engine flight, IAS=120 km/h	89,9
16	Steady level flight, IAS=190 km/h	91,5
17	Steady level flight, IAS=210 km/h	94,5
18	Steady level flight, IAS=230 km/h	93,9
19	Descending, IAS=160 km/h, ROD=5 m/s	91,2
20	Approach, grass, all openings opened	92,2

The highest equivalent noise level of 98,6 dBA is measured while on the ground during right correction and with all equipment running. During the flight, the highest equivalent noise level of 97,7 dBA was measured at maximum airspeed. As expected, this flight regime happened to be the noisiest due to maximum main rotor load.

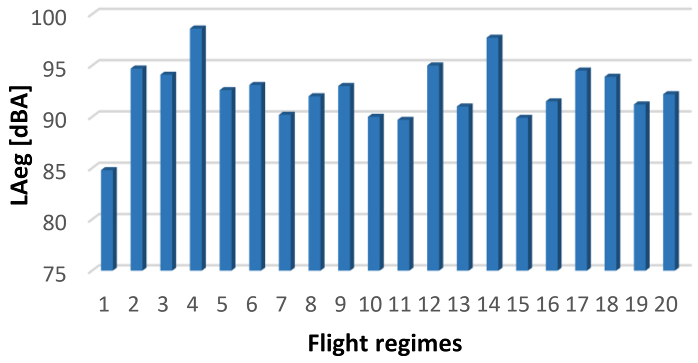

Figure 3: Mi-8 MTV-1 interior noise levels during different flight regimes

Table 3 and Figure 4 show maximum and minimum interior noise values measured, during same flight regimes.

Table 3: Maximum and minimum noise values of Mi-8 MTV-1 transport helicopter

Regime number	Flight regimes	LA_{max} (dBA)	LA_{min} (dBA)
1	AI-9 APU start-up	87,2	67,5
2	1st engine start-up	95,8	92,8
3	2nd engine start-up	95,3	93,3
4	Right correction, all equipment running	99,2	97,9
5	Taxing, concrete	94,7	89,7
6	Hovering, concrete, all openings opened	94,9	91,7
7	Hovering, concrete, all openings closed	91,8	88,6
8	Hovering, grass, all openings opened	93,2	90,5
9	Hovering, water, all openings opened	94,3	91,5
10	Transition, water, all openings opened	92,7	87,1
11	Climbing, IAS=160 km/h, ROC=5m/s	91,1	88,3
12	Hovering, two tones external load	96,3	93,5
13	Minimum speed, IAS=70 km/h	92,7	89,8
14	Maximum speed, IAS=250 km/h	98,9	96,5
15	One engine flight, IAS=120 km/h	91,8	88,2
16	Steady level flight, IAS=190 km/h	93,2	90,6
17	Steady level flight, IAS=210 km/h	95,3	93,6
18	Steady level flight, IAS=230 km/h	94,6	93,2
19	Descending, IAS=160 km/h, ROD=5 m/s	94,7	89,6
20	Approach, grass, all openings opened	94,8	90,5

The highest maximum noise level, on the ground, was measured during right correction and with all equipment running. During the flight, maximum noise level of 98,9 dBA was measured at maximum airspeed.

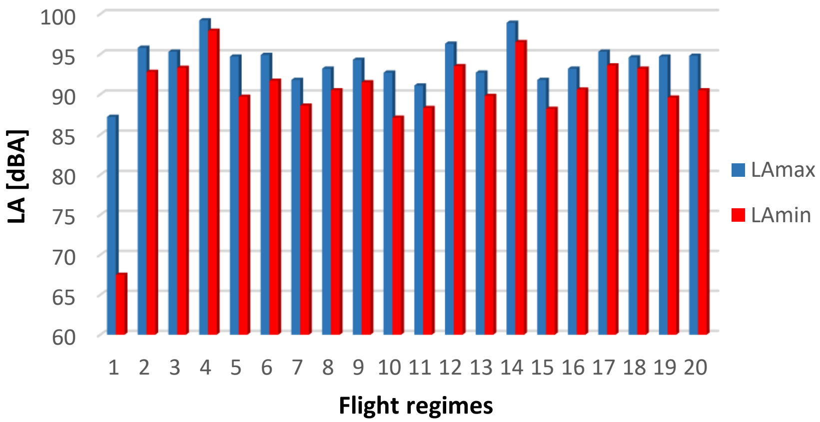

Figure 4: Maximum and minimum noise levels during different flight regimes

4. CONCLUSION

Helicopters (i.e. rotary-wing aircraft) have significant differences in noise source etiology in comparing to fixed-wing aircraft. For instance, noise levels do not primarily depend on engine power settings as in fixed-wing aircraft because the engine power is set to maximum during all operations. Changing the main and tail rotor blade angle, according to different flight regimes, makes the main difference, which is confirmed by noise data presented in this study. It has been proven that high noise levels affect pilots/crew hearing which leads to decreased concentration and situational awareness. Recommended maximum noise level is 90 dBA which is also dependent by the exposure time, according to OSHA/NIOSH health standards. Certain helicopter flight operations demand doors opened, making noise protection even more complex. Minimum noise level measured during flight was 87,1 dBA which is close to maximum recommended noise level for 8-hour duty shift. However, maximum noise level of 98,9 dBA measured during maximum airspeed is well over recommended levels, endangers human hearing and drastically approaches daily noise exposure limits. To assess time-dependent noise (i.e. noise dose) values, further measurements during longer period of flight are scheduled in the future.

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GENERAL AND ERGONOMIC ADVANTAGES OF GLASS COCKPIT AIRCRAFT USED FOR PILOT TRAINING

Ž. Marušić, D. Bartulović, L. Kezele, D. Sumpor
Faculty of Transport and Traffic Sciences, University of Zagreb, Zagreb, CROATIA,
zmarusic@fpz.hr

Abstract

Ergonomics studies the efficiency of persons in their working environment and deals with human-machine system design issues. Nowadays, ergonomics takes the human features such as capabilities, limitations, and needs into consideration to facilitate and optimize everyday tasks of aviation personnel. Influence of ergonomics in aviation safety is large. A glass cockpit is an aircraft cockpit that has digital displays on LCD screens as opposed to traditional analogue dials or gauges. Newer systems are more automated, more precise and the integration of controls is better than in traditional analogue systems, therefore number of human errors during flight simulations can be reduced, as well as a level of respondents´ performance can be increased. The accuracy and dependability of the newer systems ensure reduced pilot fatigue, resulting in safer flying for crew and passengers. The paper outlines general and ergonomic characteristics and advantages of glass cockpit aircraft used for pilot training.

Keywords*:* *ergonomics, advantages, glass cockpit, aircraft, pilot training*

1. INTRODUCTION

Ergonomics can be defined as "the study of the efficiency of persons in their working environment". Occasionally, the term ergonomics is used strictly to refer to the study of human-machine system design issues [1].
Application of ergonomics is versatile, and it has been present even in an elementary way since the beginning of civilization.
The focus of ergonomics, in the early days, was on advancement of some general principles to manage the design of flight deck displays and controls. This had later expanded into the experimental analysis of the design and layout of equipment, in close association with the analysis of the demands and workload that the equipment and tasks imposed upon the human operator.
Nowadays, ergonomics takes the human features such as capabilities, limitations, and needs into consideration.
Influence of ergonomics in aviation safety is large. The paper outlines general and ergonomic characteristics and advantages of glass cockpit aircraft used for pilot training.

2. GENERAL AND ERGONOMIC ADVANTAGES OF GLASS COCKPIT AIRCRAFT USED FOR PILOT TRAINING

The person-machine system is shown in Figure 1. The machine components are displayed on the right. Displays (e.g. visual and auditory) inform the human about the status of the internal system or about conditions external to the system, while controls allow the human to effect changes in the system status [1]. The human component of the system is shown on the left side of Figure 1. Information displayed must be perceived and processed by the human, and then conscious decisions may be made. In order to affect control settings, mechanical response may be sent. The line described in Figure 1 dividing the machine and human, represents the human-machine interface. Information travels in both directions through this interface.
As ergonomics deals with obtaining the information across the interface, the ergonomist must make sure that controls and displays are compatible with human capabilities and task needs [1].

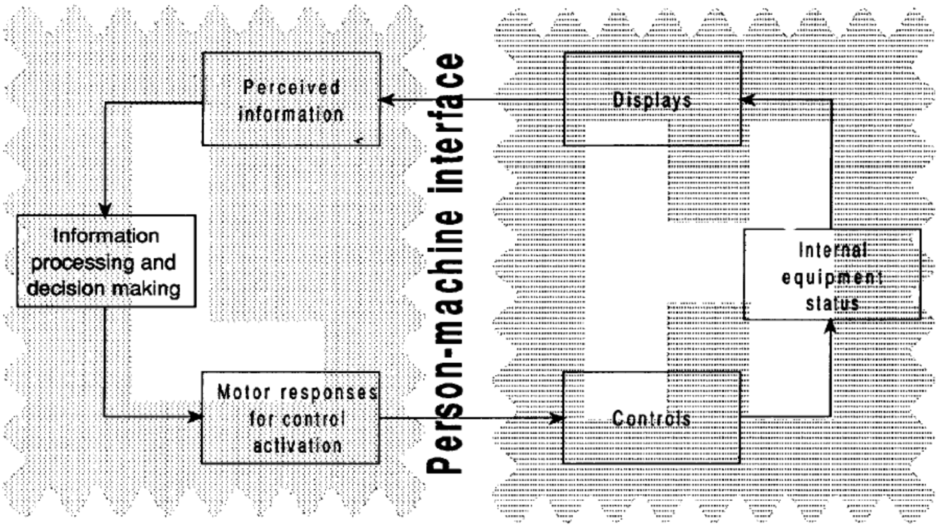

Figure 1: Representation of a person-system machine
Source: Taken from Marušić**,** Ž., 2014 [1]

The most important sensory system by which humans acquire information from external sources is the visual system (i.e. the eyes and the associated parts of the nervous system). Speech is generated by the vocal system, which is the result of the interaction of several of its components. Audio signals and speech are sensed by auditory system, which conveys them to the brain for processing [1].
Mitigation of the adverse effects of noise on hearing and speech intelligibility is one of the most important tasks of ergonomics, and it is done by solving the problem at the root. Main objectives of ergonomics are to consolidate working (and living) places with human features. Some of the basic human features are those associated with the size and shape of the various parts of the body and with their movements [1].

The heart of ergonomics are displays and controls. The SHEL concept refers to liveware (human), hardware (machine), software (procedures), and environment (the situation in which the L-H-S system must function). As shown in the SHEL model (Figure 2), they are mostly part of the liveware-hardware and liveware-software interfaces. In the case of displays, the transfer of information goes from the hardware to the liveware. Information are transferred, from the liveware to hardware, by control devices. Usually there is an information loop involved in this process, and ergonomists have to optimize the flow within this loop [1].

Figure 2: The SHEL model
Source: Taken from Marušić, Ž., 2014 [1]

2.1. General advantages of glass cockpit aircraft

Glass cockpit which was introduced in the 1970s, today offers many benefits to pilots worldwide. Glass cockpits, or in the proper term, Technically Enhanced Cockpits, refer to the development of Flight Management Systems (FMS) to monitor and control the aircraft [2].
A glass cockpit shown in Figure 2 is an aircraft cockpit that has electronic or digital displays on liquid crystal displays (LCD screens as opposed to using traditional analogue dials or gauges that were commonly found in an aircraft cockpit. Newer systems are more automated, more precise and the integration of controls is better than in traditional analogue systems [2].

Figure 2: Example of glass cockpit aircraft
Source: Taken from [2]

Through its Electronic Flight Instrument System (EFIS), a flight deck display setup that replaced the traditional dials found in what the industry called as "steam cockpit" that used to rely on mechanical gauges, the glass cockpit provides improved aircraft operations and navigation. The Captain and the First Officer, through individual primary flight screens, obtain access to aircraft status and various vital and pertinent information, such as attitude, heading, altitude, airspeed, lateral/vertical path, engine power, selected course, and navigation. In addition, the glass cockpit includes a Multifunction Display LCD that relays supplementary data such as radio management, aircraft systems, engine instruments, checklists, flight plan, terrain, traffic information, charts, traffic and weather, and wind direction and speed. In order to provide additional information and function to the aircraft's glass cockpit, Boeing developed the Engine-Indicating and Crew-Alerting System (EICAS), an integrated system that includes all engine instrumentation with crew advisory, caution, warning, and alert messages. Additionally, Airbus developed the Electronic Centralized Aircraft Monitor (ECAM) system as support to EICAS. Designed to decrease pilot stress during emergency and abnormal situations, the ECAM system operates a colour-coded scheme of information that instantly informs the pilot about a specific emergency situation and provides procedural help [3].

2.2. Ergonomic advantages of glass cockpit aircraft

The greatest advantage of glass cockpits over traditional cockpits is that the automation systems are more precise, the information is more correct, and the data is displayed more ergonomically. Glass cockpits also include feedback loops and the capability for self-checking to alert the pilot to problems before they become emergencies. The system also provides a checklist for some issues that the pilot can use to attempt to troubleshoot the problem and correct it immediately. As electronic and digital instruments become more sophisticated, glass cockpits will become standard for aircraft in the future. Although there is additional training necessary for pilots who switch from traditional analogue instrumentation to glass cockpits, the accuracy and dependability of the newer systems offer reduced pilot fatigue, resulting in safer flying for crew and passengers [2].

2.3. Use of glass cockpit aircraft for pilot training

It is a benefit for pilots to have the advanced skills necessary to operate an all-digital glass cockpit. Nowadays, glass cockpit is at the core of modern aircraft dominating the commercial aviation industry, for example: Boeing 737NG, Airbus A320 family, and the double-decker A380. At the pilot training school, Alpha Aviation Group (AAG), programme offers hands-on, real time training with the EASA-approved Level D Full Flight Airbus A320 Simulator. Furthermore, as a distinction to other flight schools that still utilize basic aircraft with analogue cockpits for its training, AAG has equipped with a modern single fleet of Cessna 172s outfitted with the similar glass cockpit system used in airline companies (Figure 3). This advanced competency and knowledge about operating an innovative aircraft system is a surely beneficial to a pilot's successful career [3].

Figure 3: The Cessna 172, a four-seater, single-engine aircraft equipped with modern digital avionics (AAG)
Source: Taken from [3]

It is necessary to achieve relevant experience, industry knowledge, and professional skills, as the demand for competencies in the aviation industry is rising fast. At AAG flight school, candidates are provided with targeted and effective training that fully prepares them for a rewarding career as licensed professional pilots and as aviation leaders [3].

2.4. Advantages of glass cockpit aircraft for pilot training

With the development of digital technology, the integration of multiple aircraft instruments into one LCD display is no longer a privilege reserved for large aircraft. Now it is the reality and the need for general aviation aircraft as well. Use of liquid crystal displays (LCD) in flight training devices can reduce human error during flight simulations [4], therefore can improve a level of respondents´ performance. The standard "basic six"

configuration of the instruments shown in Figure 4 is outdated and unprofitable for maintenance, especially on aircraft subjected to intensive vibrations due to take-off and landing on grassy surfaces, especially due to frequent take-off and landing cycles and exploitation conditions in general.
Modern “solid state” devices and displays do not have this problem because they do not contain mechanically sensitive parts within themselves and are therefore less susceptible to malfunctions. Glass cockpit shown in Figure 5 becomes an undefined standard for aircraft.

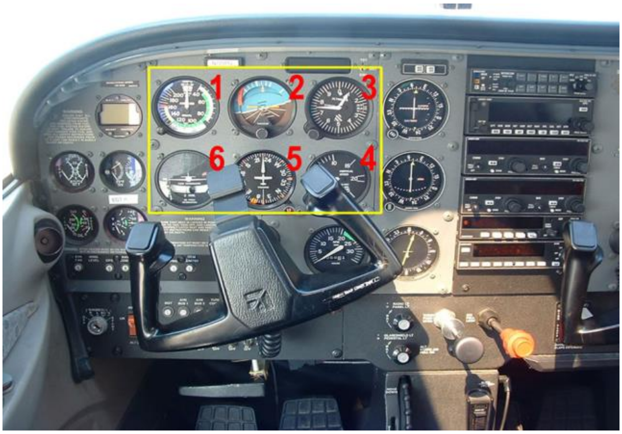

Figure 4: Standard Basic Six instrument configuration with the old type of COM/NAV equipment – cockpit Cessna 172R (1998)
Source: Prepared by author [5]

Figure 5: Retrofit Garmin G500 Glass cockpit – cockpit Cessna 172N (1979)
Source: Prepared by author [5]

Analog instruments:

- The mechanical parts are subjected to failure due to vibration,
- The mass and size of the instruments is larger,
- Expensive repairs and replacements,
- Vacuum gyroscopes,
- Obsolete concept and support for instrument repair gradually disappears.

Digital Glass cockpit:

- There are no moving mechanical parts in the displays, the so-called "solid state" technology,
- Multiple instruments integrated into one display,
- The integration of instruments and aircraft systems,
- Low energy consumption,
- Possibility of installation on older aircraft.

It is a great advantage to own fleet of aircraft equipped for training purposes in identical configurations and with identical instruments to facilitate use in exploitation, as this would eliminate the need for VFR/IFR classification of aircraft if all aircraft in fleet were equipped for VFR/IFR flight. This would also reduce the cost of logistics and storages needed to track rotating parts because the aircraft fleet would then be identical.
Summary of advantages of glass cockpit pilot training aircraft:

- All the aircraft in the fleet have the same cockpit,
- All aircraft can perform VFR/IFR flights,
- Familiarising with the cockpit is easy as all aircraft have the same cockpit,
- Lower maintenance costs,
- Lower storage costs of because all aircraft have the same equipment,
- Simple transition of students from one aircraft in the fleet to another,
- Easier transition to type rating courses.

3. CONCLUSION

Ergonomics deals with general principles to manage the design of flight deck displays and controls and it ensures that controls and displays are compatible with human capabilities and given tasks. The SHEL concept explains theoretical interactions of liveware (human), hardware (machine), software (procedures), and environment, and they should be taken into account during the glass cockpit design as far as possible.
Glass cockpits represent the development of Flight Management Systems (FMS), and provide improved aircraft operations and navigation.
Glass cockpit is designed to reduce pilot´s stress as well as to improve pilot´s performance during emergency and abnormal situations, the system operates a colour-coded scheme of information that instantly informs the pilot about a specific emergency situation and provides procedural help.
There are many simultaneous advantages of glass cockpit pilot training aircraft, but the best advantage of glass cockpits is that the automation systems are more precise, the information is more correct, and the data is displayed more ergonomically, therefore number of human errors can be reduced, as well as a level of respondents´ performance can be increased.

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ERGONOMIC DESIGN RESPONSIBILITY IN THE ENGINEERING FIELD-A CASE STUDY

A. Mocan[1], A. Draghici[2]
[1] Politehnica University, Timisoara, ROMANIA, ancamocan2003@yahoo.com
[2] Politehnica University, Timisoara, ROMANIA, anca.draghici@upt.ro

Abstract

Within the European university system, engineers are not sufficiently taught about the role and use of ergonomics and because of this do not consider themselves responsible for integrating it in their design process. They are furthermore not encouraged on the job by their managers to apply ergonomics principles in their day to day work and do not receive adequate post university training in this domain. The purpose of this paper is to add to the body of research by applying an ergonomic knowledge survey in a Western European manufacturing facility. The results are analysed, compared to the general global and European trend and a series of proposals meant to improve the usage of ergonomic design principles within the working engineering community are made.

Keywords: *ergonomic design, engineering, ergonomic education*

1. LITERATURE REVIEW

Engineering is the design under constraints of cost, reliability, safety, environmental impact, ease of use, available human and material resources, manufacturability, government regulations, laws and politics [1]. As in any scientific discipline, during the process of engineering design planning, the goals and objectives of the to-be-designed system are identified. Upon finding out what these objectives are, performance specifications are defined, in order to understand the constraints under which the system will operate [2]. Design implies creating a structure that will systematically solve issues that might organically appear. The main concern in system design is that, while alternative design concepts are identified and tested, ergonomics related aspects are not considered to be critical inputs to be taken into consideration. Most of the time ergonomics is pushed further down the design line, into the evaluation stage and result in actions dubbed as "too little, too late"[3]. What this means is that the design of the system is already too advanced to make meaningful changes, or the alteration made are too small to make any impact.
One of the reasons why this behavior exists in its current state is the lack of ergonomics based engineering courses or study directions offered by technical universities.
Ergonomics has a vast field of activities in varying disciplines that cover a wide range of topics such as work station design, product design, occupational health and safety, material handling, interface design, work/rest schedules, aesthetics and environmental ergonomics, to name a few. As it can be clearly seen from its scope, the topic covers

human behavior in any work condition. Because of this, engineers tasked with creating human work structures and models should be aware of the discipline that defines this. Human error has long been identified as a contributing factor to incident causation therefore for every work station design and installation of a product line which are related to engineering activities, anthropometric data among workers should be available. Human-machine interaction models should be applied and performance information should be studied. It is clear that parts of the scope of ergonomics have appropriate applications in engineering environments. [4] This line of thought, however, is not seen mirrored in the academic training programs currently existing on the market. There are 189 undergraduate and graduate programs at the moment that offer ergonomics based trainings and specialization, out of which approximately 70 are of a technical nature. These programs also have a decidedly North American availability, the European market showing availabilities mostly in Sweden and the United Kingdom [5].
This leads to an overwhelming majority of European engineers that have little to no experience ergonomic design, designing machines that are suboptimal that do not fully respond to human needs. In order to stop this behavior it is clear that ergonomic aspects have to be discussed in depth already on a design planning phase and followed through in the entire production process. This can only be done if design engineers are ergonomically literate and consider it their responsibility to apply ergonomic principles to their design. This, however, proves to be an issue, as it was shows that engineers do not take into account the ergonomics and work environment aspects of a project because they are not aware of their impact on other employees' work environment [6]. Even more drastically, it has been shown that engineers have an active resistance to integrating ergonomics into the design discussion, as the topic was not sufficiently covered during their school training which led to the thinking that this was not part of their responsibilities. [7] Ergonomics needs to start being applied from the moment the product gets designed. The purpose of this article is to analyze whether the lack of Ergonomics specialization availabilities within Belgium have influenced the perception of ergonomic design responsabilities in the engineering department of a multinational production company. As meaningful policy changes cannot happen without a critical mass of research backing up the claims that ergonomic education for engieners is not present enough in university curriculumns this article will present the level of ergonomic applciation and involvement that results from current level of ergonomic studies. Furthermore the paper strives to understand the company's general design policies and its managerial involvement in the product design process.

2. METHOD

The research question the study started from was: What is the level of ergonomic design application in manufacturing facilities? This topic was broad enough to be branched out in 2 influence areas: the engineers and the managers. Were the engineers sufficiently trained and willing to apply ergonomic design to their day to day work, but met resistance from managers? Was management actively trying to encourage ergonomic application in the work design, but was hindered by the engineers' lack of knowledge? Or was it some sort of a combination of the two?
The following section will describe in detail the methods used to gather this information, the resulting findings and the discussions that arise from them. A qualitative, nonrandom sampling questionnaire was deemed the best approach for this research, due to its capacity

to provide empirical data in a fast manner, which was deemed necessary due to the reorganization process that was scheduled in the researched company by the end of the year.

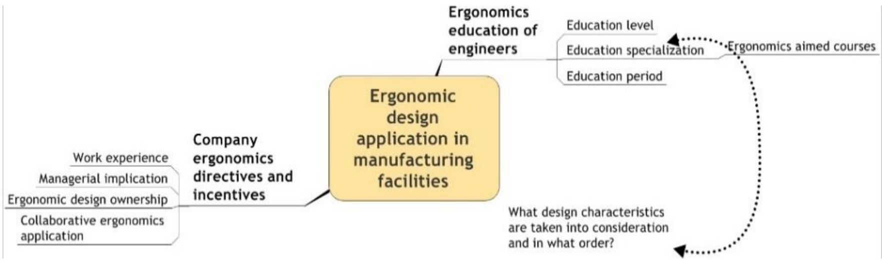


Figure 1: Mapping the data to be collected

The sampling was nonrandom, as specified above, as the target of the study was defined as the engineering department of a specific manufacturing facility. The firm's management was approached with the purpose of the study and the questionnaire and asked for permission to contact the engineering department for a round of general discussions to present the work and its purpose and its subsequent questionnaire. A total of 50% of targeted engineer agreed to participate in the study and filled in the questionnaire.
The ten part questionnaire was developed with the purpose of understanding the two influence areas determined beforehand to have an influence and impact on ergonomic decisions, particularly in regards to product design in the machine production industry.
The questionnaire was therefore split into two parts, each targeting one of the different branches. The first four questions are aimed to understand the general background of the respondents, namely what type of engineering background they have, what academic level they have reached, how many years they have been employed since finishing their education and how vast their work experience has been (i.e. with how many companies have they worked). The following question aims to find out, based on the respondents' best recollection, how many hours of ergonomic training their educational background provided in order to be able to assess their pre-existing knowledge of the topic at hand.
The following set of five questions are meant to understand the respondent's relation to ergonomic design: do they consider themselves responsible for it? Have they been encouraged to use it, and if yes, how and by whom. The final question asks the respondents to list the factors that they consider the most important to be taken into account when designing or redesigning a product in order to gouge the existence of underlining uniformity in execution.

3. RESULTS

One of the first findings of the questionnaire that should impact the further analysis, is the general profile of the engineers working on the site targeted by the study. The majority have been working for a long period of time - 60% of respondents have been in the workforce for more than 20 years and for a limited number of firms- half have worked with maximum four firms, while the other half with maximum two. This leads to a situation in which, while well experienced in their field over a long period of time, the engineers have not seen different ways of working. They have therefore a significant knowledge specifically related to their current employer, but little in relation to overall industry standard.

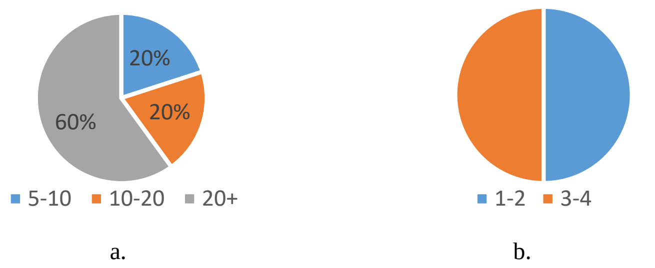


Figure 1: a. Years of employment b. Number of companies worked for

As was expected in the targeted production environment of the company, Figure 2a shows that the majority of the responding engineers were specialized in mechanics. The interesting finding was that almost half (40%) had a double specialization. Another point of interest that proves hard to analyze, is the self-reported level of education. This is related to the country's previous educational system, where a "Masters" implied the specialization period of the Bachelor, and not, as it's currently implied, a separate stage of studies. Because of this the data cannot be meaningfully used for further analysis and correlation, and requires further interviews with the respondents to understand the meaning of the words used.
The analysis of fifth question, where the respondents were asked how many hours of ergonomics or ergonomic design they had done during their studies, led to a shocking conclusion. With the exception of one engineer, who majored in industrial design and reported around one hour per week of ergonomic topics throughout his entire studies, all others replied that they had done zero hours. While there is a possibility that other tangential topics were covered during the studies, it is clear that the respondents were not considering those topics to be similar to their understanding of ergonomics.

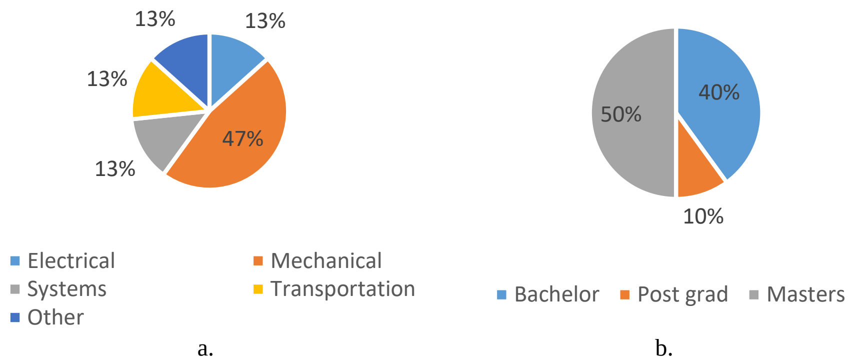
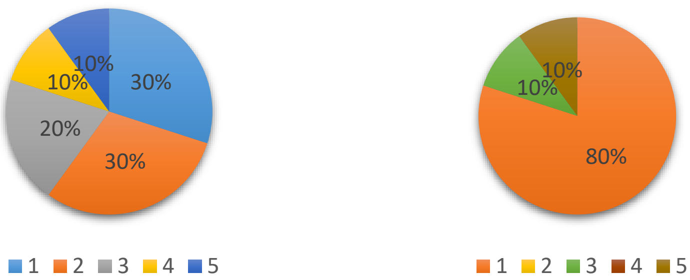


Figure 2: a. Engineering specialization b. Level of education

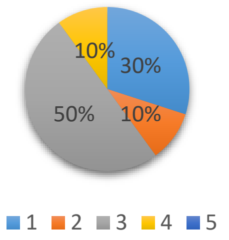
Starting from the sixth question onwards the questionnaire focused on understanding the relationship between engineering and ergonomics by utilizing rating scale answers. As can be seen in Fig. 3, even though the engineers were tasked with designing new products for upcomming projects, more than 60% of them considered strongly that ergonomic design was not their responsability. That, coupled with the 80% of them that have aknowledged that they have not received any sort of ergonomic trainining after university, leads to an environment where employees do not think of ergonomics as a design constraint to be taken into account. This coroborates other studies [8], [9] that also showed engineers having poor knowledge of how to apply ergonomics principles in their day to day work. The discussion here should be expanded in the future to analyze what kind of training the other 20% have received, both in content, level of detail as well as in style and overall duration.



