USE OF REMOTE LABORATORIES IN ERGONOMICS EDUCATION AND RESEARCH

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Abstract

International collaboration in teaching and research has expanded as a result of the widespread accessibility and use of the World Wide Web. While on-line education has experienced the greatest growth, the use of remote laboratories in research and teaching is new. The development of a remote ergonomics laboratory using a new Internet technology is described. The purpose of the remote laboratory is to provide international access to an advanced thermal manikin technology which provides a platform for measuring the thermodynamic properties of protective clothing during exposure to controlled environmental conditions. To date, the laboratory has generated global interest and promoted international collaboration in ergonomics teaching and research.

1. INTRODUCTION

Rapid expansion of Internet use and its growing popularity as a social media tool has impacted communication and education worldwide in a positive way. The technology also offers new opportunities in engineering and science education and provides new avenues for teaching through interactive experimentation and simulation (1). Broadband availability in conjunction with data compression programs make quality audio and video streaming of lectures on the Internet possible. Computer and Internet based learning has now become an important part of education internationally. A special challenge for online education in the engineering, science, and technology fields, however, is how to include the traditional hands-on laboratory settings through the Internet. Hands-on laboratories have been an integral part of most human factors and ergonomics education in the past (2). Concepts presented in lectures are usually complemented with laboratory experimentation. Traditionally, hands-on education has been considered the "backbone" of engineering and science education which allows students to conduct practical experiments, allows students to observe dynamic phenomena in real-time, allows students to test hypotheses, allows students to learn from their mistakes, and offers students the opportunity to reach their own conclusions (3). With the rapid advances in microprocessor and communication technologies, more and more equipment can now be reconfigured and controlled remotely. This development has made hands-on training via the internet possible. Currently, there are two approaches to conducting laboratory exercises online. These include virtual labs and remote labs. The virtual laboratories are based on software that simulates the laboratory environment only. They are especially useful when equipment is too expensive, unsafe, or unavailable for use by students. Virtual laboratories, on the other hand, allow students to repeat an experiment multiple times, giving them the chance to see how changed parameters and settings can affect the outcome. Since the virtual laboratory exists only in the computer, students can learn safely from failures without causing physical damage. Remote laboratories, however, are actual physical facilities used to conduct experiments and, when not used properly, may cause damage or harm. Such facilities are controlled remotely in real-time through the Internet. The experiments use actual equipment and actual instruments. However, they are located at a different place from where they are being controlled.

To promote student access to hands-on learning in the field of ergonomics and human factors engineering, not only at the local level but also regionally and internationally, an existing thermal manikin laboratory at Boise State University was reconfigured to accommodate the Internet-based remote control technology. The laboratory now serves as an educational platform for academic partner institutions regionally and internationally.

2. THE LABORATORY

The Ergonomics Laboratory is equipped with a thermal manikin system capable of assessing the heat exchange characteristics of protective clothing worn under controlled environmental conditions. Equipment includes a manikin air pressure system, manikin air heating system, environmental ventilators, infrared radiators, and digital thermometers measuring manikin input and output temperatures needed to compute the manikin heat gain or heat loss.

2.1. IT Issues

Before the facility became suitable for use as a remote laboratory, the IT infrastructure for the remote connections had to be resolved. Issues relating to network firewall policies and the selection of appropriate software providing the connection and interface needed to be agreed upon also prior to start-up.

2.2. Training

Initiating a remote laboratory experiment always requires a support staff. Furthermore, students and researchers must be fully aware of the experimental procedures, must be knowledgeable in using the remote controls properly and safely, and must be aware of the time requirements associated with collecting accurate data. This can be achieved through in-house training.

2.3. Outcome Assessment

Assessing the learning outcome or value of the remote laboratory assignments requires the collection and evaluation of feedback from the student users. This information should be used to correct deficiencies and should be used to modify the laboratory experience. Use of a remote laboratory presents an on-going learning and revision process for the laboratory sponsors as well as for the laboratory users.

3. CONTROLS

The Internet platform serving the Remote Laboratory at Boise State University is provided by Apriori, LLC through its "Reach-In" browser technology. This system allows novice Internet users, i.e. users with no special computer skills, the ability to control mechanical devices through the internet using their computer and their home Internet connections. This functionality is possible in any geographical location in the world that has Internet access.

3.1. Technology Advantages

The technology platform provides opportunities for long-distance international remote laboratory use in the following ways:

- The software reduces latency to less than 1 second which makes it suitable for visual control of the instruments and equipment.
- The software works in all major browsers without the need for special downloads.
- The software can control any hardware component over the web.
- The technology allows many users to interact on one site without compromising the quality for the user in control.
- A queuing methodology allows for global users to join a queue from anywhere on the Internet.

A student or researcher with sufficient connection speed can log onto the remote laboratory website and control all of the assigned laboratory devices from anywhere in the world. The user has the ability to control a camera, pan up and down, and zoom in and out on every instrument located in the laboratory. At a click of their mouse, a user can control multiple mechanical devices at any one time. The laboratory remote control schematic illustrating the relationship between the key components and the sub-systems of the laboratory are illustrated in Figure 1.

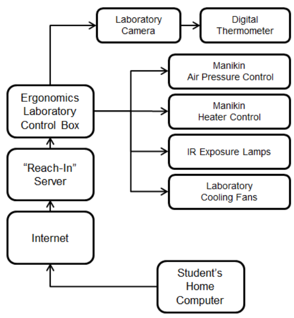


Figure 1: Layout for of the laboratory remote control system.

4. SYSTEM FEATURES

The key feature of this system lies in its architecture which minimizes the latency time of the hardware components and the latency of the software that controls all of the devices. A main server acts as a "hub" for all information transfer. A dedicated replication server is included that handles the video stream separately since the video stream represents the largest amount of data transfer. A camera is connected to an on-site control box. The mechanical devices in the laboratory are connected to motherboard located inside the control box which converts the digital data signals into voltage outputs. The voltage outputs act as the driving force to articulate the geared camera hardware back and forth, up and down, on, and of, etc. A kernel of software is located on the control box that communicates with the main servers providing an "IsAlive" beacon. Service technicians can respond if the "IsAlive" beacon does not check-in within 15 seconds.

5. LABORATORY USE

The ergonomics laboratory contains an inflatable thermal manikin system designed to measure the heat transfer characteristics of clothing systems. The technical design features are illustrated in Figure 2. While the manikin needs to be clothed by a staff member, all controls required to operate the system can be manipulated remotely via the Internet. A student, or a researcher, logs on to the laboratory website and sees the laboratory "live" through a camera that is in the "ON" position 24/7. The camera is illustrated in Figure 3. The user can engage the manikin sub systems consisting of the manikin air pressure system and the manikin internal air heating system activated through by the power control relays as shown is Figure 4. This provides the "start-up" operating configuration for the manikin. The manikin must reach thermal equilibrium with the laboratory environment prior to testing. The user can then operate the laboratory IR exposure lamps and the laboratory cooling fans to change the manikin exposure conditions. Using the camera's directional controls and the "zoom" feature, the user can monitor the digital thermometers that display the manikin input air temperature as well as the manikin output air temperature as illustrated in Figure 5. The temperature values are then used to calculate the heat loss or heat gain exhibited by the manikin during exposure to the various environmental conditions and / or clothing configurations.

6. CONDUCTING AN EXPERIMENT

To determine the heat transfer characteristics of a garment requires the student or researcher to perform two measurement procedures sequentially by using the following steps which are illustrated schematically in Figure 6:

- The thermal manikin must first reach thermal equilibrium in a "semi-nude" configuration (wearing short pants only). This serves as the "control" configuration as illustrated in Figure 7A.
- The temperature difference between output air and input air is then observed and recorded and subsequently entered into a standard energy loss calculation (formula).
- Once thermal equilibrium is reached, heat radiation exposures or

wind conditions can be added. Again, the manikin input and output temperature values are recorded at equilibrium.