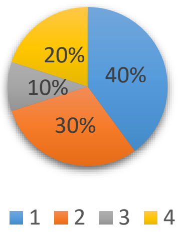
a. b.

Figure 3: a. Ergonomics responsibility b. Post university ergonomics training

Questions eight and nine showed that the situation was not improved by managerial involvement. Within the analyzed group, participants have not often participated in a cross functional design team with 30% of them never having even done so. Furthermore, 40% of respondents have never been encouraged by a manager to take more of an interest in ergonomics. This issue has been found throughout other companies [10], not just in a machine production environment, but also in other areas, such as medical design [11]. This is related to the fact that managers relate ergonomics to comfort [12], which always takes back seat to functionality and price. They do not take into consideration the defects reduction and quality improvement in the production process that a good ergonomic design can lead to, along with the cost saving that this implies. It has been shown that improvement in ergonomics design can lead to higher efficiency, lower misuse of products and productivity increases. All this translates to customers that are willing to return for more products from the same manufacturer. [13]



a.



b.

Figure 4: a. Participation in cross functional design teams b. Managerial encouragement to apply ergonomics.

The final question, as previously mentioned, was to request that the respondents list the factors that they consider the most important to be taken into account when designing or redesigning a product. This was done in order to find out if their engineering education or subsequent company policy had incentivized them to prioritize a set of design policies above others. The answers to the question provided the best cue that a companywide design policy either didn't exist or was not actively implemented in the studied company. The variability of answers is very visible, as each engineer set a different ranking in place. This made a de facto design trend very difficult to set. Almost all agree that ease of transportation is one of the lowest priorities to set in a design process, while final product integration seems to be the overall highest ranking aspect. In the middle of the scale people most often set ease of maintenance.

Final product cost	5	6	6	5	2	7	3	7	5
Design time	1	2	7	6	3	9	9	6	4
Final product integration	8	7	1	2	1	5	1	1	1
Aesthetics	3	8	9	4	7	2	6	3	9
Usability	7	1	4	3	6	1	2	2	3
Ease of maintenance	9	5	2	8	5	6	5	5	7
Modularity	2	4	5	7	4	4	7	9	6
Ease of production	6	3	3	1	8	3	4	4	2
Ease of transportation	4	9	8	9	9	8	8	8	8

Figure 5: Representative subset of design factor rankings

4. DISCUSSION

The research started off from the question of what is the level of ergonomic design application in manufacturing facilities? Based on the answers received in the survey the answer to the question within the studied environement is that ergonomic design application is almost nonexistet.

Through the answers in the questionnaire it was clear that the engineers did not start off with a clear understanding of what ergonomics is and how it is integral to their product design. This was caused by a clear lack of ergonomic training during their university years. This state carried on in their work environment, as little to no additional training was provided into the topic by the companies worked at. There seemed to be was no perceivable overarching companywide ergonomics policy. If one existed then the engineers were clearly not aware of it. There was also no incentive structure in place to help guide engineers to a more ergonomic design alternative. Discussions before and after the interview have shown that the company cared most about production cost and timing. It has been shown by other researchers that bad ergonomics design leads to poor assembly [14], which increases costs and production time. It is therefore in the interest of managers looking to decrease costs to invest in ergonomics trainings for their engineering department. This was not the case in the studied environment, as managers did not seemed to provide any support structure to guide engineers in the right direction.

In order to change this type of situation in a significant way a 3-direction change has to happen. On a country level a change in education policy has to be proposed, by describing the benefit of adding ergonomics studies to the curriculum in engineering schools. This will prepare engineers with basic ergonomics knowledge and how to apply it to their work environment. Upon this knowledge, a second step would be company specific ergonomic training for engineers, which can help them understand the companies' ergonomics requirements and application scheme. This, however, means that managers and decision makers also need to understand how ergonomic applications benefit the bottom line of the company. That implies ergonomic training for managers and the presence of a trained ergonomist within a decision making structures of a company.

Either one of these points applied singularly will get drowned out by the "business as usual" way of working. Which is why all 3 have to be applied simultaneously in order for sustainable change to happen.

5. CONCLUSION

Within the analyzed facility ergonomics literacy, application and attention given by the management was minimal. Engineers had generally not been trained on the topic in school, have not discussed it clearly during their career and were not incentivized to apply it in the current design situations they were encountering. The managers were also not prioritizing ergonomics application, due to attention falling more on the speed of design. This kind of behavior leads to, at best, corrective ergonomics actions, of the too little too late sort, and at worst no ergonomic actions at all.

While this research corroborates other industry studies on a worldwide level, more localized research is needed to understand which industries are lagging behind others in terms of ergonomics applications and how this gap can be closed in the future. This extension of the research can be used to put together a memorandum to the country wide decision makers, both in business as well as in public policy to grant ergonomics the attention it deserves within the formal and informal education process.

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ERGONOMICS PREDICTION MODEL FOR PEAK EXPIRATORY FLOW RATE OF BAKERS IN ABEOKUTA, NIGERIA

A. I. Musa
Department of Mechanical Engineering, Moshood Abiola Polytechnic, P.M.B 2210, Abeokuta, Nigeria, E-mail: kunlemusa@yahoo.com; musa.adekunle@mapoly.edu.ng

Abstract

The study established a model to determine the Peak expiratory flow rate of bakers in Abeokuta, Ogun State, Nigeria. A total of three hundred (300) individuals were investigated with One hundred and fifty (150) bakers who are exposed to flour dust and One hundred and fifty (150) as non-bakers. The participants were male and female without any discrimination but with equal distributions in both bakers and non-bakers. Peak expiratory flow rate (PEFR) and anthropometrical parameters were measured using mini-Wright peak flow meter (PFM 20, OMRON) and Detecto PD300MDHR (Cardinal Scale manufacturing company USA) column scale respectively. PEFR measured and were compared using T-test and regression analysis with curve estimation. The prediction model equation for PEFR based on body mass, height, age and years of experience (where applicable) were determined. The study showed that PEFR in bakers was 172.87 ± 6.18 L/min as against 279.60 ± 23.60 L/min for non-bakers from the regression analysis. Similarly, the multiple correlation (R^2) revealed that baker has 0.438 and 0.241 for control group. The Study concluded that using the developed model will serve as a great importance to workers. Prediction equation was derived for use of bakers irrespective of the gender to determine and diagnose early the lung obstruction disease.

Keywords: *Bakery, Flour, Dust, Workers, Peak expiratory flow rate*

1. INTRODUCTION

Peak expiratory flow rate (PEFR) is noted as one of the useful and very simple parameters for assessing lung function status and monitoring treatment of patient with bronchial asthma and obstructive lung disease [1]. Many studies on PEFR have been carried out previously in Nigeria [2], [3], [4]. It is very uncertain to determine the national norm in Abeokuta for healthy men and women as the lung function varies with socio-economic and nutritional conditions. Essen [5] demonstrated that the grain dust exposure is a common cause of respiratory symptoms and these workers developed obstructive change on pulmonary testing. The most frequent reported clinical features among workers exposed to dust are wheezing, lung function and asthma [6]. Peak expiratory flow rate is the cheapest and easiest method in identifying and assessing the degree of airflow limitation of individual [2].

In recent years, bakery industries are one of the fastest growing agro allied industries creating impacts of daily life in Abeokuta metropolis of Ogun State, Southwest Nigeria. Bakery products are being used on large scale as daily food items in locality of the state. The peak flow readings are often classified into three (3) zones of measurement of green, yellow and red. The green zone indicates that the asthma is under control while the yellow indicate caution, which mean respiratory airways are narrowing and additional medication may be required. The red indicates a medical emergency, that is, severe airways narrowing may be occurring and immediate action is needed to be taken. Different studies have been conducted to establish the lung function status of bakery workers respiratory problem due to a daily exposure to flour dust [7], [3]. Many studies have been conducted to develop prediction equations that can be used globally to obtain normal reference values [2], [3]. However, the data on which these equations were based mostly from Caucasian populations and the data for Nigeria are limited on bakery workers. Musa et al., [2] presented the prediction model of female bakers within Abeokuta Ogun State where he determined the PEFR with four factors of body mass (kg), height (cm), age and years of exposure. But, the data obtained is limited to the female bakers not gender bias. Research revealed that there is sparsity of peak expiratory flow rate prediction model equations studies conducted in African.

Elebute and Femi-Pearse [8] performed a study to establish the standard values of Peak Expiratory Flow Rate (PEFR) in Nigeria where they measure the anthropometric parameters and PEFR of 142 healthy subjects. The study revealed that the mean values of male PEFR were 482.1L/min (±83.3) and 385.6L/min (±65.7) for female. This study conducted by [8] was considered as outdated and this prompted the present research to revalidate their findings. The objective of this study is to determine the regression equations for predicting peak expiratory flow rate of a bakery workers using a curvilinear model that considers changing trends of PEFR with age, body mass, height and year of exposure given the fact that the paucity of such data existed in Abeokuta, Ogun State in particular and Nigeria as a whole. The developed model will be available and applicable for all gender either male or female bakers.

2. MATERIALS AND METHODS

The present study was carried out on three hundred (300) non-smokers healthy bakers whose age is above 19years. One hundred and fifty (150) males and One hundred and fifty (150) females with equal distribution for the bakers and non-bakers with the same age bracket were investigated. Both bakers and non-bakers had no earlier report of systematic diseases.

A structured questionnaire was administered to the participant as a tool for data collection. The data collected includes the details demographic data of the participant such as age, marital status, education level, smoking status, duration of flour dust exposure, working experience in the bakery industry where applicable.

The PEFR was measured in standing position using mini-Wright peak flow meter (PFM 20 OMRON) (figure 1). Prior to measuring the PEFR, clear instructions were given regarding the technique of the test and it was also demonstrated to each participant. The test was performed three times on each participant and the best of the three attempts was selected for data computation. Detecto PD300DHR (Cardinal Scale manufacturing company, USA) column scale with digital height rod (figure 2) was used to measure the body mass (kg) and height (cm) of the participant respectively.

Figure 1: mini-Wright peak flow meter

Figure 2: Detecto (PD300DHR column scale with digital height rod

A statistical significance of regression coefficient by T-test and multiple correlation coefficients (R^2) were calculated to evaluate the significance test of the curve fit regression. The statistical software SPSS version 17.0 was used to fit the model.
Reference to the data collected the relationship between the PEFR and the anthropometric parameters of the bakers and non-bakers were used to develop the required model where PEFR remain the dependant of all remaining four factors.
The model follows trend in equation 1 and 2 below [2],

$$y = a+b_1x_1 + b_2x_2 + b_3x_3 \_\_\_\_\_\_\_\_\_\_ b_nx_n \quad (1)$$

$$PEFR = a + b_1(body\ mass) + b_2(height) + b_3(Age) + b_4(years\ of\ exposure) \quad (2)$$

Where a is the constant and b is the coefficient of regression. Each coefficient b represent the effect of the independent variable y, b_4 is only applicable to the bakers only.

3. RESULTS AND DISCUSSIONS

Table 1, Table 2 and Table 3 showed anthropometric parameters, PEFR descriptive statistic, T-test (One sample test) and regression coefficient analysis of the bakers and non-bakers.

Table 1: T-test (One sample test) for the Subjects

	Bakers					**Non-Bakers**			
	N	**Mean**	**Std. E Mean**	**Std. Dev**	**T**	**Mean**	**Std. E Mean**	**Std. Dev**	**T**
Body mass (kg)	150	56.97	0.56	6.85	101.86	60.17	0.67	8.26	89.28
Height (cm)	150	165.97	0.51	6.18	328.84	165.55	0.64	7.90	256.81
PEFR (L/min)	150	172.87	1.56	19.15	110.53	279.60	1.93	23.60	145.11
Age (yrs)	150	26.03	0.28	3.39	94.15	25.95	0.29	3.60	88.21
Yrs of Exposure	150	2.45	0.06	0.70	42.88				

Table 2: Result of Regression coefficient analysis of the Bakers

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
(Constant)	36.760	45.484		0.808	0.420
Body mass	0.411	0.332	0.147	1.239	0.218
Height	0.562	0.370	0.181	1.519	0.131
Age	1.763	0.487	0.312	3.617	0.000
Yrs of Expo	-10.810	1.739	-0.395	-6.215	0.000

a. Dependent Variable: PEFR

From Table 2 and the trend in Equation (2), the model for the determination of PEFR for baker can be deduced and written as in Equation (3).

$$PEFR_{baker} = 36.76 + 0.41(Body\ mass) + 0.56(height) + 1.76(Age) - 10.81(yr\ of\ exposure) \quad (3)$$

Table 3: Result of Regression Coefficients analysis Non-bakers

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	233.695	43.536		5.368	0.000
Body mass (kg)	1.575	0.315	0.551	4.995	0.000
Height (cm)	-0.348	0.366	-0.116	0-.951	0.343
Age (yrs)	0.339	0.585	0.052	0.580	0.563

a. Dependent Variable: PEFR

Similarly, from Table 3 and the trend in Equation (2), the model for the determination of PEFR for the participant who are not exposed to dust (i.e non-bakers) can be deduced and written as in Equation (4).

$$PEFR_{control} = 233.70 + 1.58(Body\ mass) – 0.35(height) + 0.34(Age) \qquad (4)$$

Equations (3) and (4) imply that the body mass, height, age and years of exposure affects the Peak Expiratory Flow Rate of any bakery workers.

Table 4: Multiple correlation coefficient

Model	R	R^2	Adjusted R Square	Std. Error of the Estimate
Baker	.662[a]	0.438	0.422	14.5585
Control	.491[a]	0.241	0.225	20.7743

a. Predictors: (Constant), Age, Body mass, Height,
b. Dependent Variable: PEFR

Table 1 revealed that the mean values for the PEFR are 172.87 ± 19.15 L/min as against the 279.60 ± 23.60 L/min for the control respectively. The PEFR prediction equation gave the best fit of the data for the bakers in Abeokuta irrespective of the genders, male or female. The linear model used in the equation showed that b_1, b_2, b_3 and b_4 are regression coefficient. Table 4 showed that multiple correlation coefficient (R^2) for bakers and control group were 0.438 and 0.241 respectively. There is a statistically significant increase in PEFR along with an increase in height, age and body mass.
Various researchers have studied PEFR values in healthy individuals [2]. The age and sex distribution showed that the population to be heavily skewed in favour of males. The present regression analysis should be appropriate for the two sexes from age 19years and above.

4. CONCLUSION

The difference in predicting PEFR value among different population in the bakery industry studied may be possible due to the sampling as well as environmental, nutritional and generic factors. These factors require further studies. The Peak Expiratory Flow Rate (PEFR) measurement is a very simple, reliable, reproducible ventilator function test which can be performed by using mini Wright peak flow meter (a cheap, portable instrument).

The key determinants of reduced lung function in this study were long duration of flour dust exposure, poor use of personal protective equipment (PPE). This shows the risk of occupational lung diseases from reduced lung function in bakery workers that are exposed to flour dust. It is also shows that knowledge and effective use of PPE is a major contributor to low percentage of workers with lung function.

It is therefore recommended that periodic and scheduled screening of lung function using simple tools like respiratory symptoms evaluation and Peak Expiratory Flow Rate should be done on workers at risk for early detection and prevention of occupational lung disease. The use and education of PPE should be encourage and promoted as it has been shown to significantly reduce the risk of lung function impairment.

In addition, it is a limitation of the study that portable mini-wright's peak flow meter was used to record PEFR values for the individual. Variation in technical performance of equipment used introduces another factor to account for different values among different equipment.

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STUDY ON THE RELATIONSHIP BETWEEN MUSCULOSKELETAL INJURIES AND LIVING FUNCTION OF PHYSIOTHERAPISTS

Y.-K. Ou[1], C.-N. Yeh[2], Y.-L. Wang[2], C.-M. Kuo[1], Z.-W. Chen[1]
[1] Southern Taiwan University of Science and Technology, Department of Creative Product Design, Tainan, Taiwan, ouyk@stust.edu.tw
[2] Chi-Mei Medical Center, Department of Physical Medicine and Rehabilitation, Tainan, Taiwan, pt850620@gmail.com

Abstract

Musculoskeletal injury is an inflammatory or degenerative disease of the body's musculoskeletal system, which includes tendonitis, muscle strain, joint degeneration, and ligament strains. Physiotherapists assist patients with works such as rehabilitation, record treatment, and hands-on treatments, and most of the work is cumbersome and repeated. The Disabilities of the arm, shoulder (DASH) and hand assessment questionnaire and Rapid upper limb assessment (RULA) were used in this study to understand the complexity of physiotherapist's work content and the situation of their physical pain through observation. The results showed that the nine physiotherapists had a score of 7 on the RULA scale after four month of observation, which showed that the work of the physiotherapist was more complicated and repetitive. The average DASH scale score was 49.11 points (SD = 15.31), which indicated that the physiotherapist's upper limb function had affected their quality of life and ability of work.

Keywords : *Musculoskeletal injury, Rula, DASH, Physiotherapist*

1. INTRODUCTION

Physiotherapists belong to rehabilitation technicians in occupational classification. Their expertise are to assist the patients with dysfunction, limitation or disability to restore their life function and return to work through the help of various medical devices, assistive devices and protective accessories. The physiotherapist will diagnose and implement the patient's rehabilitation treatment plan based on the doctor's diagnosis, and provide the most appropriate assistance and advice according to the patient's condition after test and evaluation. According to studies, the prevalence of musculoskeletal injuries among hospital workers was up to 65.4%, mostly was the waist and back injuries, followed by the neck and knee [1]. Moreover, the musculoskeletal injuries incidence of women is twice as likely as men [2].
Musculoskeletal Disorders (MSDs) refers to diseases limited to muscles, joints, tendons, ligaments, nerves, and bones, including partial blood circulation system. The main reason is due to professional activities and the working condition influences when performing

tasks [3]. Musculoskeletal injuries are broadly defined as physical factors at work, such as frequent or prolonged paralysis or exposure to vibrations, which can cause musculoskeletal injuries [4].
According to the annual report of the Labor Insurance Agency's Occupational Disaster Statistics, the cases of payments due to musculoskeletal injuries in the past decade has increased up to 375 people per year from 2009. Furthermore, there are more than 500 cases of musculoskeletal injuries each year after then, which accounts for more than 55% of the occupational diseases. Therefore, it is known that musculoskeletal injury is common occupational injury in Taiwan. According to the labor safety and health cognition survey, about 40% of musculoskeletal injuries are related to the work content and mainly cause pain in the shoulders, neck, waist and wrist area.
Physiotherapists continuously to suffer from the risk of musculoskeletal injuries when operating physiotherapy for the treatment of musculoskeletal injuries. Physiotherapists are prone to work-related musculoskeletal injuries. It is because their work might be repetitively labor-intensive, and the lifetime prevalence rate is as high as 90%. Even worse, about one out of every six physiotherapists departed because of musculoskeletal injuries [5]. Studies indicate that physiotherapists assisted patients in different levels of functional dependence very often, such as patient shifts, gait exercises, exercise on mats, and provide resistance and handling equipment which were necessary for patients. Such working condition exposed physiotherapists to acute or chronic work injuries. The most common injuries were the lower back, wrist, upper back, and neck [6]. Therefore, this study discusses the condition and influence of physiotherapist's physical pain through scales, questionnaires, and interviews.

2. METHOD

2.1. Research design and procedure

A four-month cross-sectional study was conducted between August 2017 and November 2017. 9 physiotherapists (4 males and 5 females) of the Rehabilitation Department of a medical center in the southern part of Taiwan were recruited after received the human trial committee of the hospital. Each subject signed the consent form after the explanation by the researcher, and completed the research questionnaire. In addition, the researchers observed and recorded the one-day work of subjects in the orthopedic treatment area during the study.

2.2. Data Collection

Questionnaires were used to collect data on demographics and work-related musculoskeletal conditions. The demographics include personal data (including age, gender, etc.), work experience (including years of work, common treatment methods, commonly used medical equipment, working hours, etc.) and pain scores. Subjects are required to indicate the area of body pain and level of discomfort in the pain scale. There are also two upper limb function assessment scales, which includes the Disabilities of the arm, shoulder and hand (DASH), in order to understand the subject's current musculoskeletal status, and rapid upper limb assessment scale (Rapid upper limb assessment (RULA) for job posture assessment. RULA is a reliable and validated method of observation which can help in assessing the Biophysics and posture load severity of the musculoskeletal system. Two scales were evaluated by two researchers in the experiment. Researchers took photos in different working postures, and measured joint angles by using a standard goniometer.

2.3. Data Analysis

SPSS 22(SPSS Inc., Chicago, IL, USA) statistical software was used for analysis in this study. The statistical analysis of descriptive statistics and scale data were included. $P < 0.05$ was defined as significant level in the study.

3. RESULTS

3.1. Demographic data

The details of demographic data of the subjects are shown in Table 1. Nine physiotherapists were recruited in this study, including five women and four men. The recruitment site was the Rehabilitation Department of Tainan Branch of Chi Mei Hospital. All subjects served in orthopedic units. Subjects were 31-51 years old (mean 40.7 years; SD = 6.8). The number of years of work is 7-29 years (average 17.4 years; SD = 8), and the working hours for each physiotherapist are eight hours. Three of the nine physiotherapists have to be deployed to the electrotherapy room for assistance about 3-5 times per week due to staff shortages and scheduling factors. The deployment time is four hours.

3.2. Work characteristics

The physiotherapists who serve in orthopedics are limited to approximately 20-30 minutes' treatment time per patient. It can be seen that each physiotherapist must works for 20-30 minutes before 2-minute rest time and at the same time waiting for the next patient's report. In addition, the rest time for physiotherapist who assists in the electrotherapy room is less regular and fixed. It is because the patient in the electrotherapy room checked in by the patient himself after registered randomly rather than prearranged. Which led to the situation that patients often checked in to the electrotherapy room at the same time and resulted in an overloading situation. The physiotherapists who serve in orthopedics have to take care of about 16 to 20 patients on an average day; However, there were about 4-5 physiotherapists and average 130 patients per day in an electrotherapy room, which means that each physiotherapy requires an average of 26-32 patients per day to take care of.

Table 1: Demographic data

Variable	
Gender[n(%)]	
Male	4(44.4)
Female	5(55.6)
Age(year)	
Mean(SD)	40.7(6.8)
Range	31-51
years of experience (year)	

Mean(SD)	17.4(8)
Range	7-29
Sports habits	
Yes(%)	4(44.4
No(%)	5(55.6)
Department [n(%)]	
Orthopedics	6(66.7)
Orthopedic and Electrotherapy	3(33.3)

3.3. RULA work posture assessment

Table 2 shows the percentage of RULA score of each physiotherapists, including the score and total score of RULA on two different areas of the body. The physiotherapist's upper arm used to work with the angle range from 45 to 90 degrees for a long time. The upper arm score was between 4 and 5 points. The physiotherapist's lower arm scored 2-3 points, with the staggered with their hands that are happens frequently for physiotherapists who served in the orthopedic. The palm and wrist scored are 4 points, which shows the wrist angle often produced more extreme distortion and rotation. The physiotherapists usually had to press a certain pressure to the patient's affected area barehanded during treatment, which are likely cause their wrists to bend and twist. Therefore, all physiotherapists scored 2 points on the wrist distortion. The neck scores are mostly around 4 points, and the angle is 10-20 degrees. The working posture of physiotherapists required to tilt and rotate their neck, and had to tilt the head up to adjust the higher instruments. The trunk scores are mostly 5 points, and common angle is 20-60 degrees while producing a rotation posture. The scores of legs are within normal range. Score A shows an average score of 6 on the upper limb (SD = 1), Score B shows an average of 8.11 points on the neck, trunk and leg (SD = 0.78), which was exceeded the maximum limit of 7 points, and total RULA scores of 9 physiotherapists are all 7 points (SD = 0). The data had clearly indicated that physiotherapists were in a more complex posture and staggered state when performing orthopedic services, and at the same time the work they performed was also much more difficult.

Table 2: The percentage of RULA score of each physiotherapists(n=9)

	1	2	3	4	5	6	7	Over 8	Mean (SD)
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)		
Upper Arm	-	-	-	4 (44.4)	5 (55.6)	-	-	-	3.56 (0.5)
Lower Arm	-	3 (33.3)	6 (66.7)	-	-	-	-	-	2.67 (0.5)
Wrist	-	-	-	9 (100)	-	-	-	-	4 (0)
Wrist twist	-	9 (100)	-	-	-	-	-	-	2 (0)
A Score	-	-	-	-	4 (44.4)	1 (11.1)	4 (44.4)	-	6 (1)

Neck	-	-	1 (11.1)	5 (55.6)	1 (11.1)	2 (22.2)		-	4.44 (1.0)
Truck	-	-	1 (11.1)	3 (33.3)	5 (55.6)	-	-	-	4.44 (0.7)
Leg	7 (77.8)	2 (22.2)	-	-	-	-	-	-	1.22 (0.4)
B Score	-	-	-	-	-	-	2 (22.2)	7 (77.8)	8.11 (0.8)
Final Score	-	-	-	-	-	-	9 (100)	-	7 (100)

3.4. Upper limb function assessment questionnaire

The upper limb function assessment questionnaire was used to understand the musculoskeletal status, the result showed that the scores of the nine physiotherapists ranged from 33-65 with an average score of 49.11 (SD = 10.37). The scoring method of upper limb function assessment questionnaire is from 0 to 100 points, 0 point referred to the least functional impairment of the upper limb, 100 points referred to severe impaired upper extremities. As it could be seen from the scores, all nine physiotherapists had a condition of impaired upper extremities, of which the younger physiotherapists had the least impact, and the older the physiotherapists, the more severe the symptom. The work status score in the upper limb function assessment questionnaire ranged from 0-56.25 points (average 49.11 points; SD = 15.31). This showed that the current musculoskeletal status of all physiotherapists had seriously affected the ability to work and may caused a decrease in services quality. In addition, in the scores of exercise and art, there were a total of four physiotherapists participating in cycling, running, aerobic boxing, and aerobic exercise. The score ranged from 18.75-50 points (average 31.25 points; SD = 13.5), which showed that their current impairment of upper limb function had affected the quality of leisure activities.

4. DISCUSSION

The purpose of this study was to understand the musculoskeletal injuries and other work-related risk conditions occurrences when physiotherapists perform physical therapy. In the target study group, the self-assessment of subjects reported a high prevalence of musculoskeletal injuries. Especially for the hand, the waist, and the sole were the most commonly injured. The severity of symptoms reported by each body part was also related to gender. Male subjects had more severe symptoms at the hands and waist, and female subjects had more severe symptoms of the soles of the feet, which the phenomenon was related to the habit of working posture. Men used to perform barehanded treatment using sitting postures because of their high height, which resulted in the need of using lumbar force to produce more strength in the treatment with the sitting posture. Women, on the other hand, had to performed the treatment by using a standing position. Therefore, female physiotherapists were more likely to experience plantar discomfort due to standing posture.

As shown in this study, musculoskeletal injuries and discomforts were the major problems of physiotherapists' occupational injuries. Studies had shown that

physiotherapists must perform high repetitive treatment actions when performing physical therapy operations on patients. With a long-term abnormal posture resulted in an unacceptable posture load on the body, and therefore caused a high incidence rate of musculoskeletal injuries. The bending postures of the upper limbs (between 45 degrees and 90 degrees) and dorsiflexion (between 45 degrees and 90 degrees) where the most commonly postures which physiotherapists used for performing physical therapy. This working posture caused excessive physical burden on the musculoskeletal system of workers, , and would eventually lead to the development of the body's musculoskeletal injuries if the posture last for a long time. Through this study, it was known that the average total RULA score of upper limbs was 5.6 points. The subject's posture may be limited by the working environment (such as: bed height, instrument height, etc.), which resulted in posture limitation during treatment. Therefore, it is recommended that the working environment and working posture habits have to be adjusted as soon as possible to avoid more serious injuries.
The limitations and future research directions: The investigation of this study focused only on one hospital. The investigation range should be expanded to more hospitals in different levels in the future. In addition, it can also be compared with the staff with different types of work in the hospital (such as nurses, other medical departments, administration, and etc.), to learn whether there are differences to provide different improvement proposals.

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MEASUREMENT OF SHORT-TERM LOCAL MUSCLE FATIGUE BY USING EMG FREQUENCY ATTRIBUTES

J.-S. Park[1], J.-Y. Kim[2], D.-J. Kim[2], J. Lee[2], S. Im[2], H. Kim[2]
[1]Dept. of Information and Management Engineering, Hanyang University, Ansan, Korea, jspark21@hanyang.ac.kr
[2]Dept. of Information and Management Engineering, Hanyang University, Ansan, Korea, jungkim@hanyang.ac.kr

Abstract

We attempted to find parameters that can sensitively assess the short-term muscle fatigue. In this study we separated EMG signals into low (15-45 Hz), medium (46-95 Hz) and high (>95 Hz) frequency band and to investigate the parameters including median power frequency (MPF), [Medium/Low] frequency band ratio, and High/[Medium+Low] frequency band ratio, because the frequency change is the main phenomenon in muscle fatigue. The deltoid muscle which is sensitive to shoulder fatigue was selected from 10 participants and EMG was measured at 30%, 40%, and 50% MVC when the shoulder flexion was at 90 degrees. As a result of the analysis MPF and High/[Low+Medium] parameters decreased as the time passed at all MVC conditions. [Medium/Low] under 50% MVC condition. The parameters tested in this study can be further applied to examine efficacy of detecting the low level or short-term muscle fatigue in various muscles and experimental conditions.

Keywords : *EMG, Fatigue, Sensitivity, Shoulder, Muscle*

1. INTRODUCTION

In order to quantify local muscle fatigue EMG parameters such as median power frequency (MPF) or mean frequency (MF) have been used among various studies, although they were not sensitive enough to depict low level muscle fatigue occurring during a short period of time. Bai et al. (1984) and Esau et al. (1983) attempted fatigue analysis using an H/LFB (high/low frequency band) ratio of (130~238)/(20~40) Hz. Allison and Fujiwara (2002) suggested that fatigue causes amplitude changes in certain frequency bands. To solve this problem, frequency band analysis can be used as an alternative to evaluate muscle fatigue in a specific experimental environment. The surface EMG of the biceps brachii was measured and the medium frequency of the power spectrum was compared with the changes in the low frequency (15-45 Hz) and high frequency (> 95 Hz) bands. The medium frequency shift is closely related to the amplitude and high-to-low frequency amplitude ratio of the 15-45 Hz bandwidth. Karthick and Ramakrishnan (2016) measured EMG during dumbbell exercise in 30 participants. The frequency band of the surface EMG signal is divided into three frequency bands of low

frequency band (LFB) (15-45 Hz), medium frequency band (MFB) (55-95 Hz) and high frequency band (HFB) Respectively. The mean slope of all participants for M/LFB was found to be 400 times greater than the mean slope of H/LFB. This slope change shows that the M/LFB ratio is more sensitive to the progression of the muscle fatigue state.
This study attempted to find parameters that can sensitively assess the short-term muscle fatigue. In this study we separated EMG signals into low (15-45 Hz), medium (46-95 Hz) and high (>95 Hz) frequency band and to investigate the parameters including median power frequency (MPF), medium/low frequency band ratio, and High/[Medium+Low] frequency band ratio, because the frequency change is the main phenomenon in muscle fatigue.

2. METHODS

2.1. Participants

We recruited 10 participants with no shoulder surgery and no pain during 6 months. Anthropometry data of participants was presented at ages of 23.9 (±4.46) years, heights of 175.6 (±6.22) cm and body weights of 69.3 (±8.06) kg.

2.2. Experimental Design

In this study, the deltoid muscle was selected. The deltoid muscle was used in various studies including Kim et al. (2003), Svendsen et al. (2004), Shinozaki et al. (2014), Tllyes et al. (2009) and Basmajian and De Luca (1985) to investigate the stabilization of the shoulder. Shoulder posture was fixed flexion 90 degrees.

Experimental design used between subject design. Independent variable was % MVC (maximum voluntary contraction). Dependent variables were MPF (median power frequency), [Medium(46-95 Hz)/Low(15-45 Hz)] frequency band ratio and High(>95 Hz)/[Low(15-45 Hz)+Medium(46-95 Hz)] frequency band ratio.

2.3. Experimental Procedures

Muscle contraction level was used as independent variable, and 30%, 40% and 50% MVC were used as three levels of independent variable in this study. Force levels were measured by digital loadcell (Kim et al., 2003). We defined muscle contraction level of 30%, 40% and 50% MVC by using the average of two consecutive measurement of MVC when specific difference was not greater than 5kg×force. Participants were asked to maintain their 30%, 40%, 50% MVC during one minute respectively. Rest time was 10 minutes between each trial, the order of 3 trials was counter-balanced to minimize carry-over effect.

2.4. Apparatus

Loadcell and monitor were used to measure shoulder muscle force while maintaining muscle contraction level. Also, handle was attached on length adjustable iron string to be easily handed. EMG measuring system using surface electrode method was used to measure EMG. Used surface electrode was bipolar surface electrode with 1 channel. This study used high gain bioamplifire (×2,500), bandpass filter S75-01 (range: 1~1,000Hz), and high speed videograph I/O port L19-02 included in EMG system. And sampling rate was used as 1,024Hz.

2.5. Analysis Method

This study used 40s duration out of 60s experiment time by removing each 10s of start and end. the 40s duration was also divided into one second window and mean power frequency (MPF) was derived by using fast Fourier transformation (FFT). MPF, [Medium/Low] and High/[Medium+Low] data were normalized based on experiment data collected in the very beginning of the experiment as formula and calculated in equation 1-3. The statistical analysis was performed by using SPSS v18.0.

$$\mathrm{MPF}_{\mathrm{t-normalized}} = \mathrm{MPF}_t/\mathrm{MPF}_1 \quad (1)$$

$$[\mathrm{Medium/Low}]_{\mathrm{t-normalized}} = \frac{[\mathrm{Medium/Low}]_t}{[\mathrm{Medium/Low}]_1} \quad (2)$$

$$\mathrm{High}/[\mathrm{Medium+Low}]_{\mathrm{t-normalized}} = \frac{\mathrm{High}/[\mathrm{Medium+Low}]_t}{\mathrm{High}/[\mathrm{Medium+Low}]_1} \quad (3)$$

$$\text{where } t = 1, 2, \cdots, 40 \text{ (sec)}$$

EMG signals were separated into low (15-45 Hz), medium (46-95 Hz) and high (>95 Hz) frequency band and to investigate the parameters including median power frequency (MPF), [Medium/Low] frequency band ratio, and High/[Medium+Low] frequency band ratio, because the frequency change is the main phenomenon in muscle fatigue. [Medium/Low] frequency band ratio and High/[Medium+Low] frequency band ratio data was normalized based on experiment start data as calculated in 1 second.

Using calculated MPF, [Medium/Low] frequency band ratio, and High/[Medium+Low] frequency band ratio data, slope was measured by regression and defined as rate of change in each muscle fatigue (Öberg et al., 1994; Öberg 1995).

3. RESULTS

Table1 shows the average values of the parameters according to the %MVC level. MPF decreased when %MVC value increased. [Medium/Low] showed an increasing tendency with increasing %MVC value. High/[Low + Medium] parameter showed a slightly decreasing trend when the% MVC value increased.

Table 1: Means of parameters at each %MVC level

Parameters	30% MVC	40% MVC	50% MVC
MPF	0.812783	0.790408	0.663751
[Medium/Low]	0.824196	0.868907	0.971753
High/[Medium+Low]	0.791353	0.771035	0.712563

The variance analysis was performed to compare the performance of parameters at each %MVC level (Table 2).

Table 2: ANOVA result: difference of mean values of parameters at different %MVC levels

Parameters	Source	SS	DF	MS	F	Pr>F
MPF	%MVC	4.3	2	2.15	39.91	0.001
	%MVC*Subjecs	10.982	18	0.61		
[Medium/Low]	%MVC	6.379	2	3.19	54.958	0.001
	%MVC*Subjects	36.603	18	2.033		
High/[Medium+Low]	%MVC	1.339	2	0.669	14.646	0.001
	%MVC*Subjects	16.737	18	0.93		

Frequency shift during 30% MVC and 40% at each parameters are shown in Figures 1 i 2.

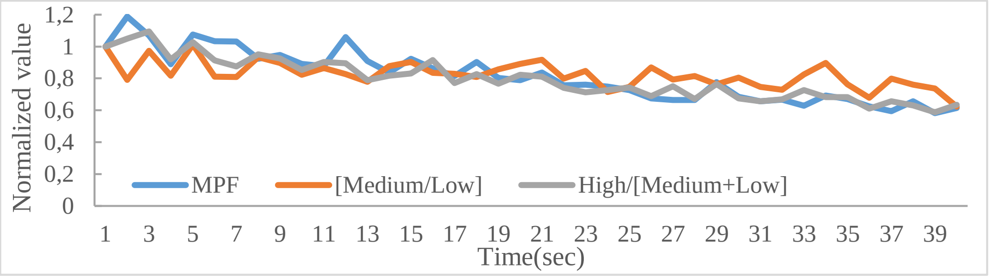

Figure 8: Frequency shift during 30% MVC at each parameters

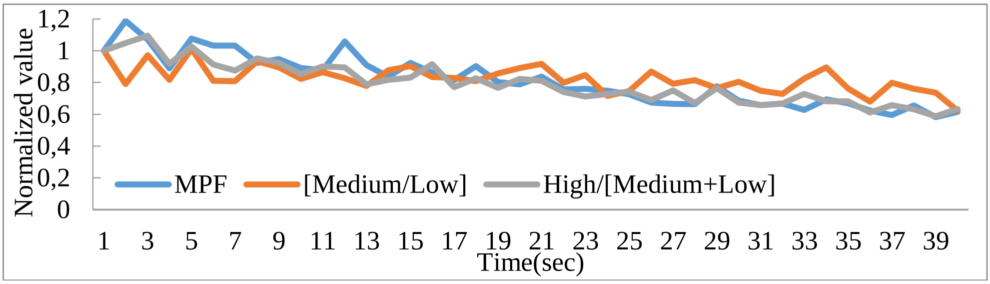

Figure 9: Frequency shift during 40% MVC at each parameters

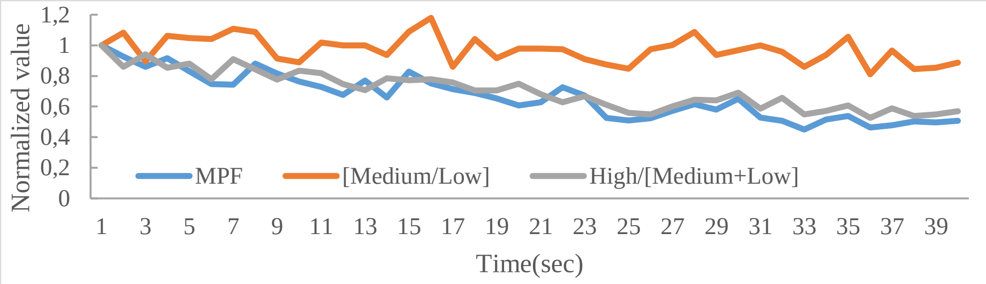

Figure 10: Frequency shift during 50% MVC at each parameters

Table 3: Regression analysis result of each parameters

Parameters / Conditions	MPF		Medium/Low		High/[Medium+Low]	
	Slope	R^2	Slope	R^2	Slope	R^2
30% MVC	-0.013	0.871	-0.004	0.402	-0.010	0.876
40% MVC	-0.013	0.865	-0.003	0.180	-0.011	0.894
50% MVC	-0.011	0.840	-0.003	0.210	-0.010	0.850

As the result of time series analysis, fatiguing phenomena was presented at various levels of muscle force in three parameters. MPF and High/[Low + Medium] parameters decreased as the time passed at all MVC conditions. [Medium/Low] under 50% MVC condition, the decrease of the mid-frequency band was very limited (Figure 3). Result of regression analysis showed that [Medium/Low] frequency band ratio had low slope value and low R^2 value (Table 3).

4. DISCUSSION

As a result, the sensitivities of MPF and High/[Medium+Low] were high in the time series analysis, however, those two parameters showed a similar performance in detecting the early fatigue of the deltoid muscle. However, the [Medium/Low] parameter was shown to be very insensitive to detect the early fatigue because its insensitive response at 50% MVC as well as very low R^2 value. Therefore, the parameters using various band ratio indicated a potentially sensitive one; however, it is necessary to examine the parameters with a greater variety of muscles and postures in order to use them as an alternative or more sensitive tool to detect early fatiguing sign.

5. CONCLUSION

Measuring the short-term muscle fatigue is a challenging task since it usually takes time to get the muscles fully fatigued. Therefore, MPF, [Medium/Low] and High/[Medium+Low] parameters were tested in this study to detect the time-varying trend of fatiguing in a short period of time. Although the sensitivity of the frequency-band-ratio parameters did not outperform the MPF, taking advantage of frequency attribute can be important step to predict early fatiguing sign of muscles. The study can be further conducted for other major muscles that are often vulnerable to injury and source of discomfort. The reliability of the parameter performance can be also improved along with further investigation.

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PERFORMANCE OF NEOPRENE WETSUITS IN DIFFERENT UNDERWATER THERMAL ENVIRONMENTS

V. M. Potočić Matković, I. Salopek Čubrić
University of Zagreb Faculty of Textile Technology, Zagreb, CROATIA,
marija.potocic@ttf.hr, ivana.salopek@ttf.hr

Abstract

Wetsuits are designed for the protection of divers in different underwater environments (i.e. where the temperature of water is in the range 10-25°C) and to reduce the thermal shock due to the stay in cold water. In this research, the focus is given to the investigation of neoprene wetsuits produced in three thicknesses, i.e. 3, 5 and 7 mm. In the experiment participated divers wearing wetsuits in different underwater thermal environments. The thermography is used to investigate the changes in body temperatures of participating divers due to the different thickness of wetsuits and different thermal environment. Additionally, the thermal resistances of neoprene materials are measured in controlled conditions using the sweating guarded hotplate. The results indicated strong correlation between thickness and heat resistance. Thermography indicated the great impact of the environmental temperature, thickness of wetsuit and physiology of divers on changes of skin temperature during immersion over time.

Keywords: *fabric, neoprene wetsuit, thermal environment, thermography, sweating guarded hotplate*

1. INTRODUCTION

Wetsuits are designed for the protection of divers in different underwater environments (i.e., where the temperature of water is in the range 10-25°C) and to reduce the thermal shock due to the stay in cold water. Dominantly are worn by divers, surfers, windsurfers, canoeists, and others engaged in different water sports. Regarding the main properties of wetsuits, it is expected to be soft and elastic (due to the fact that wetsuits are worn next to the human skin), but at the same time of high tensile strength and tear resistance in order to protect the divers from being hurt by rocks, coral or animals. Considering the requirements, wetsuits are nowadays mostly made by laminating the neoprene foam and elastic fabric.

The measurements of wetsuits' efficiency is performed either using the human trials or in laboratory with simulated real-life conditions. A number of investigations is focused at comparisons of those two approaches. According to Mak et al., there is very limited researches that address the correlations between the results of measurements using human trials or thermal manikins in order to provide appropriate recommendation for the development of applicable standards for wetsuits [1]. Their investigation was focused at

comparison of heat loss measured using two thermal manikins and human trials suits. The outcomes of the investigation indicated that the heat loss from the manikins was a good representation of the heat loss from humans [1]. In another study, Hall et al. compared performance and body temperature of triathletes swimming in cold water (the temperature of 14°C) with and without wetsuit. During the experiment, a part of athletes gave up because they were unable to complete swimming without the wetsuit. The results indicated a significant difference in the change of linear temperature rate of athletes that were swimming with and without wetsuit [2]. The research conducted by Pavlik et al. was also focused at performance of athletes wearing wetsuits. Based on the results, the authors concluded that wearing wetsuits improves the swimmer performance [3]. The similar conclusion came out as the result of research conducted by Tomakawa et al. They suggested that use of wetsuit improves swimming performance and reduces energy consumption in swimming portion [4]. Regarding the athletes satisfaction when wearing wetsuits, the study indicated that, for female and older divers, the functional performance of wetsuits is more important than for male and younger divers [5].
In the previous investigation conducted by authors of this paper, thermography is used to measure changes in upper body temperature of divers wearing thick neoprene diving suit before and during immersion [6]. After 25 min of immersion, lowest skin temperature was recorded in the zone of neck and it was 17% lower than before immersion. In this research, the focus is given to the investigation of neoprene wetsuits produced in three thicknesses. The thermography is used to investigate the changes in body temperatures of participating divers due to the different design of wetsuits and different thermal environment.

2. EXPERIMENTAL

In the experiment participated four experienced divers, among which two male divers. The divers are 40±1 years old, of average body constitution and in good health. During the experiment, divers wore neoprene diving suits in three thicknesses - 3, 5 and 7 mm. The diving sessions are carried out in three different underwater thermal environments, as described in Table 1. The first and second thermal environments (i.e. TE1 & TE2) are relatively warm summer environments (air temperatures 26.5°C and 29.0°C; water temperature 23.6°C and 24.4°C), while the third thermal environment (TE3) is much colder autumn environment (air temperature 17.0°C, water temperature 18.4°C).

Table 1: Conditions in different thermal environments

	Water temperature (°C)	Air temperature (°C)	Air humidity (%)	Wind speed (km/h)
Thermal environment 1 (TE1)	23.6	29.0	52	8
Thermal environment 2 (TE2)	24.4	26.5	70	9
Thermal environment 3 (TE3)	18.4	17.0	67	4

For the measurement of body temperature before and after immersion, the thermal camera FLIR E6 is used [7]. After the indicated time period (5, 10, 15, 20 or 25 minutes), divers would come out of the water and the skin temperature of the chest is measured. The illustration of measurement using the thermal camera is given in Figure 1.

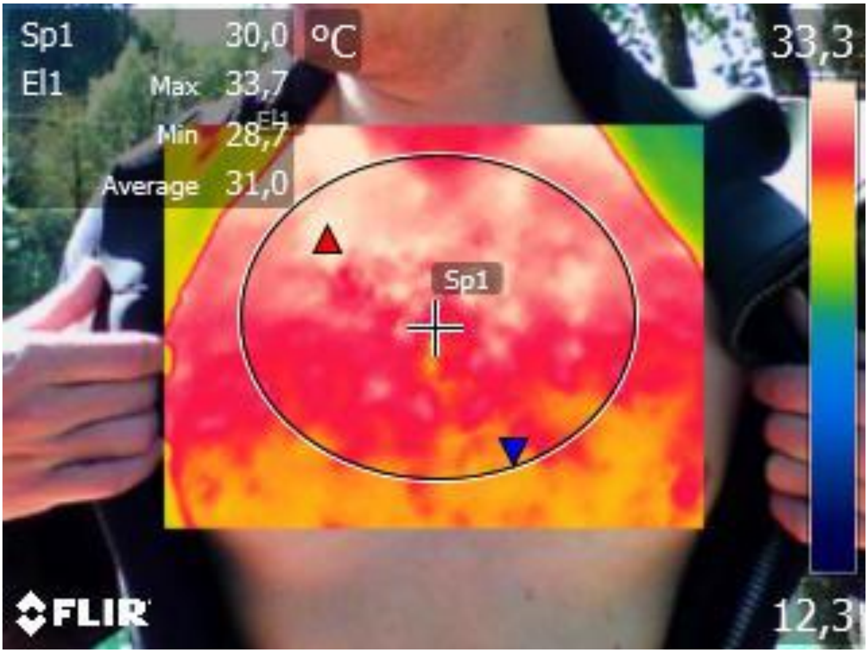

Figure 1: Thermal measurement of skin temperature for a diver wearing 7 mm neoprene wetsuit

Measurement with thermal camera provides the actual data of the skin temperature in the real environmental conditions on a real person. However, the metabolism of each individual is different and the environmental conditions change rapidly, what can have a major impact on the results of measurement. Therefore, the heat resistance of neoprene materials is also measured using the sweating guarded hotplate in laboratorial conditions [8]. During the tests, the sweating guarded hotplate was placed into an air conditioned chamber where the following conditions were established and maintained: air temperature of 20°C, 65% of relative humidity of the air and the velocity of airflow of 1 m s^{-1}.

3. RESULTS AND DISCUSSION

The results present the skin temperature of divers wearing 3, 5 and 7 mm thick wetsuits compared to skin temperature of diver without wetsuit in three thermal environments, i.e. TE1, TE2 and TE3 (Figures 2-4). The heat resistance of neoprene materials, as well as the linear correlation of thickness and heat resistance of measured samples, are given in Table 2 and in Figure 5.

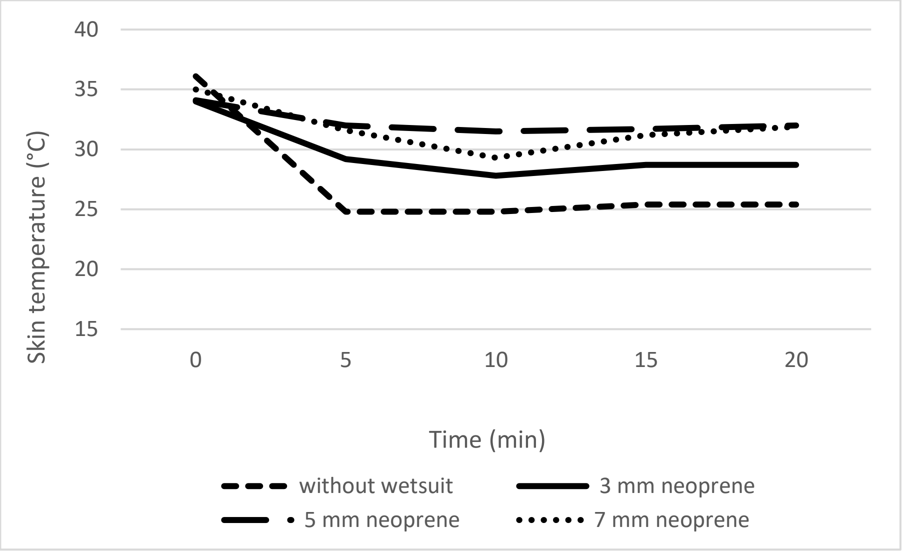

Figure 2: Skin temperature of divers in thermal environment 1 wearing 3, 5 and 7 mm wetsuits compared to skin temperature of diver without wetsuit

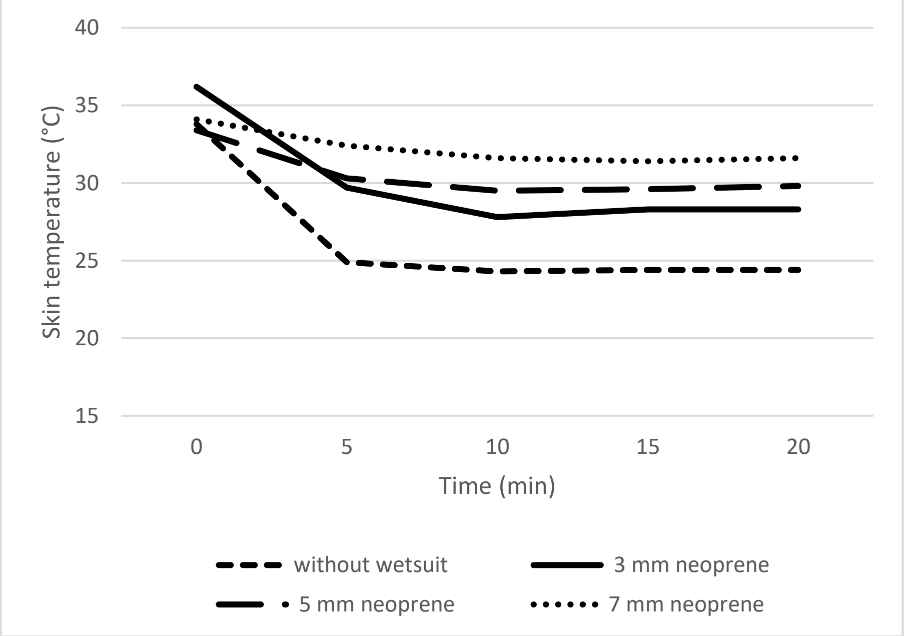

Figure 3: Skin temperature of divers in thermal environment 2 wearing 3, 5 and 7 mm wetsuits compared to skin temperature of diver without wetsuit

The first and second measurements (presented in Figure 2 and Figure 3) are performed in relatively similar thermal environments, and the results are somewhat different because divers react differently to the cold water. The skin temperature of four divers was different before immersion, but the initial differences seem to have no effect after the 5 minutes of immersion. The skin temperature of a diver without a wetsuit drops abruptly and after the first 5 minutes reaches the temperature slightly higher than the temperature of the water. In the next 15 minutes, the skin temperature remains almost constant, even slightly increases, but after 20 minutes, the diver feels cold and therefore the measurement is completed. Three divers in the wetsuits lose heat gradually; the skin is coldest after 10 minutes, and then the temperature slightly increases. The influence of the thickness of neoprene wetsuit (3, 5 and 7 mm) on heat retention in both measurements is clearly seen.

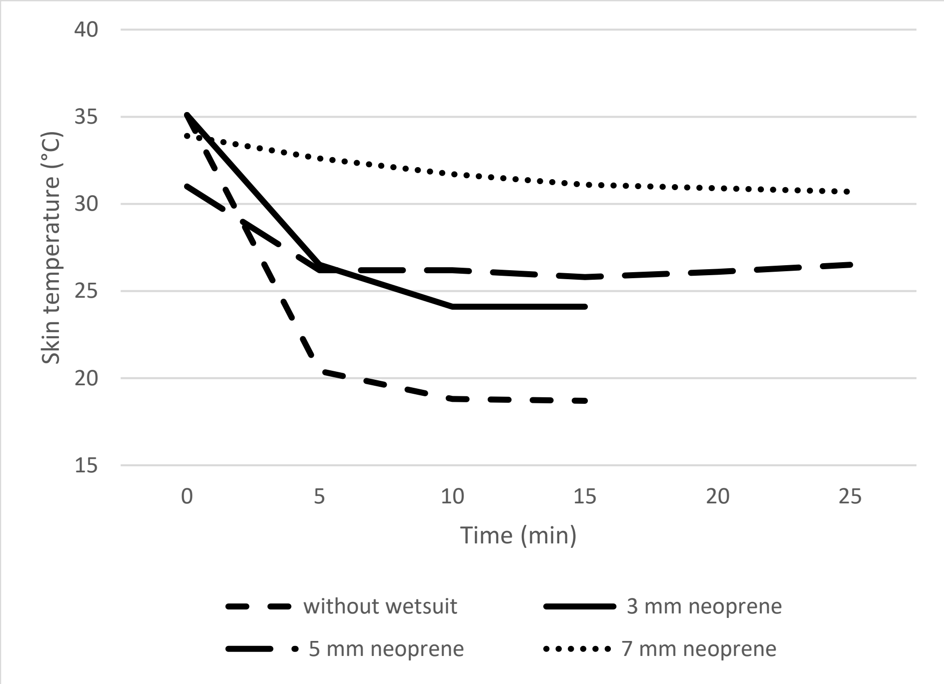

Figure 4: Skin temperature of divers in thermal environment 3 wearing 3, 5 and 7 mm wetsuits compared to skin temperature of diver without wetsuit

Third measurement (presented in Figure 4) is quite different because of the low water temperature (18.4 °C). A diver without a wetsuit loses heat abruptly in the first 5 minutes and then somewhat slower. After 10 minutes, the skin temperature almost reaches the water temperature, and after 15 minutes, the measurement is completed because a diver could not withstand the cold. A diver in a 3 mm wetsuit also quickly loses the heat, and although the temperature of the skin is far warmer than a temperature of the diver without wetsuit, the diver wearing 3 mm wetsuit does not feel comfortable after 15 minutes. Therefore, the measurement is completed. However, divers in 5 and 7 mm wetsuits lose the heat slowly. The difference in heat retention between the suits of 5 and 7 mm is more

evident than in the previous two measurements, but both divers feel comfortable in the cold water even after 25 minutes.
The precise measurements of heat resistance on the sweating guarded hotplate (results shown in Table 2) refer to the measurements of two samples of 3 mm neoprene, five samples of 5 mm neoprene and two samples of 7 mm neoprene. The samples are produced by different manufacturers, what is assigned as M1, M2 and M3 (Table 2). All producers are well known and respected on the market.

Table 2: The heat resistance of neoprene samples

Sample	Designation of manufacturer	Thickness, mm	Heat resistance, m^2KW^{-1}	
			Mean value, m^2KW^{-1}	Coefficient of variation, %
n1	M1	3	0.0692	0.46
n2	M1	5	0.0783	0.48
n3	M2	3	0.0751	0.43
n4	M2	7	0.1331	0.67
n5	M1	5	0.1091	0.83
n6	M1	7	0.1771	0.29
n7	M3	5	0.1096	0.73
n8	M1	5	0.1239	0.59
n9	M1	5	0.1009	0.37

As seen from Table 2, the heat resistance of measured neoprene samples is in the range 0.0692 to 0.1771 m^2KW^{-1}. The values of the coefficients of variation are rather low indicating that obtain values of heat resistance are credible. The results show significant differences between the values of heat resistance, regardless of the same thickness of material (Table 2).
Although the linear correlation (Figure 5) shows the dependence of heat resistance on the thickness of the neoprene ($R^2 = 0.7496$), the neoprene of 5 mm may have almost equal heat resistance as a neoprene of 3 mm (seen from the comparison of samples n2 and n3). Also, one neoprene sample of 7 mm (sample n4) has quite similar heat resistance as the 5 mm neoprene produced by different manufacturer (sample n8). The differences between the values of 5 mm neoprene samples produced by the same manufacturer (in this case M1), are well seen if the samples n2, n5 and n8 are compared. The measured values for the mentioned neoprene samples are 0.0783, 0.1091 and 0.1239 m^2KW^{-1}. The reason for such difference between the results is related to the fact that producer laminated different knitted fabrics on neoprene material.

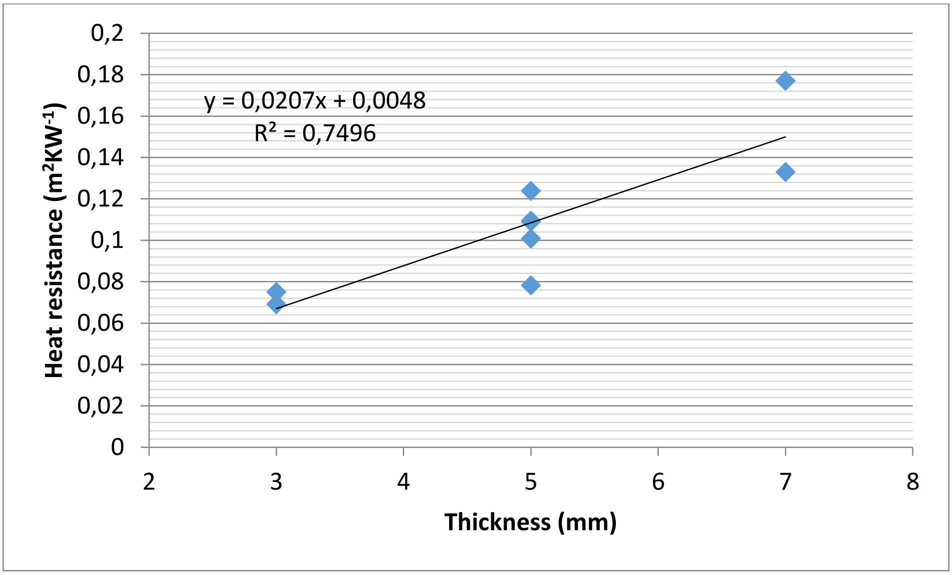

Figure 5: Linear correlation of thickness and heat resistance of measured samples

4. CONCLUSION

Based on the research presented, the following conclusions are made:

- field based thermal imaging, as well as laboratory measurements of heat resistance, clearly show a positive influence of the thickness of neoprene on retaining of body heat in the water.
- measurements with a thermal camera additionally pointed out the influence of the person's metabolism on the change of body heat over a given period of time.
- sweating guarded hotplate measurements have shown that all materials declared as neoprene of 3, 5 and 7 mm do not have the same heat resistance characteristics.