- To measure the thermal characteristics of clothing systems, the procedures used for the "control" conditions are repeated with the exception that the manikin is now clothed as shown in Figure 7B. The energy loss values are then compared to the "control" conditions. This provides values for the thermal properties of the clothing system being tested under the selected environmental exposure conditions.

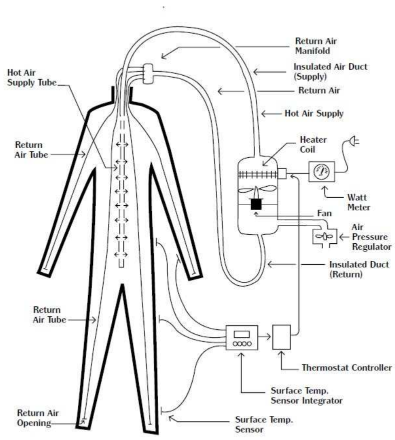


Figure 2: Illustration of inflatable thermal manikin system used in the remote laboratory.

Figure 3: Remote controlled internet camera allowing un-interrupted visual access to the laboratory.

Figure 4: Remote control relays used in activating thermal manikin sub-systems.

Figure 5: Temperature monitors showing manikin input air temperature and manikin output air temperature values which are needed to compute manikin heat loss values.

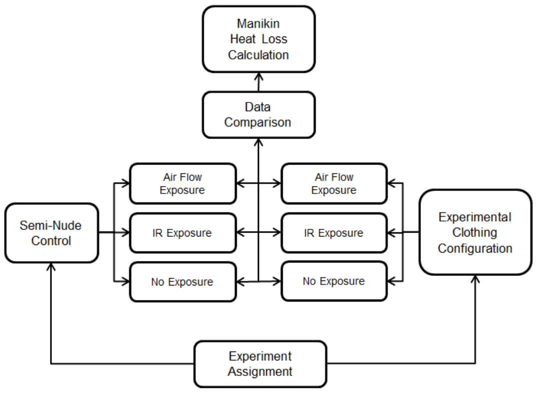
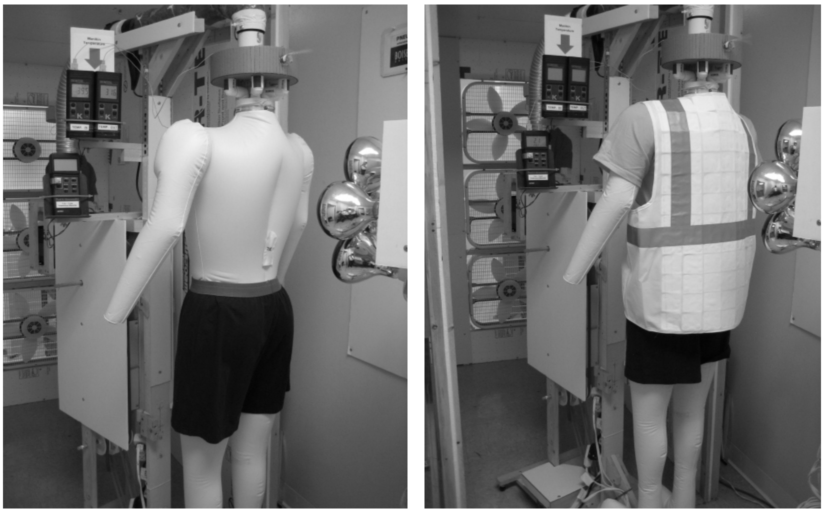


Figure 6: Testing protocol schematic



A B

Figure 7: Illustration of thermal manikin in a semi-nude "Control" configuration (A) and in the "Experimental" configuration (B).

7. ACCESSING THE LABORATORY

Access to the remote thermal laboratory is currently open to the global Internet community. Visitors are permitted to operate the equipment "at-will" to observe the technical functions of the key manikin equipment. User tracking has shown that persons from all continents around the world have accessed the facility either as a viewer or as an active "player" operating the various manikin sub-systems. Although the current features appear to offer visitors a video-game "entertainment" opportunity, the goal of the open access policy is to promote interest in ergonomics research. However, when experiments are being conducted locally or "in-house", the remote controls are disabled. This allows the researchers to eliminate outside interference or interruptions. However, the camera continues to remain "on" during experiments which allows visitors anywhere in the world to view these activities 24/7. The current URL for this remote laboratory website is: http://www.reach-in.com/demos/conduct-an-experiment.