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OCCUPATIONAL RISK ASSESSMENT IN DEBURRING AIRCRAFT PARTS USING RULA AND ERIN METHODS

A. Realyvásquez, F. B. López-Rubio, F. U. Castrejón-Villegas, G. Hernández-Escobedo, J. González-Reséndiz
Instituto Tecnológico de Tijuana, Tijuana, MEXICO,
arturo.realyvazquez@tectijuana.edu.mx

Abstract

Even today, injuries, illnesses, and other work-related accidents are common in the manufacturing industry. Such accidents are mainly derived from poor or inappropriate workstation designs that lead to incorrect body postures and thus increase the probability of workplace hazards. This article seeks to determine the level of occupational risk to which manufacturing company workers are exposed when deburring aircraft parts. To this end, we assess the level of musculoskeletal disorders (MSDs) risk using the Rapid Upper Limb Assessment (RULA) and the Individual Risk Assessment (ERIN) methods. The results of RULA showed a general risk score of 7 and a high level of risk, whereas ERIN showed a general risk score of 19 and a medium level of risk.

Keywords*: work risk factors, postures, ergonomic assessments, RULA, ERIN*

1. INTRODUCTION

Ergonomics can be defined as the science that studies the interactions among humans and other elements of a work system. Also, ergonomics is the profession that applies theories, principles, data, and design methods to optimize human well-being and overall system performance [1]. The main goal of ergonomics is to preserve worker health, safety, and comfort [2], since a healthy, comfortable, and safe work environment improves work performance [3]. In this sense, several job-related factors can compromise worker health, safety, and comfort. Such factors may be environmental, psychosocial, or posture-related. As regards environmental risk factors, we can find lighting [4, 5], noise [5, 6], and temperature [5, 7], whereas psychosocial risk factors in the workplace include mental workload and job demands, among a few [8]. Finally, uncomfortable and forced postures can also be a source of workplace hazards [5, 9].

Ergonomics relies on a wide range of assessment methods that help determine whether a given workstation provides a healthy, comfortable, and safe environment to the worker. In the case of posture assessment methods, the literature discusses systems, approaches, and techniques such as the Rapid Entire Body Assessment (REBA) [10], the Ovako Working Posture Analysis System (OWAS) [11], the Rapid Upper Limb Assessment (RULA) [12, 13], and the Individual Risk Assessment (ERIN, by its Spanish acronym) [14], among others.

Ergonomic studies conducted in the Mexican manufacturing industry demonstrate that Mexican manufacturing companies lack appropriate ergonomic work conditions, and consequently, they are a source of numerous workplace risks or hazards [15–18]. For instance, a study conducted in a computer manufacturing company located in Ciudad Juárez found that the task of repairing computers exposes workers to high musculoskeletal disorders (MSDs) risks [15]. Similarly, Hernández et al. [17] explored the relationship between workload and fatigue among Mexican assembly operators and determined that manipulated weight ranging from 3 kg to 14 kg contributed to a lack of worker energy, increased worker exhaustion, and consequently, decreased worker performance. Finally, Hernández et al. [18] found that the tasks performed by advanced manufacturing technology (AMT) operators demanded both physical and mental efforts that jointly caused early fatigue.

Numerous findings of studies conducted in the Mexican industry thus demonstrate the importance of ergonomically assess the working conditions of Mexican manufacturing companies. That said, this work aims to assess the level of MSD risk to which workers of a manufacturing company located in Tijuana are exposed when deburring aircraft components, namely seat rails. To conduct such an assessment, we rely two ergonomic assessment methods: RULA and ERIN. Also, at the end of the research, we propose ergonomic interventions to reduce the detected risk levels. Following section states the theoretical fundamentals of workplace hazards, and the RULA and ERIN methods.

2. LITERATURE REVIEW

2.1 Workplace hazards

A workplace hazard is any aspect of a workstation that has the potential to harm or cause an adverse effect on workers [19]. Workplace hazards or occupational risks derive from multiple activities or different environments and are categorized into six types: safety hazards, physical hazards, biological hazards, chemical hazards, work organization hazards, and ergonomic hazards [19]. Ergonomic hazards are the focus of this research. They are primarily the result of repetitive movements, use of excessive force, frequent lifting, and poor postures [19]. Also, long-term exposure to ergonomic hazards in the workplace can cause fatigue and MSDs. In this sense, two common ergonomic assessment methods include RULA and ERIN.

2.2 The Rapid Upper Limb Assessment (RULA)

RULA assesses the workers' exposure to ergonomic risks factors or ergonomic hazards, which can cause MSDs [14]. This assessment is performed by watching workers complete their tasks [20] and takes into account four variables: the number of movements performed, static muscle work, force, and postures [21]. Likewise, the RULA assesses two body segment groups: A) arm, forearm, and wrist; and B) neck, trunk, and leg [12, 21]. Also, each side of the body – right and left – is analyzed separately [21, 22], and RULA uses a worksheet that includes pictures of worker postures for each body segment. The final score ranges from 1 to 7 and reflects the level of MSD risk. That is, the highest score values denote very high MSD risk [21]. Table 1 below depicts the MSD risk scale and the action levels proposed in by the RULA [21].

Table 1. Levels of MSD risk and action levels of RULA

MSD Risk Level	Score	Action Level
Level 1	1-2	Negligible risk, no action required.
Level 2	3-4	Low risk, change may be needed.
Level 3	5-6	Medium risk, further investigation. Change soon.
Level 4	7	Very high risk. Implement changes.

RULA results allow evaluators to visualize and understand better the potential workplace hazards that a particular job or task may promote. Also the analysis can contribute to the implementation of ergonomic measures that improve job postures and thus decrease the levels of MSDs risk. Finally, as can be observed in Table 1, the proposed action levels suggest evaluators a time to make changes, depending on the detected level of MSD risk.

2.3 The Individual Risk Assessment (ERIN)

ERIN is a practical tool for assessing work-related MSDs. It was designed for easy use without need for an advanced degree in ergonomics [23, 24]. ERIN is based on current epidemiological evidence regarding MSDs, available ergonomic tools, and the collaboration of ergonomists, industrial engineers, occupational health and safety experts, and human resources specialists [23]. The goals of this tool are to assess workstations, detect levels of MSDs risk, and determine the action levels required to diminish such levels [24]. To perform the assessments, ERIN considers seven variables: posture and frequency of movement of the trunk, shoulder/arm, hand/wrist, and neck; the rhythm resulting from the interaction of work speed and the duration of each task; intensity of effort; and a self-assessment (workers must indicate how much stress is required to complete the task) [14, 23].
ERIN relies on a system of scoring each body part posture. In order to simplify the posture identification, ERIN combines pictures with descriptive words [14]. Then, to obtain the global risk score for a worker, the evaluator adds the risk values of the seven variables. [14]. The results of an ERIN-based evaluation can help determine the level of ergonomic intervention required to reduce the risk of injury and MSDs in the workplace. In this sense, Table 2 shows the levels of risk identified by ERIN and their corresponding action levels [14, 23, 24]. As can be observed, the lowest risk level is found in the green area and has a global risk score of 7-14; in this case, changes are not necessary. On the other hand, the highest risk level is found in the red area and has a global risk score equal to or higher than 36. In this case, changes must be immediately implemented.

Table 2. Risk levels and action levels of ERIN

Area	Global Risk	Risk Level	Action Level
Green	7-14	Low	Changes are not necessary.
Yellow	15-23	Medium	Further investigation required. Possible changes.
Orange	24-35	High	Changes must be implemented soon.
Red	≥36	Very High	Changes must be immediately implemented

In conclusion, both RULA and ERIN offer two major advantages: the evaluations can be easily conducted using a worksheet and a pencil, and the assessment, including the recording equipment, does not interfere with the worker's work.

3. METHOD

This research was conducted in a manufacturing company located in Tijuana, Mexico. The company primarily supplies the aerospace and defense industry, which provides approximately 80% of the company's total revenue. The remaining 20% derives from the application of these technologies in adjacent markets. The company specializes in three core areas or segments: Avionics and Control, Sensors and Systems, and Advanced Materials. Operations in the Avionics and Control segment focus on technology interface systems for commercial and military aircraft, similar devices for land- and sea-based military vehicles, communication systems, high-performance digital receivers, specialized medical equipment, and other high-end industrial equipment. On the other hand, the Sensors and Systems segment includes operations that manufacture high-temperature and high-pressure sensors, specialized power and motion components, power distribution systems, specialized harsh-environment connectors, and other related systems mainly for aerospace and defense purposes. Finally, the Advanced Materials segment produces process-related technologies, such as high-temperature resistant materials and parts used for a wide range of military and commercial aerospace purposes, state-of-the-art insulation materials, and warfare countermeasure products.
The methodology of this research is cross-sectional and non-experimental. The following sections discuss the materials used to conduct the ergonomic assessment, the characteristics of the subject to be studied (i.e. worker), the task to be assessed, and the procedure followed to determine the level of MSD risk in the task of deburring aircraft parts.

3.1 Materials

The materials used in this research include:

1. HP 15 Windows 7 laptop computer
2. Samsung Galaxy video camera
3. Online software of RULA and ERIN

3.2 The subject

As allowed by the company, the evaluation comprised only one subject, a 33-year-old, female worker with anthropometric measures of 180 pounds of weight and 63 inches of height. Also this worker has three years of experience in deburring aircraft parts; she works nine hours per day, has a one-hour break in between, and works seven days per week. This means that the worker executes the same task repetitively for nine hours the seven days of the week.

3.3 Procedure

The methodology of this research comprises seven stages, thoroughly described below:
Stage 1: Reaching the manufacturing company: To this end, we requested access to the National Statistical Directory of Economic Units (DENUE), property of Mexico's National Institute of Statistics, Geography, and Informatics (INEGI). DENUE is a national directory that contains information on the economic units established in the

country, including 483 manufacturing companies. The data stored in this database includes the company's economic activity, size, juridical organization (individual or legal entity), and contact information, such as company name, phone number, website, and postal address.

Stage 2. Presenting the research: Once the company was reached, this project was presented to it by highlighting the goals of this research and benefits it would bring.

Stage 3. Selecting the task to be assessed: To determine the task to be assessed, we interviewed the company managers and supervisors to identify the tasks that involved uncomfortable postures. Then, we performed an inspection of the plant to detect other tasks. In the end, we selected the task of deburring parts. Figure 1 shows the studied worker performing this job.

Figure 1: Worker deburring an aircraft part

Stage 4. Task analysis and assessment: To this end, we used the video camera to record the movements performed by the worker (postures and exposure time) without disturbing or making her uncomfortable. Then, we analyzed the recording to identify the most critical postures of the deburring task. Finally, we applied RULA and ERIN to estimate the global risk assessment of the task. More specifically, we implemented RULA through the platform Ergonautas.upv.es [22], whereas the platform called Ergoyes.com was used to implement the ERIN method [25].

Stage 5. Results analysis. The results obtained in each method were analyzed according to the risk scales presented in Table 1 and Table 2 for RULA and ERIN, respectively. Based on this analysis, we identified the high-risk postures for the deburring task. Then, we developed a series or ergonomic improvement proposals.

Stage 6. Ergonomic improvement proposals: Such ergonomic interventions were proposed after consulting similar studies and identifying the most appropriate of those suggestions.

4. RESULTS AND DISCUSSION

4.1 The Rapid Upper Limb Assessment (RULA)

The results of the RULA for the body parts in group A (arm, forearm, wrist) showed the highest score, +3, in the wrist, since this body part is the most used in the deburring task. Then, +2 was obtained for the forearm. Finally, the arm had a score of +1 since this body part does not present an extension or flexion greater than 15°. As regards the body parts of group B (neck, trunk, and leg), the neck showed +4, the highest score, due to its incorrect postures. This high score denotes that the worker is exposed to high MSDs risks, and her neck movements can cause early aging of the cervical joints and cervical damage. In the end, the global risk score obtained with RULA was 7. Figure 2 shows the result obtained with RULA. According to the action levels introduced in Table 1, ergonomic changes must be immediately implemented to reduce MSDs risk levels in the task of deburring aircraft parts.

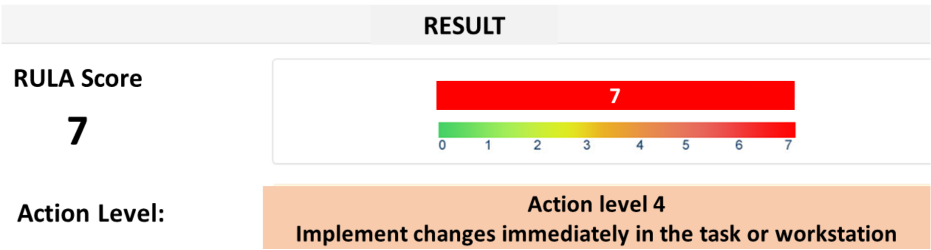

Figure 2: Risk level with RULA

4.2 The Individual Risk Assessment (ERIN)

We initially obtained +2 for the trunk due to moderate flexion, but then +1 was added for trunk twist, thus obtaining 3 as the final score. On the other hand, we obtained +4 for the arm due to moderate flexion and occasional extension. With respect to the wrist, +2 was obtained due to its slight flexion when removing the resin from the parts. As for the neck, +4 was given mainly because of extreme static flexion of more than 20º for more than one minute. Similarly, +2 was obtained for the rhythm of work due to normal work speed and an effective duration of the task that ranged from 2-4 hours. As regards intensity of effort, we obtained +2 after observing the worker's facial expressions and relaxed state. Finally, the worker assessed the task of deburring parts as moderately stressful, making 5-10 efforts per minute. In this case, we obtained +2 for effort and +2 for stress self-assessment. The global risk score obtained was 19, corresponding to a medium risk level (yellow area) and indicating that further investigations are required, as changes may be necessary.

5. CONCLUSIONS AND RECOMENDATIONS

Ergonomics has demonstrated to be an effective approach to improving overall workplace conditions. Although it is often underestimated, ergonomics can be effectively

implemented with qualified staff, training, and employee awareness of its impact. Since ergonomic assessments provide a clearer understanding and vision of high-risk tasks, we conclude that the most vulnerable body parts are the neck and the trunk. Such results highlight the need for workstation redesign to diminish MSD risks in the workplace, namely in the task of deburring aircraft parts.
Based on the RULA and ERIN results, we recommend the company to include a container below the deburring area for the worker to fluently displace the burr away the deburring table. Likewise, it is important for workers to work on adjustable-height tables, as they improve body movements and neck postures, and consequently, they can reduce risks of MSDs. Similarly, the workstation should include armrests, so the worker can comfortably support their forearms and elbows and avoid fatigue and possible pain. Also, we suggest including short breaks and five-minute stretching sessions at least every hour to restore the muscle structure and tendons. Finally, we advise the manufacturing company to implement ergonomic chairs and promote the use of gloves in the task of deburring aircraft parts.

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AN ERGONOMIC TOOTHBRUSH DESIGN FOR DISABLED PEOPLE

H. Sadeghi Naeini[1], M. Rafiee[2]
[1] Associate Prof., Industrial Design Dept, , Iran Univ. of Science & Tech.(IUST), Tehran, Iran, naeini@iust.ac.ir
[2] School of Arch. & Urban studies, Iran Univ. of Science & Technology, Tehran, Iran rafiee.mitra@yahoo.com

Abstract

The main objective of this paper is to ergonomically design a manual toothbrush for cervical spinal cord handicapped. Undoubtedly, the main goal of ergonomics is to fit the tasks and daily activities to human limitations and abilities. In this study also, the authors tried to make the conditions better for the disabled by developing a new toothbrush. Some sorts of disabled people are not able to control their hands' movement, so their difficulties in ordinary toothbrush might be ended to some health problems for their teeth. In this study, a new toothbrush was developed based on user-centered design among 27 volunteers. Interviews, hand anthropometry measurement were also done. Besides, some of the toothbrushes existing in the market were assessed in terms of ergonomic confirmations. According to the collected data and assessment of users' reflections, the preliminary step of sketching and designing was developed, and then, the design process was completed. Besides, the aspects of aesthetics in design were considered.

Keywords*:* *Disability, Ergonomics, Toothbrush design, Quality of life*

1. INTRODUCTION:

The root of disability might be associated with several sorts of factors. Some of the main causes of disability are accident, genetics, aging, diseases and so on.
In terms of social aspects, disabilities should not limit the people's activities. In this regard, all of the related experts and organizations should define some solutions and ways to help the disabled to have better and feasible social communications. Nowadays' technologies try to help people to have higher quality of life. Undoubtedly, the disabled have a special place in these regards. Furthermore, quality of daily life is so prominent in terms of social, health, safe and security aspects. Disability might be the effects of disabled health style. In this ongoing study, it was focused on tooth health of the handicapped who are not able to control their hands' movement. Some parts of this study have been done in a couple of months ago. In this paper, the progressed results are highlighted.
Spinal cord injuries (SCI) are divided into two categories: paraplegia, tetraplegia [1]. With regard to international standards of the classification of cutaneous spinal cord, each category can include complete damage or defective damage [2].

The results of tetraplegia affect the function of the arms, as well as the body, legs, and pelvic organs [1]. People with the spinal cord damage at C2-C4 levels may not even have any function in their arms or hands at all, while people with the damage at C5 level, which is more common level of damage, have limited function in their shoulder and elbows [2]. People with the damage at C6 level may have a wrist stretch, while they have better conditions in some of their functional abilities, but still lack the motion of the triceps brachii muscle, which is reserved in the C7 area; this case limits the access and exercise maneuvers [2]. At higher levels of injury, C5 and C6, the ability of the muscle under the control becomes less and alternative methods are required [3] (Figure 1).

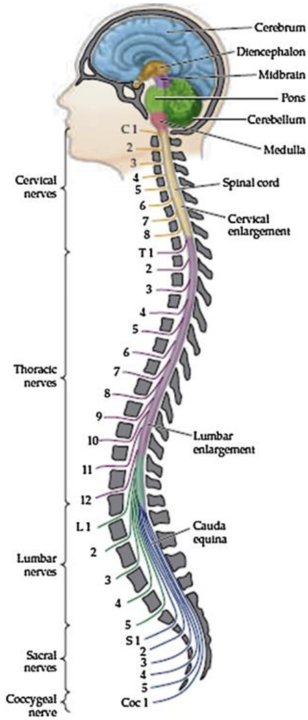

Figure 1: Spinal cord structure and neural roots classification [4]

In patients with incomplete tetraplegia, sensory intakes and motor outputs are often altered and inappropriate, and like the subjects with complete tetraplegia, sensory and motor functions disappear [2]. One of the most devastating aspects of cervical spinal cord injury is observed in the functions of the arm and hand. It has a great influence on the level of independence and is identified as the greatest extent of the defect [5]. The level and extent of the lesion affect the level of independency of the patient [6].
However, these people have problems in working with manual tools. On the other hand, brushing teeth as an effective factor in improving the level of oral hygiene requires the use of tool, namely toothbrush. Tooth brushing is the most basic way to keep a person's oral health at high level. However, even for adults, inadequate brushing can cause cavity and inflammation in the gum that ultimately leads to tooth decay or loss [7, 8]. Factors affecting oral health such as tooth decay, affect not only physical health, but also impair quality of life and disrupt effective performance, interpersonal relations, social relations,

self-esteem, and mental health. [9, 10]. Oral and dental health of people with disabilities is worse than the healthy people of the same age. Their medical, physical, social and psychological disabilities limit their access to oral health, diagnosis, prevention and medical services [11].
Toothbrush design for the mentioned group is the main aim of this study. In this practical study, one of our previous design was completed to develop an appropriate ergonomic product for the market considering the disabled's quality of life (QoL).

2. ERGONOMICS DESIGN AND QOL

Ergonomics as a multidisciplinary science aimed to design and improve the workplace conditions, product, and improve the quality of life [12, 13, 14, 15].
Occupational health and safety, tools, machinery and furniture design, better employee performance, work environmental assessment, are some of the ergonomics scopes [16].
Ergonomics has some sub-branches such as micro-ergonomics, macro-ergonomics, and cognitive, environmental, and cultural ergonomics [17]. Each mentioned groups help employers, employees, and end users to have a better, safe and pleasant life and activity.
Quality of life as the main target of ergonomics approaches are not limited to working places, it is also relating to products, services and so on. Daily life is also considered by ergonomics considerations. All sorts of users, operators, customers, and consumers are considering ergonomics interventions. In this regard, vulnerable groups such as elderly or disabled people have a specific place. In this research, we focused on the mentioned group and toothbrush design, as a target group and a daily health-based product, respectively.
Undoubtedly, the role of ergonomics in having a successful product design process is very important. Industrial design and ergonomics should have an appropriate association to develop products.

3. METHOD

This case study aimed to design a toothbrush for the disabled people who have some problems in their hand and finger movement in order to promote their tooth health. In-depth observation, interviews and user-centered design method were done to gather the appropriate data. Ergonomic analysis of existing toothbrushes was also done. In this study, our participants were 27-handicapped volunteers. Data collection was done in three phases. In the first step, we asked the participants to use some current and ordinary toothbrushes, which they use daily. The second phase was followed by our designed toothbrush in which we asked the participants to use our prototype. In the 3rd phase, which is an ongoing study, the prototype is developing to be a final product (Figures 2-4).

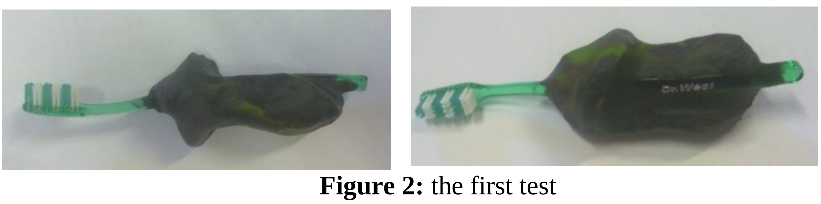

Figure 2: the first test

Figure 3: the second test

Figure 4: the third test

4. RESULTS

Our findings show that all current toothbrushes, which were our samples, have problems in terms of ergonomic considerations. Based on the data collected, more than three samples were developed and one of them was selected as a best one based on user centered design (UCD). Touchpoints of the final toothbrush design show a better condition in terms of hand grasp during tooth brushing. The results of interviews show the necessity of handle texture redesigning.

5. DISCUSSION AND CONCLUSION

Tooth health is one of the handicapped people concerns. A healthy tooth is an important factor, in terms of not only face appearance, but also physiologic factors. Some sorts of people are not able to brush their tooth due to their hand and finger movement problems. In these regards, design of some specific toothbrushes should be developed. The current toothbrushes have some problems in terms of fitting with these group demands. In this study, we tried to introduce a new toothbrush sample for our specific target users (Figure 5). However, our findings show appropriate outcomes considering the final developed prototype. There are some problems in terms of handle texture, so we are doing some more detailed design to remove the mentioned limitation.

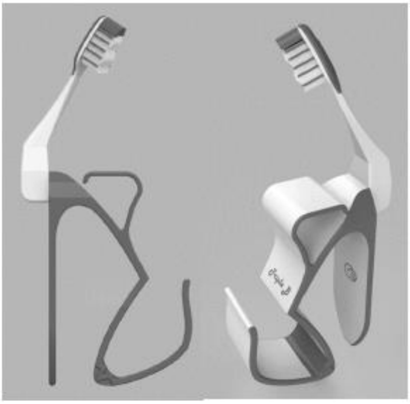

Figure 5: The recommended tooth brush design

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EFFECT OF MATERIAL CHARACTERISTICS AND GARMENT FIT ON REGIONAL THERMAL INSULATION

I. Salopek Čubrić[1], G. Čubrić[2]
[1] Department of Textile Design and Management, University of Zagreb Faculty of Textile Technology, Zagreb, CROATIA, ivana.salopek@ttf.hr
[2] Department of Clothing Technology, University of Zagreb Faculty of Textile Technology, Zagreb, CROATIA, goran.cubric@ttf.hr

Abstract

Infrared thermography is a non-destructive measuring method for the determination of temperature distribution on the surface of objects that is widely applied in almost all branches of human activity. The aim of the research is to use thermography to observe influences of different material characteristic and different garment fit on lower body thermal comfort. Thermal images of garments are obtained in two different temperature environments – moderate (t = 22°C) and cold (t = 2°C). The results indicated significant differences between surface temperatures of loose and tight models in both thermal environments. The highest difference is observed for the zone of upper shin. The results of thermographic measurements confirmed importance of material characteristics in the preservation of thermal comfort.

Keywords*:* *thermography, fabric, garment, thermal comfort, fit*

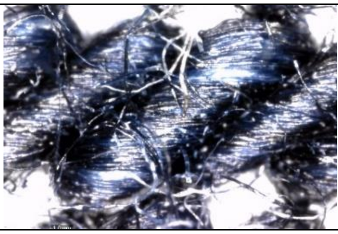
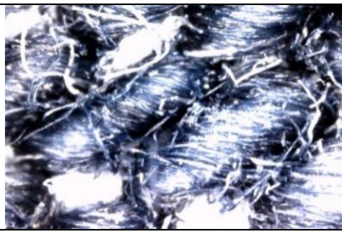
1. INTRODUCTION

Thermal comfort is the result of many factors related to the human body, climate conditions, the environment and clothing. In such context, clothing has a role of a barrier that protects the body from external factors. Thermal comfort largely depends on the structure of the material - that is, the number and characteristics of individual layers of clothing, as well as the thermal insulation properties of the material from which the clothing is made [1].
Infrared thermography is a non-destructive measuring method for the determination of temperature distribution on the surface of objects. It is very popular among the researchers in various fields. In the field of textile engineering, thermography may be used to observe the production process, textile material properties, clothing comfort, failure and product development [2, 3]. Thermogram of human body is very useful tool in the process of clothing design. It is widely used to observe differences in temperature of the body dressed in clothing produced of different materials and with different fitting properties [4]. Thermography also serves to evaluate the performance of clothing for personal use [5] and protective clothing (e.g. intelligent and thermal adaptive clothing), [6].
The research presented in this paper focuses at the use of thermography to observe influences of different material characteristic and garment fit on lower body thermal comfort in moderate and cold thermal environments.

2. EXPERIMENTAL

For the investigation presented in this paper are used 2 types of jeans trousers (assigned as Type A and Type B) in additional two modifications regarding the fit of trousers, i.e. as the loose and tight models. The characteristics of woven materials used for the production of each type of trousers (Type A and Type B) are given in Table 1. As can be seen from the Table 1, the type of raw material and fabric construction are the same, while fabrics differ in mass (410 vs. 560 g/m^2) and thickness (0.71 vs. 0.77 mm).

Table 1: Characteristics of materials used for the production of trousers

Property	Type A	Type B
Fabric Image (magnification 200x)		
Raw material	98% cotton, 2% elastane	98% cotton, 2% elastane
Fabric mass, g/m^2	560	410
Fabric thickness, mm	0.77	0.71

For the measurement of thermal characteristics, the thermal camera FLIR E6 is used. The specifications of used camera are as follows: IR resolution 120 × 90, MSX resolution 320 × 240, thermal sensitivity <0.10°C and standard temperature range –20°C to +250°C. The measurement is carried in two different temperature environments: moderate (t = 22°C) and cold (t = 2°C). The changes of temperature due to trouser type, fit and thermal conditions are observed for the following zones of lower body: pelvis, upper thigh, lower thigh, knees, upper shin and lower shin (shown in Figure 1). As defined in the previous chapter, the aim of the research is to get insight into the effect of material and garment fit to the changes of body temperature in different environments. Therefore, the results presented in this paper focus on the measurement of fabric surface temperature of participating female volunteer (40 years, height 162 cm, weight 53 kg, BMI 20) in good health condition.

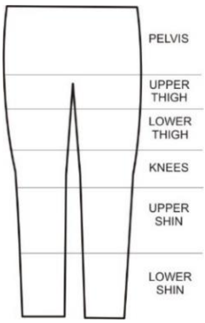
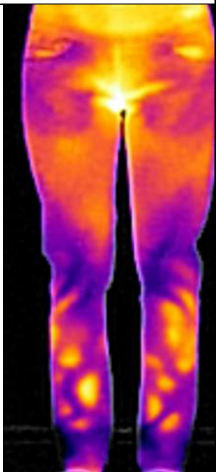
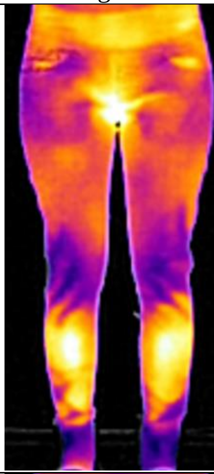
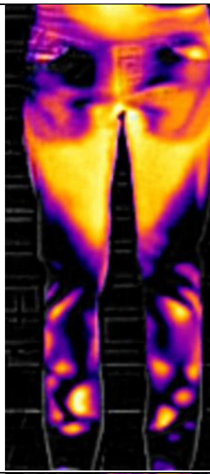
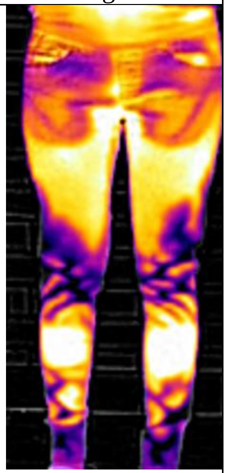
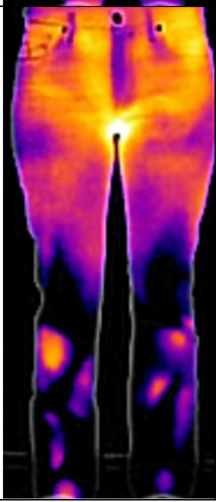
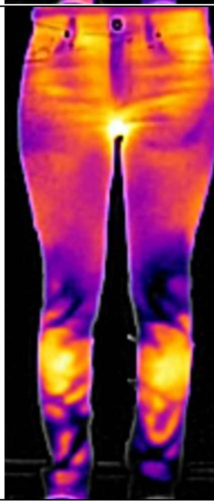
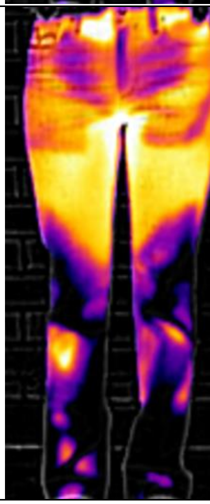
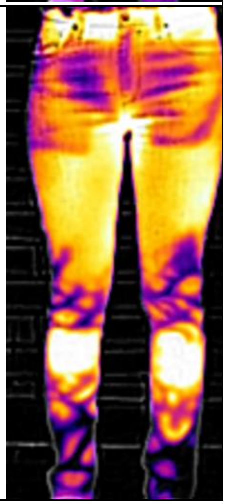


Figure 1: Observed body zones

3. RESULTS AND DISCUSSION

Thermograms taken during the measurements in the moderate and cold environments (i.e. at the temperatures of 22°C and 2°C) are given in Table 2. The results of measurements for the observed body zones (as defined in Figure 1) are given in Figures 2-5.

Table 2: Thermograms taken in moderate and cold environments

	Moderate environment (temperature 22°C)		Cold environment (temperature 2°C)	
	Loose	Tight	Loose	Tight
Type A				
Type B				

As can be seen from the Figures 2-5, the fit of trousers play an important role for the retention of heat between the textile material and skin. This especially refers for the zone of upper shin, for which the differences between the body temperature wearing loose/tight model is up to 3°C in moderate environment and up to 9°C in the cold environment. The impact of fit to the other zones is not so pronounced as in the case of upper shin, but higher differences are observed for the zones of lower thigh and lower shin (the temperature, when wearing tight model in moderate environment, is 1°C higher).

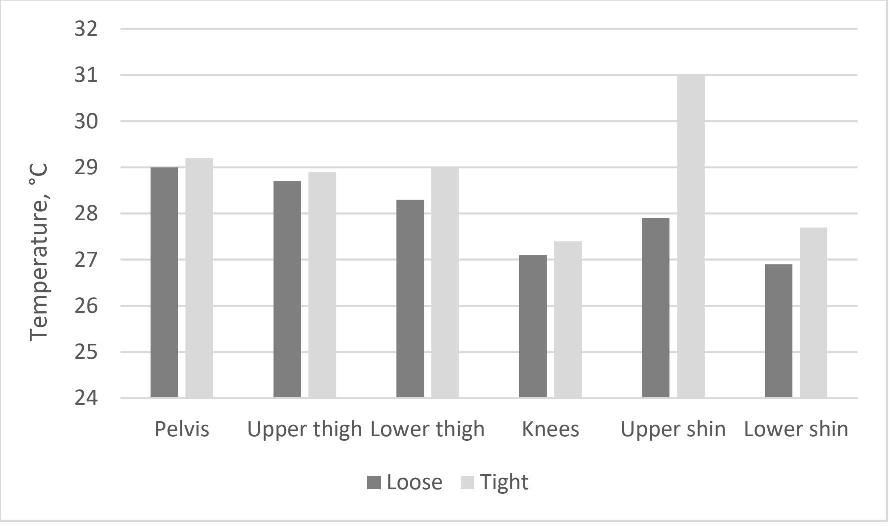


Figure 2: Fabric temperatures for the Type A in the moderate environment (temperature of 22°C)

Figure 3: Fabric temperatures for the Type A in the cold environment (temperature of 2°C)

As defined in Table 1, the raw material and fabric construction of observed two fabrics are the same, while the difference is seen in the fabric mass and thickness. Regarding the both properties, the higher values are characteristic of the fabric assigned as Type A. The results of measurements in moderate environment indicated slight differences in temperatures when wearing trousers Type A or Type B. For all the observed zones, the temperature is up to 1°C higher when wearing Model A (i.e. model with higher values of mass and thickness). The only body zone where the values of temperature are the same is the zone of upper shin. No uniform differences are observed in cold environmental conditions to confirm the influence of material characteristics to the temperature of six body zones.

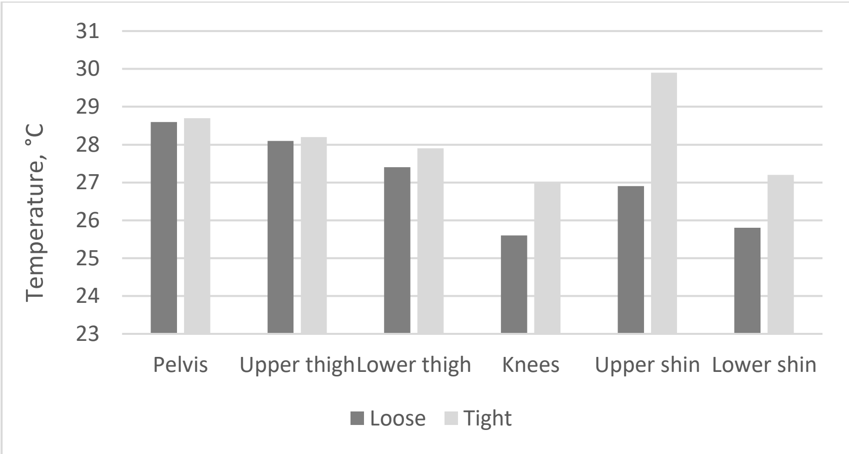


Figure 4: Fabric temperatures for the Type B in the moderate environment (temperature of 22°C)

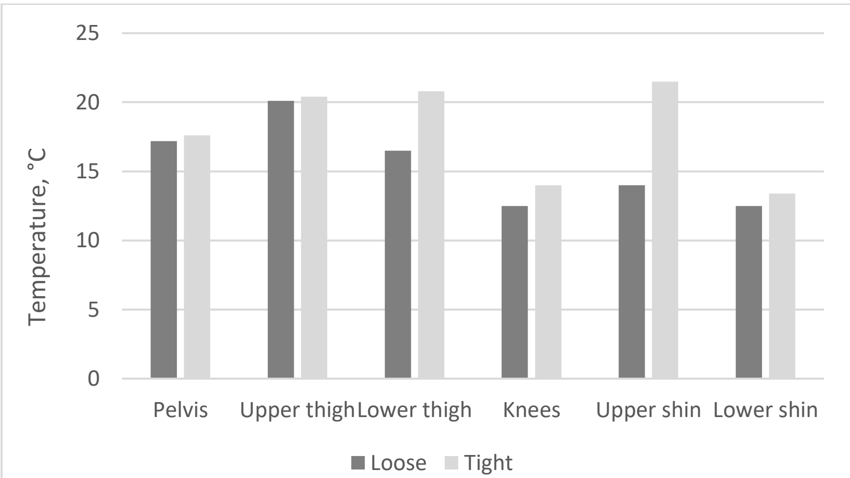


Figure 5: Temperatures for the Type B in the cold environment (temperature of 2°C)

4. CONCLUSION

The presented research focuses on the use of thermography to observe influences of different material characteristic and garment fit on the lower body thermal comfort in two thermal environments. The results presented in this paper focus on the measurement of fabric surface temperature of participating female volunteer. Based on the outcomes of the research, the following conclusions can be drawn:

- fit of garment plays an important role for the retention of heat between the textile material and skin, especially in the zone of upper shin,
- the influence of material characteristics on the temperature of body zones are well seen in the moderate environment. There is no uniformity of changes in the cold environmental conditions to confirm the influence of material characteristics.

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TENSILE PROPERTIES OF YARNS USED AS SUTURE MATERIAL WITH DIFFERENT KNOT CONFIGURATIONS

I. Salopek Čubrić, D. Zbašnik
University of Zagreb Faculty of Textile Technology, Zagreb, CROATIA,
ivana.salopek@ttf.hr

Abstract

The aim of the modern wound care is to preserve intact tissues and support the damaged parts of the human body. A large number of suture materials are nowadays used in wound closure. In many respects, they are adapted to their specific use and are chosen for the particular properties of the tissue. According to the European Pharmacopoeia, for the effectiveness and optimal performance during the use of suture, as well as for the functional lifetime, the most important properties are tensile properties, diameter and needle attachment (if applicable). The presented research focuses at the investigation of yarns used as suture material on 12 different knot configurations. The results of breaking force, breaking elongation and relative tenacity are discussed in the context of the intended end use of different surgical knots.

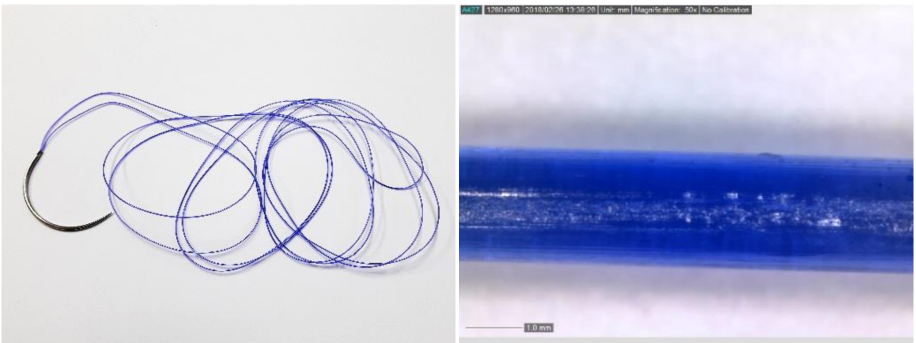
Keywords*:* *yarn, suture, tensile properties, knot configuration, tenacity*

1. INTRODUCTION

The main aim of the wound care is to preserve intact tissues and to support the damaged parts of the human body. Surgical suture is a typical medical solvation for tissue repair and the mechanical properties of the inserted material are of the greatest importance in temporarily replacing the lost strength [1].
The choice of sewing material is often based on local tradition, education and personal experience of the surgeon involved. Although individual tendencies play a crucial role in selecting sewing materials, certain guidelines must be observed to achieve optimal wound healing. Theoretically, knots should be as strong as the tissue through which they pass. The surgeon must choose the sewing material based on the type of sewing tissue, the size and structure of the seams and their ability to maintain the same tension [2].
Nowadays, a large number of different suture materials is used in wound closure. In many respects, they are adapted to their specific use and as such specified by producers. Monofilament yarns are, as suture material, preferably used in smaller sizes. The main advantage of monofilament yarn is in the fact that such yarns slide most smoothly through the tissues. On the other side, monofilament yarns are relatively sensitive to external damage, for example when the thread is grasped with medical instruments. The Figure 1 presents the typical monofilament suture yarn with needle attachment. The multifilament yarns are characterized by rough surface and the longitudinal direction of the individual fibres what results in relatively high capillarity. Such yarns can be

additionally twisted or braided [3]. The individual filaments in a braided suture lie transversely to its longitudinal axis, meaning that braided yarns have less capillary action than just twisted yarns. Due to the higher number of filaments in the structure, multifilament yarns have considerably better knot-holding security. It also has to be pointed out that multifilament yarns used as surgical sutures are usually coated, what makes the irregular surface of the yarn smoother, so the yarn passes through the tissue easily [3].
According to the European Pharmacopoeia [4], for the effectiveness and optimal performance during the use of yarn, as well as for the functional lifetime, the following physical-mechanical properties should be tested and specified:

- Diameter – the measurement is carried out on 5 samples, with an accuracy of at least 0.002 mm,
- Tenacity/breaking force – the measurement should be carried out on dynamometer, using five samples,
- Needle attachment - the test applies to the sutures supplied with an eyeless needle that is not stated to be detachable. The measurement should also be carried out on dynamometer, using five samples.



a. b.

Figure 1: Monofilament suture yarn: a. with needle attachment; b. under 50% magnification

In comparing suture types, Fong et al. concluded that polyglyconate had the highest knot-holding capacity for all the knots examined [5]. Their findings also suggest that closure of an abdominal wound should be finished with either an Aberdeen square or Surgeons' knot [5]. Nigliazzo et al. [6] showed that significant differences ($p < 0.0001$) in knot holding capacity exist between square and sliding knots (favouring sliding knots) and between square and hybrid knots (favouring hybrid knots). The previous investigation related to the yarns used as surgical sutures [7] indicated a significant difference in the values of the tensile properties of selected surgical yarns. For example, the range of breaking elongation is 21-63%, breaking force 38-66 N and tenacity 23-45 cN/dtex.
The investigation presented in this paper focuses at the investigation of yarns used as suture material on 12 different knot configurations [8]. The aim is to observe the differences of tensile properties associated with a single knot configuration.

2. EXPERIMENTAL

In the experimental part of this investigation, the influence of the type of surgical knot on the yarn properties is examined. The experiment is performed using viscose yarn in count of 155 dtex x 3. For the measurements are prepared 13 samples, among which 12 are knotted, while one stayed knot-free. The names of the used surgical knots are listed in the table 1 [8]. Tensile properties of yarns are tested on the dynamometer Statimat M produced by Textechno company. The test is carried out with overload of 0.5 ± 0.1 cN · tex^{-1} and constant speed of 200 mm per minute, as recommended in the international standard [9].

Table 1: Names and descriptions of the used surgical knot samples [8]

Samples		Descriptions
S1		**Surgeon's Semi-knot** Thread's ends are twisted about each other but end of the lower thread should be thrown above the other end of the thread.
S2		**Surgeon's Double Semi-knot** The identical method like the first form but the lower thread should have double crossing above the other.
S3		**Schloffer's Knot 1=1, Square Knot or Symmetric Knot** This method includes one pair of semi-knot on parallel or symmetric combination. The „=“ symbol indicates that the two threads enter and leave on the same side of the other thread.
S4		**Schloffer's Knot 1x1, Granny's Knot or Asymmetric Knot** This method includes one pair of Semi-knot in asymmetric combination. The symbol "x" indicates that the two threads pass crosswise and are not on the same side.
S5		**Surgeon's Knot or Reef Knot 2x1** The Surgeon's knot has a double turn on the first throw but the threads pass over each other, as in Granny's knot.
S6		**Surgeon's Knot or Reef Knot 2=1** This type of knot is consist of double Semi-knot and one more Semi-knot in a parallel combination, as in Square knot. Surgeon's Knot also knows as Ligature Knot.

Continuation of the Table 1.

S7		**Three-throws Knot 1x1x1 or Mayo-knot 1x1x1** It is tying as a combination of two throws of Semi-knot, as in Granny's Knot and one more thread pass crosswise.
S8		**Three-throws Knot 1=1=1 or Mayo-knot 1=1=1** It is tying as a combination of Square knot and one more parallel Semi-knot.
S9		**Surgeon's Double-double Granny's Knot 2x2** Double knot with two turns on each throw but threads within the knot are in cross combination. Accordingly, this type of knot consists of two of double semi-knots in cross combination.
S10		**Surgeon's Double-double Square Knot 2=2** This method includes two of double Semi-knots in parallel combination.
S11		**Single Hitch Knot or Single-loop Knot** It is a simple knot where the thread's end throws three times around standing part, below-above-below.
S12		**Double Hitch Knot or Double-loop Knot** Double-loop is the same knot form as the Single-loop, except that two turns instead of one are taken around the finger, and both of these are trust through the initial end loop.

3. RESULTS AND DISCUSSION

The results presented on the Figures 2 and 3 show the values of breaking force and breaking elongation of 12 yarns with different knots, precisely described in the Table 1 [8]. The Figure 4 shows the relative tenacity in knot determined as the ratio of the average maximal forces of the knotted and non-knotted sample.
As seen from the Figure 2, the values of breaking elongation are in the range 12-16.7 %. The lowest value is characteristic of the yarn knotted with Surgeon's Semi-knot (sample S1). Such outcome is expected due to the fact that the Surgeon's Semi-knot is the simplest among presented knot configurations. The highest value of breaking elongation has the yarn knotted with Surgeon's Knot or Reef Knot 2=1 (16.7 %). At the same time, the same sample, i.e. the yarn knotted with Surgeon's Knot, has the highest value of breaking force (19.54 N). In the literature [2], this type of surgical knot is described as the most

commonly used and highly appreciated by the surgeons. The values of breaking force for the remaining samples are in the range 15-19 N.

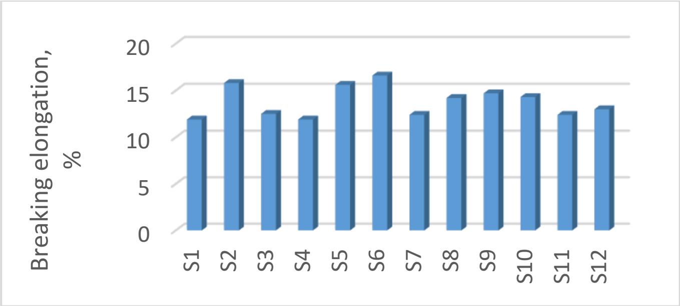


Figure 2: Breaking elongation of yarns

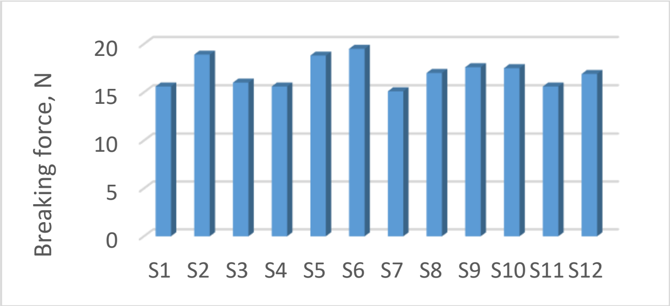


Figure 3: Breaking force of yarns

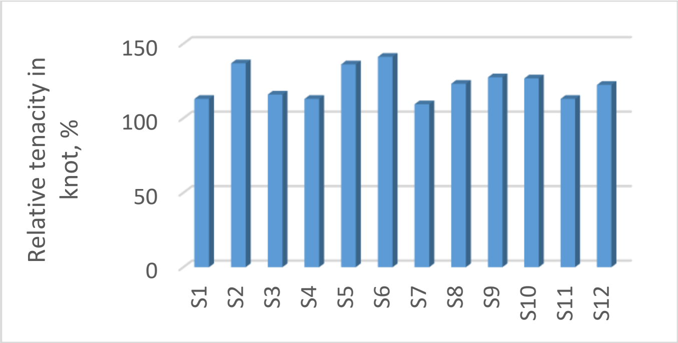


Figure 4: Relative tenacity in knot

As seen from the Figure 4, the values of relative tenacity in knot are in the range 112-141 %. The investigation pointed out that Surgeon's Knot or Reef Knot 2=1 and 2x1 should be used for the procedures where the highest tenacity of suture material is in high demand. For the opposite cases, the Mayo-knot 1x1x1 or Surgeon's Semi-knot should be considered.

4. CONCLUSION

Besides other factors, the success of an operation depends precisely on the type of applied knot. This fact caused the development of knotting techniques as well as new forms of knots and suture materials. In order to ensure the possibility of use in a particularly demanding area such as medicine and health, textile materials must have the optimal combination of properties relevant to this very important a branch of technical application of textiles - medicine.
The results of presented research showed that the values of breaking elongation, breaking force and relative tenacity in knot differ with respect to the applied surgical knot. Considering the tenacity of knotted yarns, the Surgeon's Knot or Reef Knot 2=1 and 2x1 should be used for the procedures where the highest tenacity of suture material is in demand, while for the opposite cases the Mayo-knot 1x1x1 or Surgeon's Semi-knot should be used. One should be aware that even small differences in values have a profound effect on the ultimate outcome in use, since the quality of the surgical node greatly affects the outcome of surgical operations.

AKNOWLEDGEMENT

This research is supported by University of Zagreb, within research grants TP7/17 "Design of innovative materials to preserve thermal comfort" and TP1/18 "Thermography in the research of comfort parameters of innovative textile materials".

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THE CORRELATION DEPENDENCE OF LUMBAR MOMENT ON THE BODY MASS INDEX OF MALE ENGINE DRIVERS

D. Sumpor, S. Tokić, S. Đuranović
University of Zagreb, Faculty of Transport and Traffic Sciences, Vukelićeva 4, 10000 Zagreb
davor.sumpor@fpz.hr, sandro.tokic@gmail.com, srecko.duranovic@fpz.hr

Abstract

Only seven static and dynamic anthropometric measures important for the engine driver's control panel design were selected from the 25 measured in 2015, for a sample of 51 male engine drivers from all parts of Croatia. The correlation dependence of lumbar moment M_{ly} on the body mass index BMI has been proven in the hypothetically most unfavorable static sitting working position, only with both arms beyond the equilibrium position and horizontally extended in the zone of maximal reach, and based on the really measured static and dynamic anthropometric measures. It is important to note that two most important dynamic anthropometric measures, such as normal arm reach and maximum arm reach were this time measured to the center of the clenched fist, not to the tip of the middle finger as in the past research, because of the fact that most of the frequently and manually served commands on the control panel (switches, buttons and controllers) are being served with a clenched fist or mostly clenched fist in reality.

Keywords*:* *correlation dependence, lumbar moment, body mass index, engine drivers*

1. INTRODUCTION

The factors of physical workload of the engine driver can also be excessive body mass *m* in relation to the height of the engine driver *h* expressed by the amount of the body mass index (*BMI*) as well as inadequate design of the driver cab, control panel and seats not matching the scope of anthropometric measures of the engine drivers from the target population in Croatia. The factors of anthropometric unadjusted working environment from the cabin when interacting with anthropometric measures of engine drivers can affect the task difficulty, increasing the workload of drivers while driving, reducing the performance of engine drivers, as well as reducing the safety of the transport process.
According to the Fuller dynamic TCI model “the ability of drivers - demand tasks" [1] the "tasks demand" is significantly affected by selecting the speed of traffic by engine drivers. The possible influence on the task difficulty (i.e. workload) is the placement, arrangement and accessibility of the frequently used and manually served commands to change the speed on the control panel, such as multipurpose controller (with integrated braking module, accelerator module and "dead man" function), which is commonly used in the newer tram cabs and newer locomotive cabs in Croatia.

Only seven static and dynamic anthropometric measures important for the engine driver's control panel design were selected from the 25 measured in 2015 [2], for a sample of 51 male engine drivers from all parts of Croatia.
Finding of the more realistic and more accurate functional dependence of the lumbar moment in case of engine drivers $M_{ly} = M_{ly}(BMI)$ at the level of vertebra L4/L5 on the body mass index *BMI* is a subject of ergo-assessment in this paper, in accordance with the basic research hypothesis that the lumbar moment M_{ly} predominantly linearly depends on the body mass index *BMI*.

2. RESEARCH AND RESULTS

The *BMI* expressed in Formula (1) is an important ergonomic assessment parameter since it contains two most important statistical anthropometric measures, standing height h and body mass m.

$$BMI = \frac{m}{h^2} \qquad (1)$$

Research from 2012 [3] presents how the physical workload of engine drivers in the static sitting working position expressed through the amounts of lumbar moment $M_{ly} = M_{ly}(BMI)$ at the level of vertebra L4/L5 can be intensively affected by the design of the control panel (driver cab), regarding the poor organization of frequently used commands in maximal arm reach. Lumbar moment M_{ly} has functional dependence with amount of *BMI* index $M_{ly} = M_{ly}(BMI)$ of strong strength, with correlation coefficient $R = 0.806$ [3]. It is important to note that instead of calculating for $n = 50$ random respondents from the sample in 2012 [3] for the static and dynamic anthropometric measures h_i calculated from the standing height h using harmonic analyses by Muftić and Zederbauer [4], the improved accuracy of calculation in papers which followed in 2015 [2, 5] have been realized by regression function $M_{ly} = M_{ly}(BMI)$ obtained on the basis of really measured static and dynamic anthropometric measures h_i for body segments outside the balance seating position.
But the most important dynamic anthropometric measures for control panel design such as normal arm reach h_{ndr} and maximum arm reach h_{mdr} were in all previous research in 2015. measured to the tip of the middle finger [2, 5], not to the center of the clenched fist, which is not quite right, due the frequently and manually served commands on the control panel (switches, buttons and controllers) are being manually served with a clenched fist or mostly clenched fist in reality.
As many as 82% of the 50 surveyed engine drivers from a random sample in 2012 were overweight or obese [3], also as many as 80.39 % of the 51 surveyed engine drivers from a different random sample in 2015 were overweight or obese [2], both regarding the numerical value of *BMI* ($BMI \geq 25$). The studies carried out during 2011 in Slovenia [6] targeting 245 employees at the railways indicate 66.9 % overweight or obese workers, with no significant differences between the two groups of workers regarding the nature of their work (white or blue-collar workers).
According to Wilson and Noriss from 2005 [7] and the guidelines of *Rail Safety and Standards Board* from Great Britain the actual priorities during scientific research that can be related to the safety and the group of factors "human factor" include, among others the design of the driver cab and the environment.

Table 1 contains calculated and measured values of the seven static and dynamic anthropometric measures which were measured in 2015.

Table 1: Ranges and values of seven static and dynamic anthropometric measures for the entire randomly selected sample n=51

Static or dynamic anthropometric measure	Symbol / measuring unit	Remark	Amount
h – measured **standing height** in balanced standing posture	$\overline{h}$ / cm	calculated - Expression (2)	178.9
	Δh / cm	range of measured for *n = 51*	167 – 188
	SD_h / cm	calculated - Expression (3)	5.7
m – measured **mass**	$\overline{m}$ / kg	calculated - Expression (2)	92.0
	Δm/ kg	range of measured for *n = 51*	58.9-124
	SD_m / kg	calculated - Expression (3)	14.1
h_{ndr} – **normal arm reach** or working distance, from rear side of elbow to the center of the clenched fist	$\overline{h}_{ndr}$ / cm	calculated - Expression (2)	35.5
	Δh_{ndr} / cm	range of measured for *n = 50*	31.0 - 39.0
	SD_{hndr}/ cm	calculated - Expression (3)	2.0
h_{mdr} – **maximal arm reach** or length of reach, from the rear side of the acromion to the center of a clenched fist	$\overline{h}_{mdr}$ / cm	calculated - Expression (2)	64.7
	Δh_{mdr} / cm	range of measured for *n =51*	57.0 - 73.0
	SD_{hmdr}/ cm	calculated - Expression (3)	3.7
$h_{š}$ – **hand length**, from wrist (the first crease) to the tip of the middle finger	$\overline{h}_{š}$ / cm	calculated - Expression (2)	20.0
	$\Delta h_{š}$ / cm	range of measured for *n =51*	18.0 - 23.0
	$SD_{hš}$ / cm	calculated - Expression (3)	1.1
h_r - **arm length**, from the tip of the acromion to the tip of the middle finger (in vertical position)	$\overline{h}_r$ / cm	calculated - Expression (2)	77.6
	Δh_r / cm	range of measured for *n = 51*	71.0 - 86.0
	SD_{hr} / cm	calculated - Expression (3)	3.4
$h_{p+š}$ - **length of forearm and hand** (from rear side of the elbow to the tip of the middle finger)	$\overline{h}_{p+š}$ / cm	calculated - Expression (2)	48.2
	$\Delta h_{p+š}$ / cm	range of measured for *n = 51*	43.0 - 52.0
	$SD_{hp+š}$ / cm	calculated - Expression (3)	1.9

Source: taken from Mikulčić, M. et al., 2015 [2]

The arithmetic mean or the mean value M of individual static and dynamic anthropometric measures $\bar{h}_i$ from Table 1 have been calculated according to Expression (2).

$$M = \overline{h_i} = \frac{h_1 + h_2 + \dots h_n}{n} = \frac{1}{n} \cdot \sum_{i=1}^{n} h_i \qquad (2)$$

Standard deviation SD_i of individual static and dynamic anthropometric measures h_i from Table 1 have been calculated according to Expression (3).

$$SD_i = \sqrt[2]{\frac{1}{n-1} \cdot \sum_{i=1}^{n} (h_i - \bar{h}_i)^2} = \sqrt[2]{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \Delta h^2} \qquad (3)$$

Knowing the standing height h and body mass m, using the Donskij-Zacijorskij method [8] it is possible to calculate the amounts of single segmental masses m_i for hands, forearms, and upper arms in $n = 51$ respondents, using the regression equation (4) and with determined regression factors B_o, B_1 and B_2.

$$m_i = B_0 + B_1 \cdot m + B_2 \cdot h \; [kg] \qquad (4)$$

The positions of mass centers m_i are calculated according to Table 2, measured from the upper border of the body segments.