8. COLLABORATION

International use of the remote thermal manikin laboratory as a research facility developed after visiting researchers successfully conducted in-house studies using the thermal manikin technology and wanted to continue with their experiments after returning home (4-6). The collaborations have expanded from Boise State University in the USA to the University of Zagreb in Croatia and the Hong Kong University of Science and Technology. Collaborations are being explored with universities in Central and South America. Although the advantage of using the remote laboratory increases with distance, differences in the East-West time-zones can make real-time communications regarding experimental problems and set-up requirements difficult. Nevertheless, as academic resources become scarcer, collaborative use of laboratory resources locally, regionally, and internationally will be helpful. Remote laboratories will undoubtedly play an important role in promoting collaboration in education and research in the future.

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OBJECTIVE VS. SUBJECTIVE EVALUATION OF COMFORT PARAMETERS

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Abstract

Test methods for the characterization of the properties that are essential for thermophysiological comfort include the measurement of heat and water vapor in the static and dynamic condition. These test methods can be divided into three groups: methods of fabric properties measurement, methods of the garment properties measurement (thermal manikin) and methods of comfort measurement using wear trial.
The paper describes and discusses the advantages and disadvantages of each method.

Keywords*: objective, subjective, comfort, method*

1. INTRODUCTION

The term comfort refers to the property of a thing which provides plenty of space and comfort (satisfaction and general well-being of the state of mind and body) to use and stay. It is difficult to define precisely the property of comfort of garment. Perhaps one of the best determinant of the comfort is the one that defines it as the absence of discomfort when wearing clothing or lack of awareness of the individual to an item of clothing that is worn. In any case, wear comfort shows the extent to which clothing is in synergy with the body and contribute to the optimal functioning of the body of healthy people. Comfort is not just a function of various parameters and properties of materials, but it must lead in the context of human physiological and psychological aspects [1]. Today, the comfort is considered one of the fundamental properties of textile products when it comes to the evaluation of products. The staten is included into an important goal for the 21st century that producers are trying to meet: a satisfactory balance of comfort criteria.

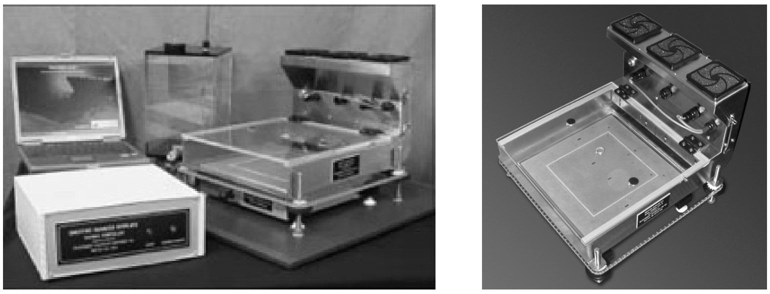
2. METHODS OF COMFORT EVALUATION

Test methods for the characterization of the properties that are essential for thermophysiological comfort are the measurement of heat and water vapor in the static and dynamic condition. Generally, these test methods can be divided into three groups [2]:

- methods of measuring the properties of fabrics (sweating guarded hot plate or similar)
- methods of measuring the properties of garments (thermal manikin) and
- methods of comfort measurement using wear trials.