Table 2: Mass centers in the percentage of the function of the body segment length

Body segment	Distance (%)
head and neck	50.02
upper torso	50.66
middle torso	45.02
lower torso	59.59
hand	36.91
thigh	45.49
lower leg	40.49
foot	44.14
upper arm	44.98
forearm	42.74

Source: taken from Milčić, D. et al., 1999 [9]

Body segment gravities F_{gzi} have been calculated according to Expression (5), and the amounts of lumbar moments M_{ly} according to Expression (6) have been obtained by the reduction of all the gravities F_{gzi} from segmental masses m_i into the origin of the coordinate system xy in Figure 1.

$$F_{gzi} = m_i \cdot 9.81 \quad (5)$$

$$M_{ly} = \sum_{i=1}^{n} F_{gzi} \cdot x_i \qquad (6)$$

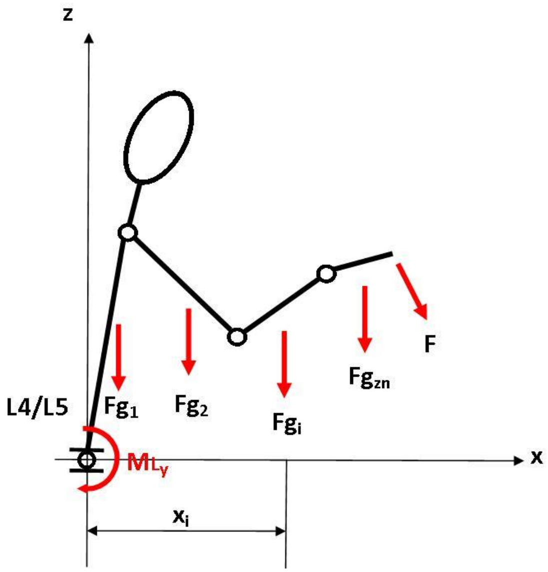

Figure 1: Two-dimensional stick model of the respondent in sagittal plane
Source: taken from Jurum-Kipke, J. et al., 2007 [10]

In compliance with the considerations of Mairiaux et al. [11], or Muftić et al. [4], the origin of the coordinate system xy represents also the point of reduction L4/L5 of the lumbar moment M_{ly} to the level between the fourth (penultimate) and fifth (last) lumbar vertebra in the mobile part of the spine viewed from above downwards.

In Figure 2 is shown at the least favourable hypothetical static equilibrium working position of stick biomechanical 2D model of an engine driver in sagittal plane [12], only with both arms beyond the equilibrium position and horizontally extended in the zone of maximal reach.

Lumbar moment M_{ly} according to regression function (7) from the diagram in Figure 3 has an acceptable correlation dependence $M_{ly}=M_{ly}(BMI)$ of medium strength with correlation coefficient $R = 0.719$, close to the border value of R for a strong strength.

$$M_{ly} = 0.663 \cdot BMI + 6.0115 \qquad (7)$$

Regression function (7) refers to the hypothetical static working position of an engine driver in sagittal plane according to Figure 2.

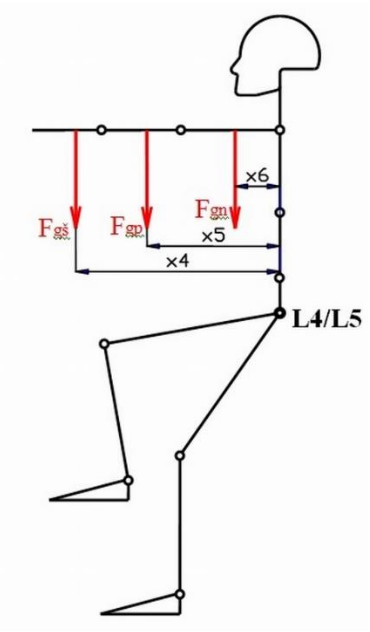

Figure 2: Stick biomechanical 2D model of an engine driver in sagittal plane, in the least favourable hypothetical static equilibrium working position, only with arms horizontally extended in the zone of maximal reach
Source: taken from Sumpor, D., 2009. [12]

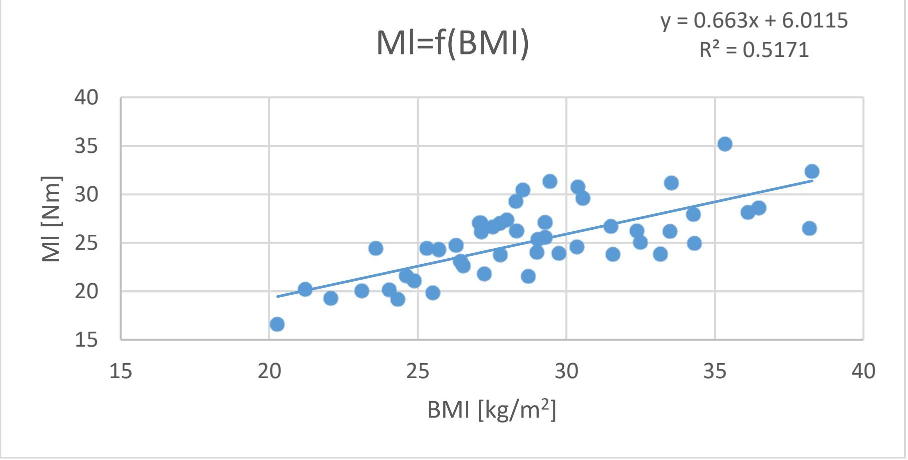

Figure 3: Regression function $M_{ly}=M_{ly}(BMI)$ based on the really measured static and dynamic anthropometric measures from the random and sufficient sample $n=51$

For the same respondents from the random and sufficient sample $n = 51$, when the body segment lengths of arms have been calculated from the standing height h using harmonic analysis by Muftić and Zederbauer [3, 4], the regression function (8) was obtained with strong correlation dependence $M_{ly}=M_{ly}(BMI)$, with correlation coefficient $R = 0.806$.

$$M_{ly} = 0.7813 \cdot BMI + 1.0229 \quad (8)$$

Regression function (7) is less linear, but much more realistic and based on the really measured static and dynamic anthropometric measures of engine drivers, since normal arm reach and maximum arm reach were measured to the center of the clenched fist.
Results present how the physical load of engine drivers in the static sitting working position expressed through the amounts of lumbar moment $M_{ly}= M_{ly}(BMI)$ at the level of vertebra L4/L5 can be intensively affected by the design of the control panel (driver cab), regarding poor organization of frequently used commands, if they are placed in maximal arm reach.

3. DISCUSSION AND CONCLUSION

In assessing the physical effort of engine drivers in the hypothetically least favourable static working position according to Figure 2, and in interaction with the increased body mass m in relation to the standing height h, it is recommended to use the regression function $M_{ly}=M_{ly}(BMI)$ according to Expression (7), obtained based on the measured static and dynamic anthropometric measures of engine drivers from the random and sufficient sample, since normal arm reach and maximum arm reach were measured to the center of the clenched fist, not to the tip of the middle finger such as in past research, because of the fact that most of the frequently and manually served commands at the control panel (switches, buttons and controllers) are being served with clenched fist or mostly clenched fist in reality.

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ORGANISM LOAD AND ENERGY CONSUMPTION AT WORKING PLACE IN FUNCTION OF NUTRITION

F. Veljović[1], I. Haxhibeqiri-Karabdić[2], A. Kustura[3]
[1]Faculty of Mechanical Engineering, Sarajevo, Bosnia and Herzegovina,
veljovic@mef.unsa.ba
[2]Medical school, Sarajevo, Bosnia and Herzegovina
[3]Faculty of Mechanical Engineering Sarajevo, Bosnia and Herzegovina,
kusturaabedin@gmail.com

Abstract

During the work, workers are often in bent, half-bent and crouching position when they need to finish their working activity. These working activities are changed many times during the working day. In this article, the use of software package CATIA for calculating the loads was described. If the working place is not designed on the right way, exceeded overloads are present and they are not desirable for the health of the worker. The worker will be more tired and less efficient on work and its health is being endangered. In this article, the load in L4/L5 vertebra is analyzed in 3 positions of the worker, during the process of taking, carrying and putting the cement in the truck. After calculations of organism load, another calculation of energy consumption is done for that specific working place in the function of workers diet.

Keywords*: biomechanics, CATIA software package, anthropology, load, diet*

1. INTRODUCTION

Ergonomics is the use of scientific information about a man with the goal of designing tools, systems and the environment for people [1]. In this work, the use of software package CATIA and calculation of loads during some specific activities are described. Using this software, it is possible to get ideal parameters for saving workers health. It is possible to get the information about the loads in the L4 and L5 vertebrae of spine. Workers are often in 3 positions during the work activities such as bending, squatting and kneeling [2]. From the previous experience, it could be concluded that there are many problems if it doesn’t take care for the construction of working place [3]. The purpose of this article is to analyze loads and to answer the question are these loads acceptable. In this article it is showed how much energy does the worker need for specific activity. Also, the needed nutrition is given to fulfill daily needs. Only if the worker`s health is saved, the satisfaction from both sides is present.

2. SUBJECT AND METHOD

In this article it is needed to perform the analysis of workers load who is carrying 2500 kg of cement from storage to truck. Through the analysis, it is needed to give the answer if organism is overloaded or the load is acceptable. It is also needed to examine the load of muscle system which is used during the working cycle. At the end, it is supposed to establish diet according to organism load. The company has one worker who handles cement with these anthropological characteristics: gender – male; height - 185 cm; mass - 85 kg.

2.1. Defining the main problem

It is needed to carry 2500 kg of cement from the storage to the truck. The buyer has specified that size of cement doesn't matter, only the load time. Figure 1 shows anthropometric characteristics of worker.

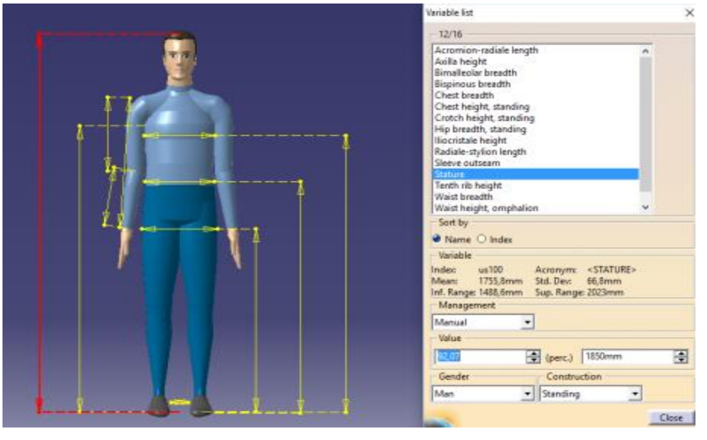

Figure 1: Anthropometric characteristics of worker

The shortest way for the worker from storage to the point of load is 40 m. He takes the cement packages from the floor, then takes them to truck and goes back to storage. The height of the loading point in truck is 80 cm. After he takes the cement in the truck, he goes back for the another one. The mass of one bag: m_1 = 25 kg
Number of required packages:

$$n_1 = \frac{m_{uk}}{m_1} = \frac{2500\ kg}{25\ kg} = 100\ bags \qquad (1)$$

Path distance: l_1 = 40 m
Lifting time: t_{pod1} = 4 s (measured). Walking speed with load: v_{ht1} = 0,8 m/s
Load transfer time:

$$t_{ht1} = \frac{l_1}{v_{ht1}} = \frac{40\ m}{0{,}8\ \frac{m}{s}} = 50\ s \qquad (2)$$

Load landing time: t_{st1} = 2 s (measured). Walking speed without load: v_{hp1} = 1 m/s
Idling time:

$$t_{ph1} = \frac{l_1}{v_{hp1}} = \frac{40\ \mathrm{m}}{1\,\frac{\mathrm{m}}{\mathrm{s}}} = 40\ \mathrm{s} \qquad (3)$$

Total time of one cycle: $t_{c1} = t_{pod1} + t_{ht1} + t_{st1} + t_{ph1} = 96$ s (4)

Total working time:

$$t_{uk1} = n_1 * t_{c1} = 9600\ \mathrm{s} = 160\ \mathrm{min} \qquad (5)$$

Working cycle: t_{rad} = 40 min; t_{odm} = 15 min;

Total working time with breaks:

$$T = 4 * t_{rad} + 25\ \mathrm{min} + 4 * t_{odm} = 185\ \mathrm{min} + 60\ \mathrm{min} = 245\ \mathrm{min} \qquad (6)$$

2.2. Conclusion of time analysis

Worker did his job for 4 h and 5 min. Working norm given from employer is T_n= 4 h and hourly rate is 10 KM. If the worker is working for 20 working days, during the period of 6 months, it can be calculated how much does this job cost: 6*20*40 KM = 4800 KM = 2400 Eur.

2.3. Analysis of characteristic postures in work

It is necessary to analyze three critical positions of body during the work:

-crouching position during the load lifting (Figure 2);
-standing position with the load in hands (Figure 3);
-position during load disposal.

Figure 2: Crouching position

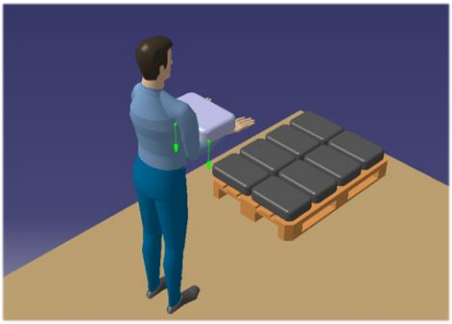

Figure 3: Standing position

2.3.1. Crouching position during the load lifting

Worker is getting low (Figure 2), hands are spread out and he is starting to accept the cement from up to the bottom. Legs are widespread, he is bent in the back region. It can be seen that this position might be critical because of the loads on legs, muscles and back due to the position and also from the load.

2.3.2 Stand up position

Figure 3 shows the worker stood up, he put cement closer to himself which means that the moment in the L4-L5 region has decreased. Hands are under the package, wrapping it from the lower side, widespread so the weight will be equally distributed. Worker is upright and the pressure on the abdominal region is decreased. In this position, worker is carrying cement for 40 m, then he puts it on the ramp in the truck which is 80 cm high and he ends the cycle.

2.3.3. Position during the postponement of cement

As can be seen in Figure 4, worker is slightly bent forward because he needs to put the cement on the ramp so he can compensate the height difference (the vertical distance from the floor in the position 2 is 1140 mm, and for this one 800 mm). The pressure in L4-L5 region is little increased. Hands are half-extended.

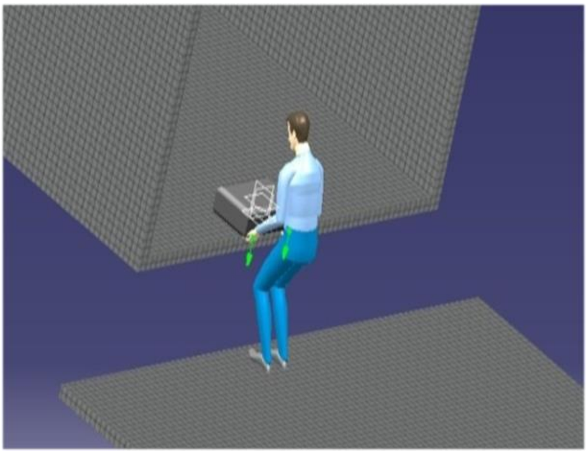

Figure 4: Position of worker during the postponement of cement

3. RESULTS

3.1. Position 1 (RULA analysis)

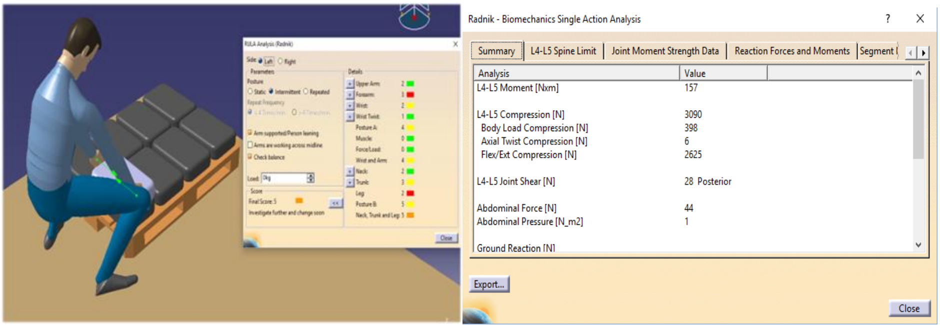

Figure 5: Analysis of posture 1

Parameters are given for the activity which is repeating less than 4 times per minute. Both sides are equally loaded and the mass of cement is 25 kg. On the Figure 5, the loads are especially expressed in the zone of forearm and legs and in the zone of neck, belly and legs, so the total mark is 5.

3.2. Position 2 (RULA analysis)

From the Figure 6, we can see that the total mark is 2 for the given parameters and the only less risky factor is mass regarding the load which has mark 3. The total mark only needs the additional research of possibility but it is not dangerous for worker.
Figure 6 shows that the loads are in accordance with the limitations. Pressure in L4-L5 is 2535 N/m^2 which is 865 N/m^2 less than allowed.

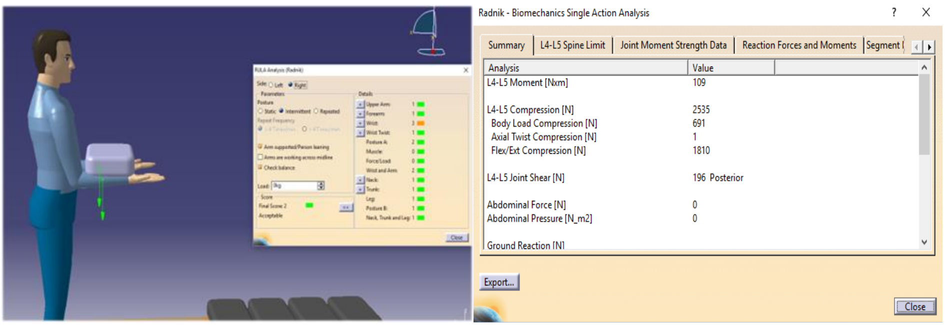

Figure 6: Analysis of posture 2

3.3. Load carrying analysis

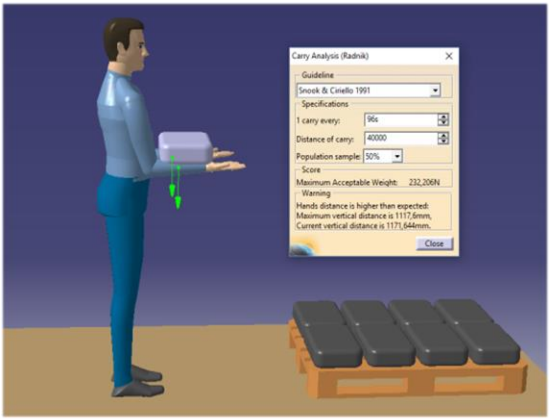

Figure 7. Load carrying analysis for specific activity

On the Figure 7 we can see that recommended weight for our parameters is 232,206 N, if we transform weight to mass we get: m_{pr} = 232,206/9,81 =23,67 kg which is 1,33 kg less than our given weight. This means that the mass of 25 kg will not represent a problem for organism load.

3.4. Position 3 (RULA-analysis)

Figure 8 shows that the worker is smoothly bended, hands are half-extended, so he is eligible to reach the edge of truck on height 800 mm. Total mark is 6. L4-L5 shear stress is 59 N/m^2 and the pressure on L4-L5 is 2628 N/m^2 so it is 772 N/m^2 less than acceptable limits or 22,7 %. This position is not bad for loads, but it has bigger concentration of strain on hands and joints because of the influence of mass so we need to work additionally, but it is acceptable for L4-L5 loads.

Figure 8: Analysis for position 3

3.5. Calculation of work energy and required diet for worker

3.5.1. Calculation of work energy

Work, which is used on holding the cement during the movement between the platforms, is possible to express as product of force in hands and the path which is crossed. On this way, the work for hands is summarizing with the spent work on lifting, spinning and dropping the cement so we can get the total work which is spent on hands during the work activities.
Force in hands $F1$ [N] is calculating as a summation force, which burden both hands and is given from the mass of cement weight which worker carry and based on gravity acceleration:

$$F1 = m \cdot g = 25 * 9{,}81 = 245{,}25 \text{ N} \quad (7)$$

m [kg] - mass of cement,
g[m/s^2] –gravity acceleration of earth.

The path which hands pass holding the cement represent length which worker passes from the place of cement assumption to the truck and it is measured from the cement brunt in the starting and ending position. The path during lowering is measured from the standing position to the last position in which he leaves the cement in the truck and the distance is measured between the load brunt.
The work $A1$ [J] which represents force on the path is calculated from the formula below:

$$A1= F1 \cdot \text{s} = 343{,}35 * 22 = 5395{,}5 \text{ J} \quad (8)$$

F [N] –force which affects hands,
s [m] – path which hands crosses holding the cement in 3 positions.

Force needed for transferring cement from one place to another is calculating with this formula:

$$F = \text{m} \cdot \text{g} \cdot \mu \ \text{[N]}$$

$$F1 = 25 \cdot 9{,}81 \cdot 0{,}5=122{,}625 \text{ N} \quad (9)$$

F [N] –force which affects hands,
g [m/s2]–gravity acceleration of earth,
μ - coefficient of friction between foot and floor, frame value is 0,5.

Power used during 1 shift is given with the formula below:

$$E = \text{A} \cdot \text{f} \cdot \text{P} \cdot \Theta$$

$$E1= \text{A1} \cdot \text{f} \cdot \text{P} \cdot \Theta = 5395{,}5 * 0{,}69 * 2{,}41 * 2 = 17944{,}35 \text{ J/RC} \quad (10)$$

A[J] –total work for cement transfer,
f –frequency repeating of activity per minute,
P –period of activity duration,

Θ –factor of fatigue, which depends of frequency and mass of cement; it goes in the following limits: 1.1 – easy chores and 2. – heavy chores.

3.5.2. Calculation of BMR energy

The amount of energy required for organism for its functioning (breathing, work for organs, food sorrowing, exchange of matter) is called main metabolic rate.
We are using Harris –Benedict`s formula [4].
For male subjects:

$$BMR = 65{,}51 + (9{,}563 \cdot M) + (1{,}85 \cdot H) - (4{,}676 \cdot Y) \quad [kcal/day] \qquad (11)$$

Where is:

- M [kg] - mass of subject,
- H [cm] - height of subject,
- Y[-] –years of examinee

$$BMR = 65{,}51 + (9{,}563 \cdot 85) + (1{,}85 \cdot 185) - (4{,}676 \cdot 26) = 1099{,}039 \text{ kcal/day}$$

1 kcal = 4,186 kJBMR

BMR = 4396,156 J/day BMR = 4396,156 /3= 1465,385 J/RC

Total power used in the working cycle represents the sum of BMR and power used during one shift:

$$E_{u1} = E_1 + BMR = 17944{,}35 + 1465{,}385 = 19409{,}738 \text{ J/Rc} = 19{,}40 \text{ kJ/Rc} \qquad (12)$$

The formula used for calculating energy needs:

$$EP = ITM \cdot 24 \cdot ffa \quad [kcal] \qquad (13)$$

Where is:
ITM [kg] –ideal body mass

- 24 - fast, oriented value basal metabolism expressed as kcal/kg/hour
- ffa- factor of physical activity
- ffa =2,10 from Table 1.

Table 1: Weight coefficient of physical activity [4]

Gender	*Easy physical activity*	*Medium physical activity*	*Heavy physical activity*
Male	1,56	1,78	2,10
Female	1,55	1,64	1,82

The ideal body mass:

ITM= (TV (cm) – 100) – ((TV (cm) – 150)/4) [kg] (14)
where is: TV [cm] – body height.
ITM= (185 – 100) –((185 – 150)/ITM= 76,25 kg

3.6. Proposal of menu

EP = 76,25·24·1,78 =3257,4 kcal = EP/3= 1085,8 kcal/RC (15)

According (15), average energy value of meal for one week is 1085,8 [kcal]. Menus are shown in Table 2-6. Calorie value increases by 5 % because of the fat and spice which are added: 1061,5.

Table 2: Menu - Monday

Meal					*Total*
Beef and potatoes	Beef	Potatoes	Cake	Pastry	1058,4
	250 [g]	240[g]	100[g]	100[g]	
	364 [kcal]	174 [kcal]	250[kcal]	220[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1008					

Table 3: Menu - Tuesday

Meal					*Total*
Minced meat and spaghetti	Minced beef	Spaghetti	Juice	Pastry	1113
	200 [g]	300[g]	water	200[g]	
	436 [kcal]	324 [kcal]		300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1060					

Table 4: Menu - Wednesday

Meal					*Total*
Beans	Sausage	Beans	Cake	Pastry	1056,3
	250 [g]	300[g]	100 [g]	200[g]	
	357 [kcal]	149 [kcal]	200 [kcal]	300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1006					

Table 5: Menu - Thursday

Meal					*Total*
Beef meat with potatoes	Beef	Potatoes	Juice	Pastry	1072,05
	260 [g]	240[g]	0,5 [l]	200[g]	
	397 [kcal]	174 [kcal]	150 [kcal]	300[kcal]	
Calorie value increases by 5 % because of the fat and spice which are added: 1021					

Table 6: Menu - Friday

Meal					Total
Grilled chicken and potatoes	Chicken	Potatoes	Salad	Pastry	1114,6
	300 [g]	240[g]	200 [g]	200[g]	
	387,5 [kcal]	174 [kcal]	200 [kcal]	300[kcal]	

6. CONCLUSION

By the help of software package CATIA, we are capable on the most qualitative way to simulate, optimize, do the judgement and analyze tasks in the variety of working activities.
In this project it is showed how it is possible to use one software package. Many analyses are presented such as biomechanical, carry, RULA. We could see that there were none big loads during the specified work so it means that worker will not have any health issues. The goal of every designer and engineer is to be sure that these problems will not be present. Every year there is a lot of loss because of the injuries and illnesses which are present on the job, so if we do the optimization and analysis of working place, manager will have many savings and, also, the worker will be healthier.
There is an option to use the palette machine to save the time needed for discharge of cement for 4 times, which means that the worker will do his job on more efficient and faster way and he will save his health. He will only need 1 hour to finish specified activity. The loads will rapidly decrease and the amount of cement will be much bigger.

7. LITERATURE

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PROLONGED REPETITIVE TRUNK FLEXION HAS NO LASTING EFFECTS ON POSTURAL CONTROL IN YOUNG ADULTS

M. Voglar[1], N. Šarabon[1,2]
[1] University of Primorska, Faculty of Health Sciences, Izola, SLOVENIA, matej.voglar@fvz.upr.si
[2] S2P Ltd, Laboratory of motor control, Ljubljana, SLOVENIA, nejc.sarabon@s2p.si

Abstract

The goal of the present study was to determine the effects of prolonged, intermittent trunk flexion (simulating crane operators work) on postural control. Furthermore, the potential beneficial effects of passive upper body support during flexion were investigated. 21 healthy young volunteers (10 females) participated during two separate visits in which they performed 1 hour of intermittent trunk flexion (60 s at 80% of max lumbar flexion and 30 s upright sitting) with and without upper body support. Two-way repeated measures ANOVA was used to compare the results. There were no statistically significant effects on distance (p = .136 to .619), mean velocity (p = .187 to .923) and mean frequency (p = .328 to .987) of center of pressure movement parameters measured during sitting on an unstable surface. Changes in seated balance were previously shown following trunk flexion however the effects were short lasting and therefore clinical importance is questionable.

Keywords: *Occupational trunk flexion, seated balance, low back pain.*

1. INTRODUCTION

Musculoskeletal disorders (MSDs) are one of the most common health problems of working population across different professions. Although MSDs are not exclusively caused by work they represent large proportion of work-related diseases [1]. Among MSDs, low back pain (LBP) is the most frequently reported problem affecting up to 85 % of working population at least once in a lifetime therefore representing important clinical, social and economic problem [2,3]. In some European countries estimated costs related with LBP reach up to 1.7 % of gross domestic product [4] and up to 6% of total healthcare expenditure [5].

Despite the efforts in most western countries the prevalence of LBP is not decreasing [6]. Main reasons are multifactorial nature of the problem and shortcomings in understanding of the mechanisms responsible for LBP onset [7,8]. Recent set of review articles concluded that there is no sufficient evidence that traditionally accepted risk factors such as heavy lifting, banding and twisting are responsible for LBP [8]. The conclusions were drawn based on the absence of evidence for causality therefore emphasising the need for further research.

However, among European workers more than a quarter (28 %) perceives repetitive movements or tiring positions as a main health risk [9]. In line with that, epidemiological studies have shown that maintaining flexed position exceeding 30° for more than 10% of work time increases the risk for LBP [10]. Furthermore, Punnett and colleagues [11] showed that persons with LBP are 5-times more likely to work in flexed position than persons without the LBP. Nevertheless, complete understanding of the mechanisms for LBP development due to occupational bending are lacking.

Several changes of mechanical and sensory-motor functions of trunk were shown following intermittent and sustained trunk flexion. Creep deformation and resulting decrease in passive stiffness occur with faster rate following sustained flexed posture of the trunk [12]. However, in both cases changes are non-linear and more prominent in initial phases [12,13]. In parallel, reflex muscle activation changes. Several in vivo animal studies have shown inhibited ligamentous-muscular reflexes following flexion [14–16]. However, in human, increased reflex gains were shown following full trunk flexion [17] and after less than full flexion [13]. It is believed that increased reflex gains compensate for reduced passive intrinsic stiffness [13]. In line with this, the increase in baseline muscle activity was shown after full passive trunk flexion [18].

Sánchez-Zuriaga, Adams and Dolan [19] further showed that the reflex latency can increase following prolonged trunk flexion. This could contribute to LBP development since longer latencies were repeatedly shown in relation with LBP [20,21]. Longer reflex latencies potentially result in mitigated postural control shown in LBP patients [22] and immediately following relatively short-lasting trunk flexion [23]. Following short-lasting trunk flexion normal postural control was regained within 10 minutes [23]. Therefore, we hypothesised that prolonged intermittent trunk flexion will result in longer lasting effects on postural control exceeding 10 minutes post flexion and that changes will be more prominent following unsupported flexion in comparison to supported trunk flexion.

2. METHODS

2.1. Participants

Twenty-one young volunteers were included in the present study (11 males: 23.2 (2.0) years, 182.3 (6.2) cm, 73.9 (8.2) kg) and 10 females: 24.3 (4.0) years, 168.3 (7.2) cm, 62.1 (9.0) kg). Exclusion criteria were either LBP within the last six months or any history of LBP that required at least one day of adjusted daily activities. Participants with any known sensory or neuromuscular pathologies that could affect postural control were also excluded. The ethical committee of the Faculty of Human Movement Sciences of the VU University Amsterdam had approved the study protocol and all subjects signed an informed consent statement prior to the experiment. The study was conducted in line with Helsinki Declaration recommendations.

2.2 Experimental procedure

Participants were invited for two visits with two different exposure conditions: supported flexion (SF) and unsupported flexion (USF). Each visit consisted of an introductory test set and three repeated identical sets of tests: control, pre-exposure and post-exposure test set (Figure 1). The control test set and a subsequent conditioning period were introduced given the results of a pilot study in which the trend indicated a potential effect of repeated measurements on the range of motion (RoM). The conditioning period required subjects to sit for 30 minutes in a standardised position, to reduce the potential effects of earlier activities. Experimental conditions were introduced on separate visits in counterbalanced order with at least 4 days between visits to reduce potential carryover effects. The control test set and the pre-exposure test set were used to calculate the reliability of the measurements within and across visits.

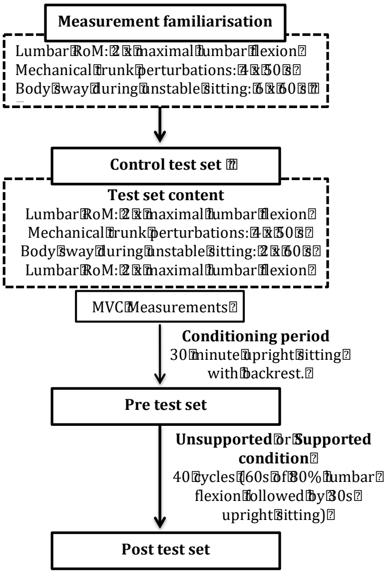


Figure 11: Flow chart presentation of the measurements. Each of the two visits contained the same testing protocol with the sole difference being the flexion (i.e. intervention) condition.

Center of pressure (CoP) was assessed using three sensors force-plate (Kistler instrumente AG, Winterthur, Switzerland). Root mean square (RMS) of distance, mean velocity and mean frequency of CoP were calculated. In each set of tests, the measurements of postural control while sitting on an unstable surface were measured following measurements of maximal lumbar RoM and measurements of trunk neuromuscular control. As a consequence, 7 to ten minutes passed between last flexion and first measurement of postural control.

2.3 Repetitive trunk flexion

In both experimental conditions, the participant was seated on a raised platform with the feet supported and real time feedback on lumbar flexion (the inclination difference between the sensors) and trunk inclination (inclination of the sensor over T12) was provided. The target lumbar flexion angle was determined as 80% from erect stance to maximal forward flexion, similar as in the study by Sánchez-Zuriaga and colleagues [19]. Intermittent flexion (40 cycles including 1 minute of target flexion and 30 s of upright active sitting, cumulatively lasting for 60 minutes) was imposed. In the supported flexion (SF) condition a padded bar provided passive support for the upper body while in unsupported flexion (USF) the position was maintained actively (Figure 2). Interested reader my find in depth description of the study protocol in our previous paper [24].

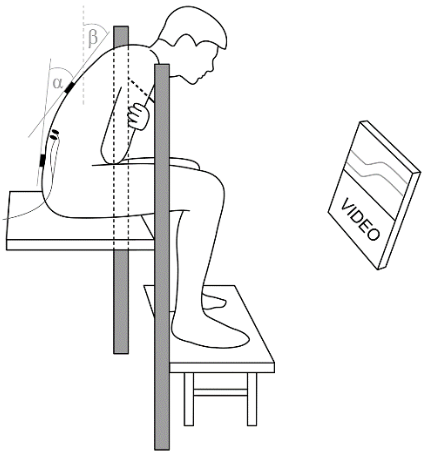


Figure 12: Position of the participant during intermittent flexion. Visual feedback was provided to the participant about the lumbar flexion (α) and trunk inclination (β) with marks for the required position.

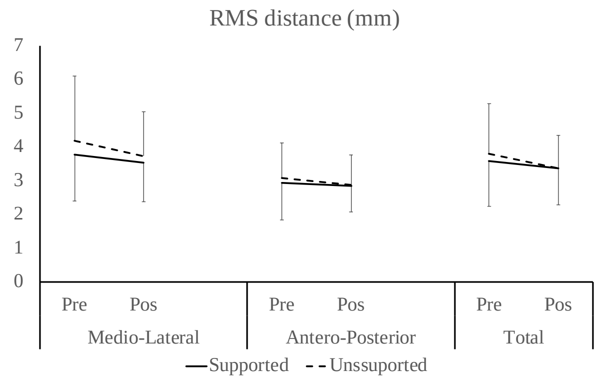
2.4 Statistical analysis

Descriptive statistics were used to report the demographic data of the participants. Transformations were used to satisfy the assumption of normal distribution, as tested with the Shapiro-Wilk test and by visual inspection of distribution plots. Intraclass correlation coefficient averaged measures (ICC) was calculated using a two way mixed model to assess reliability of the measurements. The assumption of sphericity was tested using Mauchly's test and if the assumption was violated, a Greenhouse-Geisser correction was used. Analysis of variance for repeated measurements (RMANOVA) was used to check for potential differences between the control- and the pre-tests. For the body sway measurements there were two within subjects factors (*ContrPre* (2) x *Condition* (2)) and one between subjects factor (*Sex* (2)). Effects were considered significant when the corrected $p < .05$.

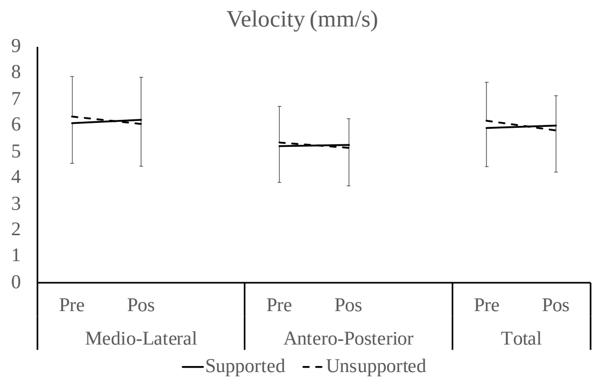
3. RESULTS

Reliability analysis have shown good to excellent within visit (ICC .72 to .95) and between visits (ICC .71 to .92) reliability of measurements. There were no significant main Pre-Pos or Condition effects and no interaction effects after SF or USF on RMS distance ($p = .136$ to .619), mean velocity ($p = .187$ to .923) and mean frequency ($p = .328$ to .987) of center of pressure movement parameters measured during sitting on an unstable surface (Figure 3).

a.



b.



c.

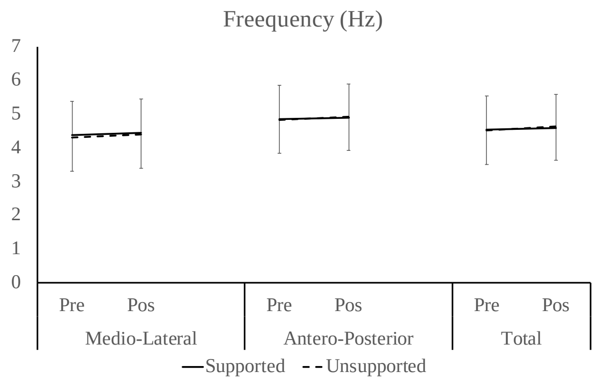


Figure 13: Graphical presentation of changes in center of preasure measurements of RMS distance (a.), average velocity (b.) and frequency (c.) while sitting on unstable surface before and after supported and unsupported trunk flexion.

4. CONCLUSION

In contrast with our hypothesis, no effects of prolonged trunk flexion on trunk postural control during sitting on the unstable surface were seen in the present study. Previous study investigating the effects of trunk flexion on the postural control during unstable sitting suggested an exposure-response relationship with larger impairments shown after longer duration of exposure and with higher external loading during trunk flexion [23]. Regardless of those factors, the changes were shown to be short-lasting and returned to the pre-exposure values within 10 minutes. In the present study, the body sway analyses were performed following the measurements of trunk stabilization in response to small perturbations. This resulted in a time window of approximately 7 to 10 minutes between the last flexion and the body sway measurements. According to the aforementioned study, potential postural deficits may have been recovered within this period. From the present study, it is therefore not possible to say whether prolonged near-end-of-range trunk flexion would result in a similar short-term impairment of postural control as reported after short creep deformation exposure. However, considering the quick restoration of normal postural control shown in the study by Hendershot and colleagues [23] the practical relevance of transient alterations of postural control is questionable.

There are a few limitations of the present study. Firstly, a convenience sample was recruited by means of personal communication and social media. As a consequence, relatively young participants were included, which limits the generalizability of the results. Secondly, the measurements were performed in the morning and afternoon, therefore some circadian influence could be expected [25]. To minimize these effects the participants were scheduled for the measurements at a similar time of the day for both conditions (visits). Furthermore, studies in real working environments that require prolonged sustained and/or repeated flexion are needed to elucidate the effects of repeated exposure to realistic occupational exposure to spinal loading.

To conclude, the present study has shown that one-hour of intermittent trunk flexion does not have lasting effects on postural control during sitting on an unstable surface. Therefore, we can probably exclude changes in postural control as mechanism responsible for back injuries and LBP following longer lasting work in flexed position.

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THE INFLUENCE OF THE PCM CONTENT ON THE PROPERTIES OF ELECTROSPUN THERMOREGULATING MATERIAL

E. Zdraveva, B. Mijović, Z. Skenderi
University of Zagreb Faculty of Textile Technology, Zagreb, CROATIA,
emilija.zdraveva@ttf.hr, budimir.mijovic@ttf.hr, zenun.skenderi@ttf.hr

Abstract

This paper focuses on the fabrication and characterization of electrospun thermoregulating fabrics incorporating phase change materials (PCM). The influence of the PCM content on the electrospun fibers morphology, thermal stability, phase change sustainability and heat storing was examined. The fibers showed cylindrical shapes and rough surfaces. The 14 % surfactant resulted in beads disappearance for both 30 and 50 wt% PCM. The PCM amount did not affected too much materials' temperature weight loss. Higher encapsulation efficiency above 30 % was calculated for the PCM 50 wt%. These fabrics are good candidates for protective clothing as can regulate the temperature near the human skin and are lightweight, thus improving body comfort.

Keywords: *electrospun, emulsion, PVA, PCM, thermoregulation*

1. INTRODUCTION

The factors that influence the balance between heat production and heat dissipation are the energy metabolism, ambient climatic conditions as well as clothing thermal properties. Clothing that protects against chemical or physical agents usually does not provide permeability to water vapour, thus in that case special fabrics or thermoregulating fabrics against body heat stress are of paramount importance [1]. Thermoregulating fabric maintains the natural core body temperature in different environmental condition, thus it provides both breathability and insulation [2]. Usually thermoregulation is based on phase change materials (PCMs) which have the ability to absorb, retain or release energy with state transfer i.e. through melting or solidification at certain temperature [3]. Electrospun nanofibrous materials as encapsulation media for PCMs provide stable form, lightweight and cost effectiveness. Some of the reported studies considered the incorporation of a series of fatty acid esters such as ethyl laurate, butyl stearate, ethyl palmitate, ethyl stearate and methyl palmitate, as PCMs inside electrospun polyacrylonitrile. The highest enthalpy reported was 110.4 kJ/kg [4]. In dual functional electrospun fibers the enthalpy was improved by electrospinning parallel fibers comprising polyurethane solid-solid PCM and polymethyl methacrylate/organic lanthanide complex. The fibers also showed narrowed PC temperature range [5]. In this work electrospun phase change fibers were prepared by emulsion electrospinning of a PCM into a polyvinyl alcohol polymer solution. The materials were examined for their morphology, thermal stability and phase change sustainability and heat storing.

2. MATERIALS AND METHODOLOGY

Materials used in this work were: polymer polyvinyl alcohol (PVA) 98-99 % hydrolysed, with Mw 146,000-186,000, non-ionic surfactant, Triton X-100 (Sigma Aldrich) and a phase change material (PCM) consisting of a mixture of plant oils with melting point at ~40 ºC (Pure Temp - Entropy Solutions inc.). PVA was dissolved in deionized water at the concentration of 8 %, while the concentration of the PCM was from 10-70 wt% by the mass of the polymer. The preparation method for the blended PVA/PCMs was reported earlier [1], with some modifications. The concentration of the surfactant in the water/oil emulsion was 30 mmol/L, while the concentration of the PCM was 15 %. Some of the materials were prepared by the addition of the surfactant into the polymer solution as well with the total concentration of 14 % from the PCM mass. PVA/PCM emulsions were electrospun with the set up comprising high voltage power supply (ES30P, Gamma High Voltage Research), syringe pump and a rotating drum collector. The process conditions were: flow rate of 1.2 mL/h, needle tip to collector distance of 20 cm and electrical voltage of 20 kV.

2.1 Characterization techniques

2.1.1 Particle size analyser

Rough estimation of the oil particles diameters was performed on Zetasizer Nano-ZS, Malvern Instruments (measurement range from 0.6 nm to 6 μm) equipped with DTS (Nano) Research Software. Emulsions (0.5 – 1 mL) were placed in DTS0012 disposable sizing cuvettes and scanned for at least 12 times. The oil/water emulsions were tested after 0, 24, 48 and 72 hours of storage at temperature of 4 ºC. The results are presented by the intensity of the scattered light from the oil droplets in relation to droplet size.

2.1.2 Scanning electron microscopy (SEM)

Fibre morphology evaluation was performed from the SEM photomicrographs taken on Jeol Neoscope 5000. The samples were prepared on metal stubs with no coating. The fibres diameter was averaged from 100 randomly selected fibres by using ImageJ software.

2.1.3 Differential Scanning Calorimetry (DSC)

Phase change reliability and heat storing performance of the materials were tested on TA Instruments DSC Q200, in a cyclic mode, (10 cycles of heating and cooling) from 0 ºC - 80 ºC with a heating rate of 10 ºC/min in nitrogen atmosphere at a flow rate of 25 mL/min. The heat of fusion and crystallization were calculated using the TA Universal Analysis software.

2.1.4 Thermogravimetrical analysis (TGA)

Thermal stability of the electrospun mats was examined on Differential Scanning Calorimetry, Netzsch STA 409 PC Luxx, in the temperature range of 25 ºC to 600 ºC.

The heating rate was 10 ºC/min in nitrogen atmosphere at a flow rate of 10 mL/min (purge) and 30 mL/min (balance).

3. RESULTS AND DISCUSSION

3.1 Emulsion stability

The results given represent the stability of the wax/water emulsions stored at 4 ºC, as the same were not stable at room temperature. The emulsions fulfilled the quality criteria after 72 hours, as shown from the intensity of the particle scattered light, Z-average and the polydispersity index (PDI), Figure 1a and b, respectively. The particle size (diameter) distribution was increasing as evident from the increased PDI, unlike the Z-average which decreased. This could be due to already sedimented bigger oil droplets on the bottom of the container thus performing the tests on smaller ones that sustained dispersion.

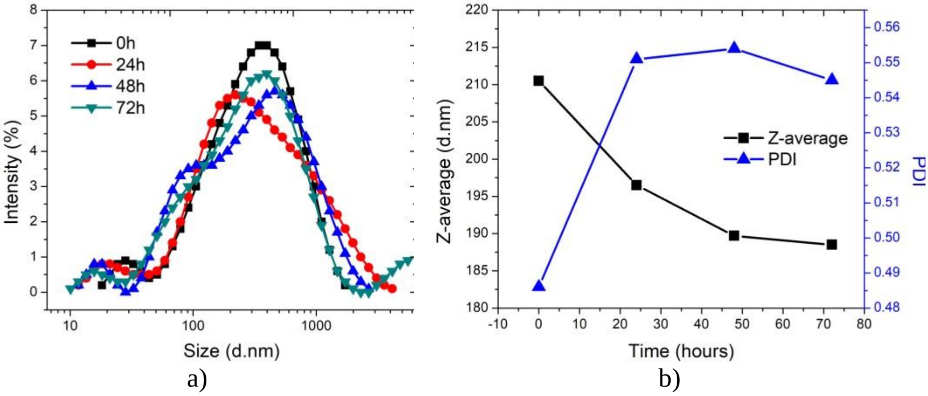

Figure 1: a) Intensity of scattered light in accordance with o/w emulsions particle size, b) Z-average and PDI of o/w emulsions changes with time

3.2 Fibre morphology

In this section the SEM images were given for the 30 and 50 wt% of the added PCM, others were reported elsewhere [2]. Both PCM/water/polymer emulsions (with no or with addition of the surfactant into the PVA solution) were successfully electrospun into fibres, Figure 2. In case of no surfactant addition into the PVA solution as the PCM concentration was increasing (above 10 wt%) the non-uniformity of the fibers and beads presence was increasing. With the addition of the surfactant (total of 14 %) the beads disappeared for both 30 and 50 wt% of the added PCM. Generally the fibers showed cylindrical shapes and rough surfaces with the evident incorporation of the small PCM particles along the fibers length. The mean fibers diameter in both cases (with and without the 14 % of the surfactant) did not show significant difference among the different PCM contents Figure 3a and b. The means fibers diameter was slightly below 300 nm and around 400 nm in case of no and 14 % of the added surfactant, respectively.

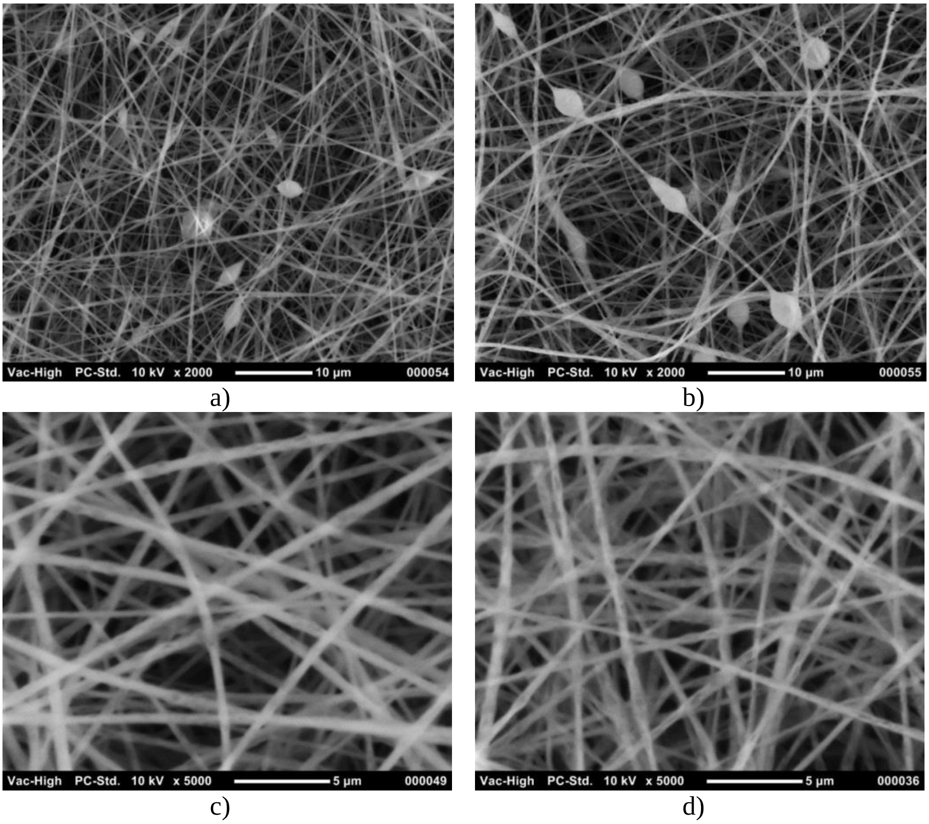

Figure 2: SEM images of the electrospun: a) PVA/PCM 30wt% and b) PVA/PCM 50wt% without, c) PVA/PCM 30wt% and d) PVA/PCM 50wt% with total of 14% surfactant.

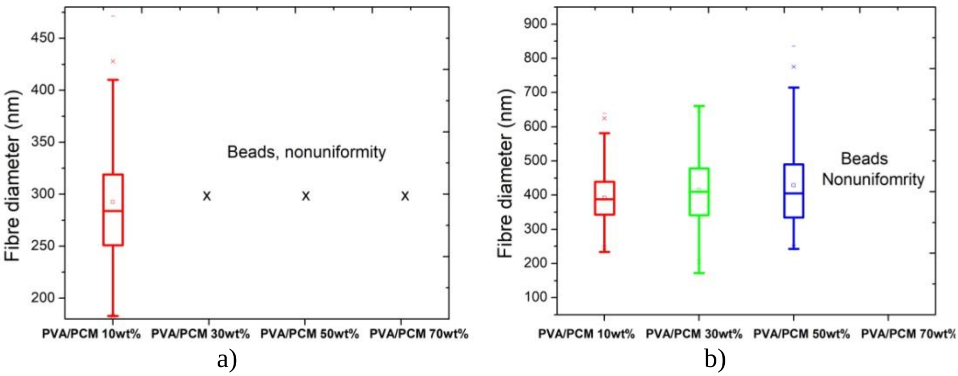

Figure 3: Mean fibre diameter of the electrospun PVA/PCM materials without and with total of 14% surfactant.

3.3 Thermal stability

The addition of the PCM into the PVA solution affected the onset temperature of polymer weight loss, as the PCM will increase its thermal stability by the PVA matrix, Figure 4. The weight loss of the electrospun PVA/PCM materials started below 250 ºC, as opposite to the PVA decomposition starting above it.

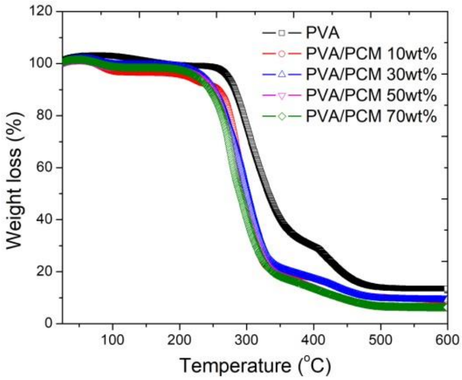

Figure 4: Weight loss of electrospun PVA/wax mats in dependence of temperature change

It was also noted that the variation of the PCM amount did not affected too much the behaviour of the electrospun materials during temperature weight loss, as the TGA curves of all the PVA/PCM materials were almost overlapping. This can suggests that the encapsulation efficiency varies even inside the materials, thus the variation of the PCM particle size also, resulted in inhomogeneous distribution of the PCM.

3.4 Phase change sustainability and heat storing

The values in Table 1 confirm the sustained function of the PCM when incorporated into the fibres in both cases (without or with 14% surfactant into the PVA solution).

Table 1: Onset melting/crystallization temperature, melting/crystallization temperature, heat of fusion/crystallization and efficiency, 10th cycle

Samples	T_{om}/ T_{oc} (ºC)	T_m/ T_c (ºC)	ΔH_m/ΔH_c (J/g)	E (%)
PVA/PCM 30wt%	35.09/32.16	37.86/31.15	48.13/47.48	23.90/23.74
PVA/PCM 50wt%	34.52/31.68	38.60/29.42	74.08/73.06	36.78/36.53
14 % surfactant				
PVA/PCM 30wt%	34.86/31.34	37.78/31.93	47.04/46.93	23.36/23.47
PVA/PCM 50wt%	35.13/30.44	38.43/31.87	68.13/67.33	33.83/33.67

The heating and cooling processes revealed regular peaks for both melting and crystallization temperatures. As expected the higher the PCM amount the higher the stored/released heat was. For both emulsions (without or with 14% surfactant) not great differences in the heat of fusion/crystallizations were observed. The changes of the onset temperatures as well as the melting/crystallization ones were negligible compared between the cycles (1st to 10th). Higher encapsulation efficiency was calculated for the PVA/PCM 50wt% above 30 %.

4. CONCLUSION

The paper gives an insight into the development of thermoregulating fabrics to be used in the design of thermally protective clothing. The thermoregulating materials were prepared by electrospinning of PVA incorporating PCM. The influence of the phase change material content on the electrospun polyvinyl alcohol fibers morphology, thermal stability, phase change sustainability and heat storing was examined. Firstly the PCM/water emulsions fulfilled the quality criteria after 72 hours of storage. Generally all the fibers showed cylindrical shapes and rough surfaces. With the addition of the surfactant (total of 14 %) the beads disappeared for both 30 and 50 wt% of the added PCM. The variation of the PCM amount did not affected too much the behaviour of the electrospun materials during temperature weight loss. Higher encapsulation efficiency was calculated for the PVA/PCM 50 wt% above 30 %.

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REVIEW OF WELLBEING SOLUTIONS IN THE CONTEXT OF DESIGNING IMPROVEMENT OF WORK QUALITY

A. Zwolankiewicz, W. Czernecka
[1] Poznan University of Technology, Poznan, POLAND,
anna.zwolankiewicz@put.poznan.pl
[2] Poznan University of Technology, Poznan, POLAND,
wiktoria.j.czernecka@doctorate.put.poznan.pl

Abstract

In the era of developing ergonomics and paying more and more attention not only to the efficiency and profitability of production, but also to the working conditions and well-being of employees, rise of the trend towards non-standard work organization solutions is noticeable. These solutions may take the form of a prowellbeing design, which consists in orienting the production of worktools towards improving the quality of employees' work by adjusting their features in a way that improves employee well-being. The aim of this article is to present available modern solutions for wellbeing design and to indicate with this example functional properties that can be controlled in order to implement non-organizational needs of employees.

Keywords*:* *ergonomics, well-being, design, improvement*

1. INTRODUCTION

The activity of ergonomics (especially conceptual) has long since begun going beyond the organization of workplaces and shaping appropriate positions at work, and more often also refers to the study and support the well-being of the employee. More and more enterprises are deciding to conduct research in the identification of factors affecting the mental and physical health of employed employees, there are also programs supporting the shaping of wellbeing at work (involving employees and company management) [1]. The design of work rooms is becoming more and more popular in a way that supports the employee's well-being. Such design is called design for wellbeing. It depends on the design of the work space, depending on the accepted concept of wellbeing. Such design meets a number of difficulties, which include choosing the concept for the needs of users by designers, the difficulty of objectively determining the design criteria, the inability to precisely determine the needs of employees. A big problem is also the determination of the final effect - changes to be made after the project has been introduced into the execution phase [2]. The aim of this article is to present the criteria of prowellbeing design on the example of literature review with solutions introduced for use. This is to indicate what organizational elements and functional features of tools and work rooms can be shaped in the design process, in addition to the safety and convenience requirements, they also play the role of supporting the formation of wellbeing.

2. CONCEPTS OF WELLBEING IN LITERATURE

Worker health considerations date back to the first half of the twentieth century, when WHO published the first definition of the word "health", in which it defined it as a physical and psychological wellbeing of a human being. Then, wellbeing began to be associated with a lack of pathology causing a sense of unhappiness and a high level of quality of life. Later on, a hedonistic approach to wellbeing was also used, according to which he is a sense of happiness and lack of negative emotions [3]. In the definitions presented in the subject literature, wellbeing is defined mainly from the emotional and psychological point of view and indicates a large dose of subjectivity in determining these states [4]. There are also distinguished terms extending these aspects with additional determinants, eg. linking wellbeing with pro-safe practices in the enterprise and organizational improvements [5]:

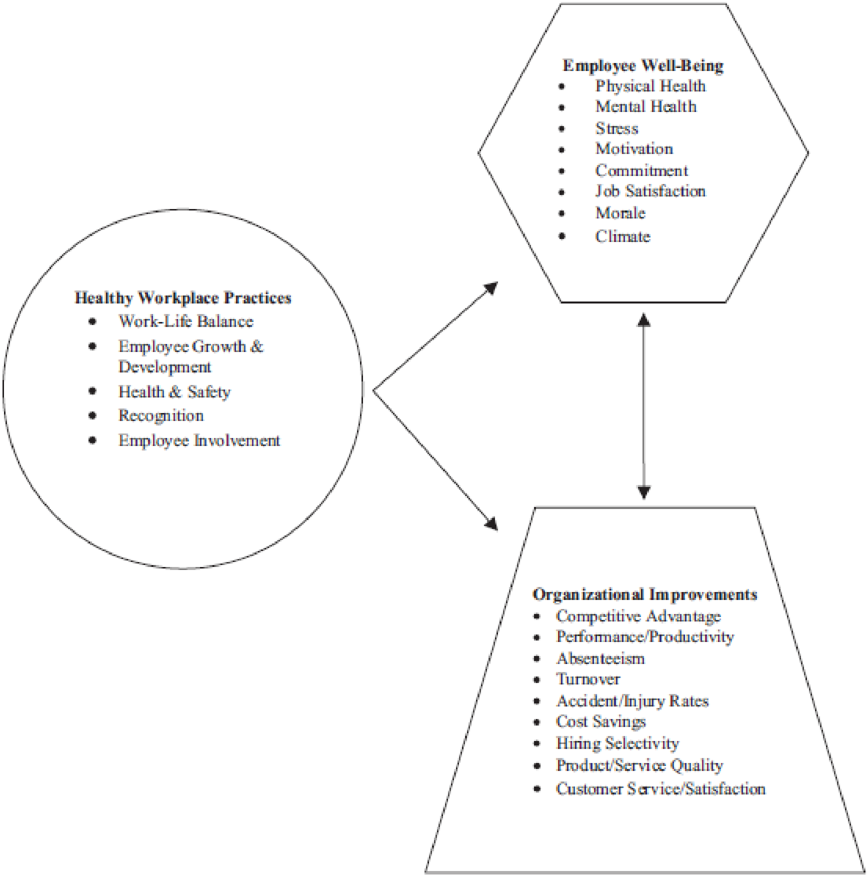

Figure 1: Wellbeing in the context of work organization
Source: Grawitch & Munz 2006 [5]

The well-being at work is also connected with the state of mind, the balance between the abilities, needs and expectations of the employee and the requirements of the environment. It is connected with the subjective achievement of satisfaction and job satisfaction. The conditions in which work takes place depends on various material (physical) and intangible (social) factors, influencing, among others, for the safety and health of employees, and consequently for well-being [6].