2.1. Sweating guarded hot plates

Sweating guarded hot plate simulates the processes that take place above the human skin. The main parts of the named device are [3]: hot plate, fans, sensors that measure the temperature, humidity and air velocity, warming regulator, computer with program and air chamber.



a) *b)*

Figure 1: Sweating guarded hot plate: a) the parts of the measurement, b) hot plate

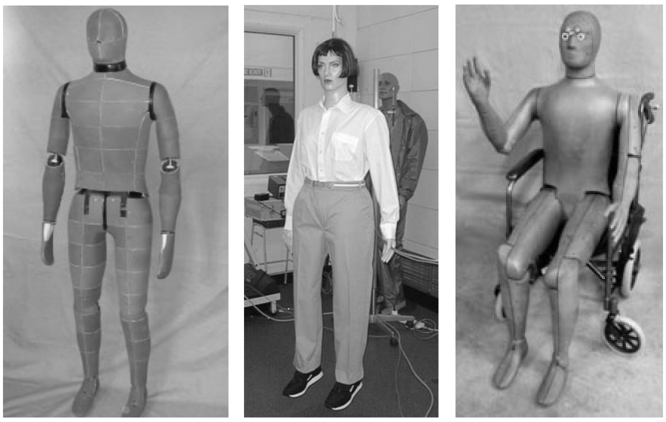
Hot plate consists of three parts which are separately heated: board to take charge of testing and two isolation ring to prevent radial heat flow. Heating unit maintains a constant temperature with a deviation of ± 0.1 º C. During the testing of thermal resistance and water vapor resistance, a power required to maintain the temperature of the plate at 35 º C is measured. During the measurement of water vapor resistance, water is supplied from the dosing unit, heated and directed to a porous plate through channels in the heating element. The plate is covered with foil or microporous film that prevents contact of water with textile products, and allow the passage of water vapor [4]. Thermal resistance (R_{ct}) and resistance to the passage of water vapor (R_{et}) are determined by calculation. Testing on the device can be made according to the following standards:
- ISO 11092: 1993 Textiles - Determination of physiological properties - Measurement of resistance to the passage of heat and water vapor under steady state conditions (hot plate)
- ASTM F 1868-XX standard method of measuring thermal resistance and resistance to the passage of water vapor through clothing using hot plates.

2.2. Thermal manikin

The manikin is a complex measurement device designed in the form of the human body that simulates the heat exchange of the human body and the environment. It is made to the basic principles that apply to the sweating guarded hot plate. Manikins are divided into a number of segments separately regulated [5]. Development of manikins began in the 40's of the 20th century when Belding in cooperation with General Electric Co. made the first manikin that was used exclusively for testing in terms of interior space. Some of the first prototypes are still in use today, Figure 2 [6].

Figure 2: The first manikin

The first fire-resistant manikin, known as "Thermo-man", was made in the 80s in the U.S. The first moving manikins had the option to set the seat position or movement of the joints. It was followed by manikins with the possibility of constant motion, defining different velocities and with the possibility of movement characteristic for cycling. A new phase in the development of manikins began producing manikins that were able to simulate the process of sweating. During the year 1989, was developed the first female manikin. It was followed by the development of the baby-manikins that enabled the evaluation of equipment for neonatal care [7]. During the year 1996, was developed the manikin that could simulate breathing [8] and was used for the evaluation of air quality [9]. Today, manikins differ by gender, ethnographic background, body size and age, and there is more than 100 different types in use [10, 11].



a) *b)* *c)*

Figure 3: Manikins: a) Adam b) Victoria c) Nemo

There is a series of standards for the specification and measurement using manikins among which we should point out the following: ISO 7920 (Determination of thermal properties of clothing), ISO NP 14505 (Rating thermal conditions in transport), ASTM F 1291 (A method of measuring the thermal insulation of the manikins), ENV 342

(Protective clothing for cold conditions), ENV 345 (Protective footwear), ENV 397 (Helmets), ENV 511 (Gloves for cold conditions).

2.3. Methods of wear trials

Methods of wear trials have a great importance in the procedure of thermophysiological comfort evaluation. Tests are performed in a controlled laboratory environment to maintain a constant temperature and relative humidity. During the test and at the end of the same, respondents meet evaluation questionnaires and give numerical ratings on questions about the level of comfort. In tests using subjects, a number of scales for assessing the degree of comfort are used. Fundamental scales are: Bedford, ASHRAE and MTV scale.

Bedford scale is created in 1936. It and was based on a study of comfort of persons performing easier jobs in the industry. Bedford has classified the answers in the scale of seven degrees, with corresponding grades 1-7, as shown in Table 1.