3. REVIEW OF WELLBEING SOLUTIONS

3.1. Components of employee well-being

To create a review of wellbeing solutions, we should start by defining elements which it consist. The employee's well-being is therefore influenced by such elements as:

- a sense of financial health, that is, good financial management by an employee, a lack of fear due to insufficient remuneration in relation to the cost of living;
- a sense of emotional health, i.e. the mental relationship of an employee with the company, a sense of belonging to the employee community, awareness of the impact that a single employee has on the entire development of the company;
- mental focus, not feeling the stress of the employee during work, enough psychic energy to perform their duties;
- physical energy, i.e. laying the work schedule in such a way that the employee is not overloaded with duties. [7]

Taking care of all of the above elements is a big challenge for companies nowadays. The lack of hands to work is becoming more and more visible in Poland. Passing through the shopping center, every second door hangs a card with the inscription "employee wanted". Social awareness has increased so much that jobseekers have begun to pay attention not only to get a decent salary, a contract of employment but also additional benefits such as health care or sports card. Enterprises looking for new ways to encourage potential employees have started to use the offers of companies that improve the employee's well-being. Polish companies offer personalized solutions such as:

- coaching (individual or group);
- training on ways to develop leadership skills;
- programs aimed at triggering positive energy;
- stress reduction programs such as MBSR (Mindfull Based Stress Reduction);
- help in resolving conflicts and mediation;
- helpline (as psychological support);
- training on healthy nutrition and dietetics;
- various types of physical activities;
- workshops allowing artistic development. [8]

The authors of this article will present in the table below the impact of individual solutions on improving the employee's work quality.

Table 1: The impact of individual solutions on improving work quality

No.	Solution	Impact
1	Coaching	Helps to increase the efficiency of employees, makes them have more energy to work; increases motivation to work (an employee who is motivated works better); teaches quick decision making; teaches how to separate private and professional life; it helps to avoid the problem of burnout. [9]
2	Training on ways to develop leadership skills	Acquiring knowledge about ways of communicating in a team; recognizing your own style of communication; learning to influence in accordance with the moral code; mastering the methods of determining the goal and effective ways to implement it; learning about decision-making techniques; extending knowledge in the field of motivating, familiarizing with methods of encouraging people to work; learning to create your own leadership position. [10]
3	Programs aimed at triggering positive energy	Encouraging employees to take up challenges to ensure adequate sleep, healthy eating, positive thinking and regular physical activity; teaching employees how to use relaxation techniques. [11]
4	Stress reduction programs	Teach you how to deal with problems; ways to focus attention; life skills in the real world and not only in virtual; building self-confidence; relaxation techniques. [12]
5	Help in resolving conflicts and mediation	They improve the efficiency of employees, they counteract the disintegration of teams.
6	Helpline	Helps you deal with personal problems that can significantly affect the quality of his work.
7	Training on healthy nutrition and dietetics	They make employees aware of the impact of a healthy lifestyle on the quality of their work, they teach the awareness of their body, help them work on their own body, so that employees have better well-being and more energy.
8	Various types of physical activities	Improvement of health, well-being, relations with colleagues, job satisfaction.
9	Workshops allowing artistic development	They teach creative thinking, searching for new ways of solving problems, openness to changes.

Source: Own study based on sources provided in footnotes

3.2. Examples of design oriented to improve the quality of the employee's work

Examples of design oriented to improve the quality of the employee's work:

- **EmiTel** - since 2016 organizes Health and Safety Week - information campaigns devoted to health-related topics; every month publishes the Health and Safety bulletin, result - a decrease in the number of accidents at work by 40% in 2017.
- **PKN ORLEN** - carried out research to determine the impact of a 12-hour daily work time on occupational safety and the comfort level of employees in production positions. Based on the results of the research, the company has developed a set of tips and recommendations, the use of which will increase the comfort of work.
- **Eurocash** - the company has created a Line of Confidence for reporting unethical behavior. You can contact the Trust Line by phone, e-mail or post. All information provided in this way is kept confidential.
- **EmiTel** - initiates employee integration meetings, promoting an active lifestyle through the organization of sightseeing tours. During the trips, employees working in different places can spend time together.
- **Stena Recycling** - organized a training program for managers and leaders for brigadiers in the implementation of which are also trained previously, direct supervisors of brigadiers.
- **3M Company** - joined the nationwide campaign "Two hours for the family" in which employees on the day they choose can come to work two hours later, leave two hours earlier, or leave during working hours for two hours to be able to spend more time with your family.
- **The VELUX Group** - has created the program "Healthy Well-being" consisting in creating healthy and comfortable working conditions. This program covers four areas: education, health, comfort and ergonomics of work and physical activity. An important component of this program is taking care of ergonomic working conditions in the office and during business trips.
- **ArcelorMittal Poland** - organizes the Days of Equilibrium during which employees participate in workshops helping them find a balance between private and professional life. In the 2017 edition there were workshops: mindfulness, relaxation exercises based on tai chi, internal motivation for employees aged 50+. [13]

Photo 1: ArcelorMittal Poland Days of Equilibrium
Source: http://poland.arcelormittal.com/typo3temp/pics/4a8fa1d2c5.jpg

The solutions presented above are examples of shaping wellbeing of employees with attention to the psychological aspect of this issue. Wellbeing is also shaped by technical projects, examples of which are presented below.

3.3. Examples of design for wellbeing

Designing for wellbeing can also take the form of changing the organization of work and technical shaping of working conditions:

Table 2: Examples of prowellbeing activities

No.	Solution	Impact
1	Green buildings	Supporting the well-being of employees by providing them with the opportunity to stay outside during work, with access to greenery. Some projects also include lighting control, air humidification, and activity support for shaping optimal conditions for employees. [14]
2	Ergonomic promotion of changing posture during work	Ensuring alternate standing and sitting during work, designing work processes that allow you to move, regardless of other factors, such as exercising by employees [15]
3	Searching for an unconventional way of supporting wellbeing	Providing additional (non-ergonomic) properties of work tools, e.g. massage chairs [16]
4	Predicting the level of wellbeing depending on the actions taken	Control of wellbeing by identifying measurement variables [17]

Source: Own study based on sources provided in footnotes

The above-mentioned examples are only demonstrative actions through which it is possible to shape wellbeing in the workplace. It should also be taken into account that all activities should seek to motivate the employee to change work depending on their needs, as shown in the diagram below.

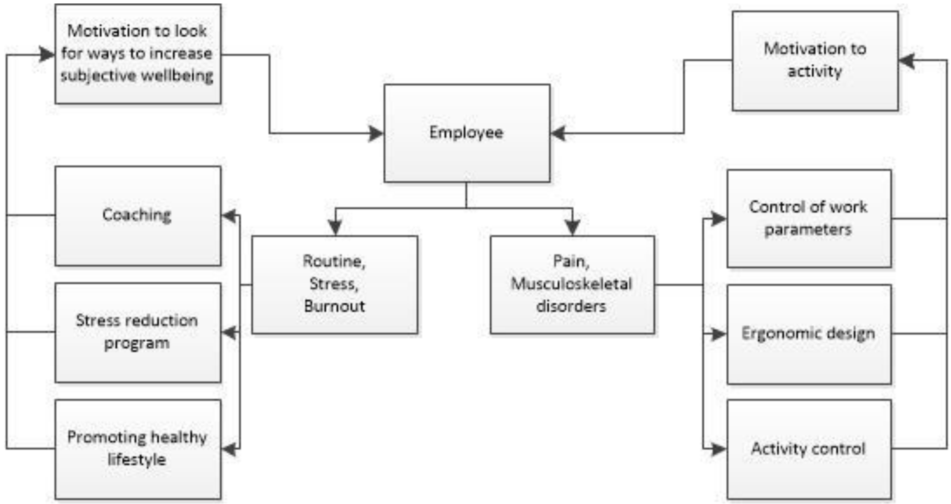

Figure 2: Wellbeing in the context of employee motivation
Source: own preparation

Employee motivation should be one of the key elements taken into account when designing for wellbeing. The project is designed to shape not only the working conditions, but also the awareness of the employees.

4. CONCLUSION

Wellbeing employees is becoming an increasingly popular issue in modern organizations. In order to achieve it, companies use various types of practices that influence both the psychological aspects of work (eg training, career counseling) and work on the way of technological projects. On the example of the studies presented and this article, it can be stated that in order to optimally shape working conditions, both types of pro-banking activities should be combined, with particular emphasis on the motivation of employees in this process. They must want to adhere to the proposed solutions and should be directed at finding their own ways to achieve subjective wellbeing.

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ANALYSIS OF ERGONOMICS AND SCIENTIFIC TEACHING ON ERGONOMICS IN AUSTRIA

E. Quendler[1], S. Schaffernicht[2], M. Wichtl[3]
[1] University for Natural Resources and Life Sciences, Vienna; Austria
[2] University for Natural Resources and Life Sciences, Vienna; Austria
[3] Austrian Accident Insurance Company (AUVA), Vienna, Austria

Abstract

Human work design is seen as a major component in the prevention of musculoskeletal disorders and in age-based and gender-based operations. For implementation is required a national ergonomic education at scientific level. The objectives of this project study were to identify the quantity and quality of courses in ergonomics offered by scientific institutions in Austria. The choice of the institutions was made by internet research as well as through additional correspondence with experts. The 14 scientific institutions surveyed offered 33 courses focusing on ergonomics in 22 study programs, which could be assigned to five categories and which differed in the sectoral focus and the portion allotted to ergonomics.Parallel to the situation of scientific teaching on ergonomics in Austria important steps to practical implementation of ergonomics in all fields of praxis are necessary. A very important step was also the reestablishment of the Austrian Ergonomic Society (ÖAE), as an ambitious and active institution.

Keywords: scientific teaching on ergonomics, quality of ergonomic courses, practical implementation

1. INTRODUCTION

These Ergonomically designed work places, in the sense of prospective ergonomics, are currently seen as a major contribution to the prevention of Musculoskeletal Disorders (MSD) and to age-based and gender-based operations. In order to anchor prospective ergonomics more intensely in the national economy, the first necessary step is to combine and intensify scientific education and training in ergonomics in Austria, especially across sectors.

This is especially important for the background that at the moment in Austria there is a lack of certified Euroergonomists. This consists in the course-based teaching of knowledge in ergonomics and, consequently, in the offering of academically trained ergonomics experts with professional experience. Their multiplier effect during gainful employment is intended to considerably improve the sustainable implementation of prospective ergonomics in practice.

Currently, 28 institutions in Austria offer teachings in ergonomics of varying intensity and sectoral orientation in 44 study programs. Among them are 13 universities and 15 technical colleges.

Although the Internet is important in conveying ergonomic knowledge, it is considered insufficient. The guidelines of the International Ergonomic Association (IEA) and of the Federation of European Ergonomics Societies (FEES), for example, require that there should also be a practical training - under the guidance of qualified trainers – [1].

The IEA (International Ergonomics Associations and FEES (Federation of the European Ergonomics Societies) have issued guidelines on the contents of ergonomics training programs. The existence of these guidelines and their application in the courses of education are prerequisites for the further development of ergonomics as a coherent and independent scientific discipline [1].
In Europe, 503 Euroergonomists have been certified to date (Centre for Registration of European Ergonomists, CREE 2017). In Austria, there is currently only one certified Euroergonomist, who acquired this qualification in another European country. Austria ranks at the bottom of the German-speaking world [3].

2. MATERIAL AND METHOD

2.1. Institutions and Colleges

On the website (http://www.studium.at/studieren/ergonomie) are listed Austrian institutions that offer ergonomics at scientific level. 28 institutions were identified with a total of 44 study programs. Six of these institutions were mentioned by the AUVA (Austrian workers compensation board). Half of them, 50.0% (14/28) of the selected institutions participated in the study with 22 study programs and 30 lecturers. The questionnaires were exhaustively filled in and returned by these 14 institutions - 5 universities and 9 technical colleges.
The most frequent ergonomics related courses were offered by the 'Universität für Bodenkultur' (University of Natural Resources and Applied Life Sciences) (21.2%, 7/33), the 'Kunstuni Linz' (Arts University of Linz) (15.2%, 5/33), the 'FH Technikum Wien' (Vienna technical college 'Technikum') (12.1%, 4/33) and the 'FH Krems' (technical college Krems) (12.1%, 4/33).

2.2 Method

There were used 2 methods, the Internet search and a semi-standardized questionnaire. An Internet search was necessary because no technical literature on the scientific teaching of ergonomics in Austria was available. The data collected provided information on each institution (address, telephone number, etc.) as well as their courses offered for the teaching of ergonomics. In order to obtain comparably representable information about courses on ergonomics in Austria, a semi-standardized questionnaire was developed.
The questionnaire was sent as a Word document by email to the institutions mentioned above. The structure of the questionnaire consisted of four parts. Firstly, there were questions regarding general information. In the second part, information was given on the course. The third part dealt with the examination situation. The fourth provided space for additional information
The questionnaires were sent to the various institutions between the end of March and the beginning of April 2017. Most of the institutions were also contacted personally through four telephone calls. The descriptive data evaluation was carried out with the spreadsheet program Excel (2016). The analytical evaluation was performed in SAS Enterprise Guide 4.2 with the Chi2 procedure.

3 RESULTS AND DISCUSSION

The 14 Austrian institutions participating in the survey offered teaching in ergonomics with different emphases in content as well as to varying extents. Courses were taught in generic ergonomics (8/33, 24,2%), in application-oriented ergonomics (8/33, 24.2%), in occupational sciences with ergonomic contents (3/33, 9,09%), application-oriented ergonomics for **workplace** design and production system optimization (8/33, 24,2%), and application-oriented ergonomics in terms of health promotion (6/33, 18,2%). The identified 33 ergonomics-oriented courses were spread across 22 fields of study at the different Austrian universities and technical colleges under review (Fig. 1).

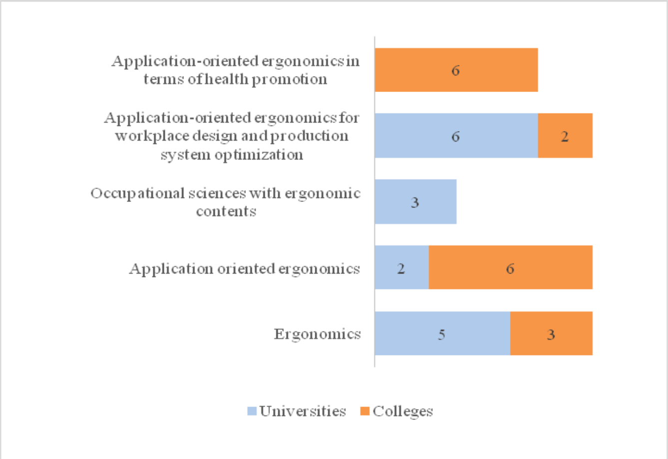

Figure 1. Main topics of the ergonomics related courses in Austria (n=33) (2017)
The majority of the courses covered less than three ECTS, averaging 2.15 ECTS (SD 1.12, MAX 5, MIN 1). This referred to the courses offered at technical colleges (MW 2.00, SD 1.16, MIN 1, MAX 5) as well as at universities (MW 2.31, SD 1.09, MIN 1, MAX 4.5).

The five areas for gaining internationally recognized expertise in ergonomics according to CREE (ergonomics: social and organizational aspects, ergonomic interventions, job-specific self-understanding, research, evaluation and work-analytical procedures as well as populations and human-scientific principles) were not sufficiently covered by the ergonomics courses offered at the different Austrian institutions (Tab.1)

Table 1: ECTS apportionment of ergonomics lectures at the surveyed Austrian scientific institutions according to the fields of knowledge of CREE (n=33), 2017.

Fields of Knowledge	ECTS
Principles, tasks and goals of ergonomics	12,5
Design of technical systems	29
Ergonomics: Activity theory and work analysis	17
Ergonomics: Physiological and physical aspects	1
Ergonomics: Psychological and cognitive aspects	5,5
Related areas	6

Also in the field of "Ergonomics: physiological and physical aspects" the offer, evaluated according to CREE, was not considered sufficient. Only one ECT was offered here. At least 2 ECTS are required for the different fields of knowledge. These missing contents have to be newly introduced or offered by foreign partners, possibly also via blended learning.
The universities and technical colleges surveyed differed significantly in terms of the ergonomics courses offered according to CREE (Chi2, $p = 0.0285 < 0.05$). At universities, the categories mostly offered were "Principles, tasks and objectives of ergonomics" (85.7%, 6/7) as well as design of technical systems (50.0%, 1/2) and "Ergonomics: Activity theory and / or work analysis "(53.3%, 8/15). At the technical colleges the categories physiological and physical aspects, psychological and cognitive aspects and related areas (88.9%, 8/9) were mostly taught. The number of lecturers in ergonomics was the same at the technical colleges and the universities included in the survey.

4. PRACTICAL ASPECTS FOR IMPLEMENTATION

A further step should be now to formulate at least one comprehensive course to compensate the missing elements in ergonomics education especially also with the focus to establish graduated Euro Ergonomists. Parallel to the situation of scientific teaching on ergonomics in Austria important steps to practical implementation of ergonomics in all fields of praxis are necessary. A very important step was also the reestablishment of ÖAE, Austrian Ergonomic Society, in the year 2012/2013 as an ambitious and active institution, also linked with FEES.

Also Austrian Workers Compensation Board constantly runs education and measures of predicial implementation of Ergonomics. The most important activities are:
- education courses for experts in the field of prevention (up to 30 teaching units for each course)
- Inhouse seminars for companies on Ergonomics (very specific adapted to the companies demands) comprising basic information and specific information for workplace design
- consultant work in Ergonomics is granted to the companies on existing workplaces as well as for planning situations

In the moment the Austrian Ergonomics Society has about 50 members, a steering board of 4 persons, one president and one manager for the operative work. In the last years in average there have been made following activities per year:
- 2 one day symposias on ergonomics
- 4-6 half day workshops on specific ergonomic content
- 1 Summer University (together with the Hungarian Ergonomic Society)

as well as special demands, for example a presentation at the 2nd International Conference "Ergonomics – Creativity and Innovativity. Good Practice" of the Lithuanian Ergonomics Society.

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GENERAL FRAMEWORK FOR IMPLEMENTING RECOMMENDATIONS OF FUTURE OF ERGONOMICS PAPER

A. Todd[1], Y. Fujita[2], J. O. Gomes[3]
[1] Rhodes University, Grahamstown, SOUTH AFRICA, a.todd@ru.ac.za
[2] Keio University, Tokyo, JAPAN, yushi1130@gmail.com
[3] Federal University of Rio de Janeiro, BRAZIL, joseorlando@nce.ufrj.br

Abstract

In 2012, the International Ergonomics Association (IEA) commissioned, white paper on the future of ergonomics by Dul and colleagues was published. This paper highlights two important focus points for creating a demand for high quality human factors and ergonomics specialists: 1. Stakeholder engagement and 2. Development and implementation of salient education programs. The paper did not however provide a protocol or model for how creating this demand or providing appropriate educational standards should be achieved. In response to this, the IEA international development standing committee has developed a General Framework Model (GFM) for the co-creation of demand for human factors and ergonomics specialists. The purpose of GFM is to provide federated, affiliated and potential societies with a step-wise approach to the development of the profession in their own country.

Keywords*:* *Development, Stakeholders, General Framework Model*

1. INTRODUCTION

The growth of any discipline requires a carefully developed and articulated strategic plan. Within this context the International Ergonomics Association (IEA), as the global association responsible for the development of human factors and ergonomics, has been actively involved in developing such plans for many years. The strategy for development of human factors and ergonomics paper published in Ergonomics by Dul et al., 2012 [1] was the culmination of a report by the future of ergonomics taskforce established by the IEA in December 2010. The purpose of this document was to provide the international ergonomics community with a vision for the future of human factors and ergonomics as a discipline and practice. It is important at this point to note that the mandate was to develop a strategy and not an operational plan [1]. As such the paper does not provide any direct frameworks for the actual implementation of the vision. The purpose therefore of this paper will be to explore firstly the ideas presented in the Dul et al. 2012 [1] paper and then provide a general framework model for consideration as a possible tool for implementation of the vision.

2. FUTURE OF HUMAN FACTORS AND ERGONOMICS

The future of ergonomics paper [1] identifies human factors and ergonomics (HFE) as a discipline with three unique features: (1) systems approach, (2) design driven, and (3) focused on two closely related outcomes; performance and human well-being. Therefore, HFE has great potential to ensure optimization of performance and well-being through being design driven and implementation of the systems approach. However, the paper also recognizes that the potential of HFE remains under-exploited, and points out that this can lead to sub-optimal systems with a number of deficiencies such as quality deficits, reduced efficiency, illness, and dissatisfaction. Among four major reasons for this situation that the future of ergonomics paper [1] identifies, the following are considered particularly important:

- Various stakeholders are not aware of the value of HFE.
- There is not enough high-quality HFE because of the absence of HFE or limited scope of HFE application.

It is therefore clear that there are primarily two areas of concern; firstly, the reality that numerous stakeholders are simply unaware of the value that HFE can bring to system design. Secondly that when there is a demand for HFE there are seldom high quality HFE specialists available to provide high quality services to meet the demand. In other words, HFE education is firmly under the spotlight here, with the need for universities to engage with what it means to provide high quality HFE learning opportunities. Therefore, the future of ergonomics paper highlights two key strategies for the development of the profession. The first strategy revolved around enhancing stakeholder awareness of what human factors and ergonomics can contribute to system design. While the second strategy focused on ways to strengthening the provision of high quality HFE research and application. The details of each of these are outlined in Table 1.

Table 1: Future of ergonomics paper key strategies for the development of Human Factors and Ergonomics

Strategies for enhancing stakeholder awareness of need for high quality HFE	Strategies for strengthening application of high quality HFE
• Communicating with specific stakeholders about the value of high-quality HFE in the language of the stakeholders. • Building partnerships with these stakeholders and their representing organizations. • Educating stakeholders to create awareness of high-quality HFE and its contributions to system design.	• Promoting the education of HFE specialists to apply high-quality HFE. • Ensuring high quality standards of HFE applications and HFE specialists. • Promoting HFE research excellence at universities and other organizations.

Source: Taken from Dul**,** J. et al., 2012 [1]

The future of ergonomics paper [1] also concludes that IEA should take a leadership role in promoting the above strategies. Therefore, the incumbent (2015-2018) IEA executive have worked to build the general framework model presented in this paper as a potential tool for communicating with stakeholders and building high quality human factors and ergonomics education programs.

System Stakeholders:

A key component of the proposal therefore revolves around understanding the contextual needs of stakeholders whether they are in industry or education. Accordingly, four distinct stakeholder groups have been identified by the future of ergonomics paper [1]:

1. System actors:
   Those people who are part of the system, e.g. employees, customers, users. Either directly or indirectly, they are affected by the design of system and affect the system's performance.
2. System experts:
   Those people who have specific professional backgrounds and contribute to the design of system, e.g. Human Factors and Ergonomics specialists, psychologists, physiologists, engineers.
3. System decision makers:
   Those people who make such important decisions as requirements, procurement, purchasing, implementation, usage, maintenance, and administration of the system.
4. System influencers:
   Those organizations or groups of people who have general public interest in work system and product/service system design (governments, standards organizations, media, etc.)

In each of these groups of stakeholders they can be broken down further into levels ranging from the individual to the global level of organization. These groups of stakeholders and the strategies identified in the future of ergonomics paper form the basis of the general framework model that is presented in this paper.

3. General Framework Model

A key component of being able to grow human factors and ergonomics is the development of relationships with stakeholders in key areas that are contextually specific to the country/region they are found. The IEA therefore developed a General Framework Model (GFM) to be applied in a variety of contexts to provide insights into stakeholder relationships and how to foster project development. The IEA development framework provides further details on a) how to categorize your stakeholders b) how to conceptualize the relationship between stakeholders and c) the need for mapping the quality of the relationship and its ability to effect change within the system.

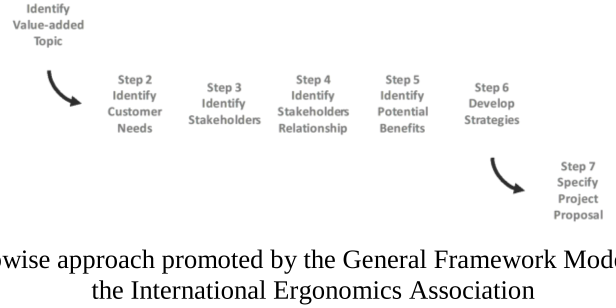

Figure 1: Stepwise approach promoted by the General Framework Model developed by the International Ergonomics Association

Step 1: Identify value-added topic

The first step of the model is findings topics that can add value. In this regard there are several key areas that should be considered:

- Significant of scientific contribution
- Potential impact for the different stakeholders (industry, academic community, and people/organization/public/society as examples)
- Contribution to uplifting the status of HFE and HFE professionals

This process of identifying meaningful topics that add value can be a difficult process particularly if the needs of industry and other stakeholders are poorly understood. It is therefore vital that a systemic HFE approach that includes a diverse group of interested stakeholders/experts is undertaken.

Step 2: Identify customer needs

Once a topic that can add value has been identified it is important to specify in more detail what the actual needs of your potential "customer" are. For this step it is important for the HFE professional to be able to illustrate how they can add value in a balanced manner that does not overstate what contribution HFE can make. Therefore, balanced specifications that consider your own biases (for or against) are necessary to identify customer needs. This can be fostered through carefully listening to the potential customer developing a contextual understanding of the situation. Typically, this is not a once off approach and requires repeated meetings using a variety of techniques including questionnaires, seminars and workshops as some examples.

Step 3: Identification of stakeholders

HFE recognizes the importance of humans within the system and they are typically expressed as stakeholders. They are a key element of socio-technical systems because they can either introduce resilience or resist systemic changes and impair performance. It is therefore important to recognise that the problems, means, solutions, and science needed to solve ergonomics related issues can be viewed differently by the stakeholders involved and may change with time. Consequently there is a need for the identification, classification, and management of stakeholders and their relationships.

A starting point to achieving this requires the identification of stakeholders. This process necessitates that both the type of stakeholder and the level of stakeholder are identified. Further details on these has been provided earlier in this paper. A short summary is however provided below:

- ✓ Types of stakeholders:
  - System Actors
  - System Experts
  - System Decision Makers
  - System Influencers
- ✓ Level of stakeholders:

- Individual
- Company
- Regional/country
- Global

This step provides an understanding of the various types of stakeholders and at what levels stakeholders are currently understood. This important step allows the mapping of the relationship between various stakeholders.

Step 4: Stakeholder relationships

The previous step allowed for the identification of stakeholders but not the relationships that exist between these stakeholders. It is important to be able to understand stakeholder relationships for a variety of reasons. Firstly, the quality of relationships between stakeholders is important in order to evaluate whether the relationship is building resilience or resisting change. Secondly, to evaluate the ability of the relationship to effect change within the system. Lastly, to determine the directionality (e.g. bidirectional vs unidirectional) between the various stakeholders in the system.

An illustration of the potential outcomes for this step are highlighted in Figure 2. This diagram provides useful insights into which relationships are of a high quality and those that are able to exert influence on the system. This is a vital step in being able to initiate a sustainable HFE program within any context.

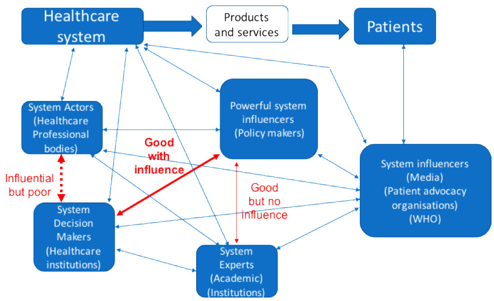

Figure 1: Illustrative example of the type of relationships that could exist within a healthcare system

Step 5: Identify potential benefits

The next step of the model requires the specification of the outputs for each of the types of stakeholders at the various levels within the system. The HFE expert needs to ensure that the needs of each stakeholder are clearly understood in order for the benefits for each of them to be clearly articulated. For stakeholder engagement it is imperative that each stakeholder has clear benefits that would accrue from HFE project provided to them. This will provide useful insights into how the proposed project should be explained to the various stakeholders. This step required the contextual understanding that has been highlighted in previous steps. A further important component of this step is its ability to define how the project should be organized taking the various stakeholders needs into account. Again the emphasis here is on taking a participatory approach to project development.

Step 6: Strategies identification

Identification of strategies for implementation are key for the success of the project. Firstly, the identification of multiple win scenarios for all the stakeholders is required. This can be a difficult and time consuming process but it is necessary to ensure the long term sustainable success of the project. Secondly, it is important to specify the project in smaller units that are easy for the various stakeholders to follow and understand. These can be done in cascade or parallel depending on the specific project and needs at hand. Thirdly, this step should clearly define the project outputs for the various stakeholders and the long term benefits for the HFE professional. Lastly there should be a focus on building networks of stakeholders. This requires that the correct questions are asked such as those highlighted below (Wheatley and Frieze, 2006 [2]):

- Why do networks form? What are the conditions that support their creation?
- What keeps a network alive and growing? What keeps members connected?
- What type of leadership is required?
- What type of leadership interferes with or destroys the network?
- What happens after a healthy network forms? What's next?

Step 7: Specify project proposal

The final step of the GFM is the specification of the proposal for the various stakeholders. The first 6 steps of the model will allow the proposal to source locally viable solutions to contextual problems. The distributed resources possessed by the human capital represented in stakeholders needs to be leveraged for such solutions to be found.

4. CONCLUSION

In response to the strategies identified by the future of ergonomics paper published in 2012 the current (2015-2018) IEA executive committee have proposed a general framework model for the development of the HFE profession. This paper provides a basic outline of the stepwise approach advocated by the model with an emphasis of clear articulation of value added topics and stakeholder engagement. The next steps for the model include several test cases to interrogate its ability to deliver on the growth of human factors and ergonomics.

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