Table 1: Bedford scale

Description	Grade
To hot	1
Hot	2
Warm	3
Comfortable	4
Moderate fresh	5
Fresh	6
To cold	7

Bedford has, in further deliberations, concluded that the practical assessment "comfortable" should be marked with the number zero. Further, the values of sensations associated with an increase in heat should be positive numbers, and the negative numbers those associated with an increase in the cold. He also suggested that the zero level is defined as an area where more than 70% of the subjects felt comfortable and at least 86% of subjects the same zone graded between "pleasantly warm" and "pleasantly cool".

ASHRAE scale was created in the year 1971. A scale is consistent with Bedfordovim considerations and contains seven levels ranging from -3 to +3. The scale is shown in Table 2.

Table 2: ASHRAE scale

Description	Grade
Hot	+3
Warm	+2
Warmer	+1
Neutral	0
Fresh	-1
Cold	-2
To cold	-3

The findings were used to create standards defined in ASHRAE 55. The standard defines the comfort zones that correspond to the clothing insulation values between 0.5 clo
(summer clothes) and 0.9 clo (winter clothes).

Based on the comparison of heat transfer in 30 different climatic conditions and subjective tests conducted on 20 subjects, score for each of the climatic conditions is defined and MTV (Mean Thermal Vote) scale formed. Connection between stimuli and score the scale shown in Table 3. At this scale ratings range -1 to +1 are considered satisfactory for the evaluation of comfort.

Table 3: MTV scale

Description	Grade
To hot	+3
Hot	+2
Warm, but pleasant	+1
Neutral	0
Fresh, but pleasant	-1
Cold	-2
To cold	-3

3. OBJECTIVE VS. SUBJECTIVE METHODS

Each of presented groups of methods has its advantages and disadvantages. But, using the combination of methods can provide the results that are more realistic, as shown in the Table 4.

Table 10: Method overview

Method	Advantages	Disadvantages
Measurement of the properties of fabrics (sweating guarded hot plate or similar instrument)	+ easy to perform + easy to handle + short time of a single measurement + good repeatability	- result is not 100% in conformity with reality - does not observe the turbulence of air between layers
Measurement of the properties of garments (thermal manikin)	+ can be used in different environmental conditions + small error of measurement + good repeatability	- no psychological component - expensive
Comfort measurement using wear trials	+ in conformity with reality	- long duration - variability of subjects - complicated to organize

Objective methods of textile fabrics and clothing testing vary greatly. Specifically, when testing the fabrics on a hot plate, the only effect on the studied parameters have properties of fibers, yarns and fabric. Furthermore, this method is not designed to measure the impact of the air layer between the textile material or between materials and plates, nor the impact of air flow through. In contrast, examination of clothing is more complex since it includes more parameters that influence the transfer of heat and water vapor, as well as the construction of clothes, the human body, etc. The other benefits of objective testing methods are in the fact that they have good reproducibility and can be used to test materials in a variety of different environmental conditions.

Subjective testing methods are certainly more closely in line with reality, than is the case with objective methods. However, their disadvantages are the long-term testing, the variability of subjects and complicated implementation.

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A STUDY ON THE PRACTICE OF ERGONOMICS IN SPAIN. A TOOLS, METHODS AND PERSPECTIVES

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Abstract
This paper shows the state of the practice of Ergonomics in Spain, and its institutionalization in the workplace through the Law of Prevention of Occupational Risks, the exploration of new fields of application, and the quest for recognition of the profession: ergonomist. An empirical research has been conducted with a methodology quantitative, to know the actual numbers of professional practitioners and to have a picture of the social and legal impact of ergonomics, along with a qualitative methodological strategy, getting involved directly through interaction with individuals who execute or make use of ergonomics within different sub investigate samples.

Keywords:Ergonomics; Practitioner; Ergonomics tools,*

1. INTRODUCTION

A consequence of the lack of research on the work of the ergonomist, there is not hardly any information on the actual practice of professional practice of the ergonomists, their modes of operation and the factors that influence the way we work and what they do, and there is a gap between knowledge and available tools and practices. As Shorrock and Murphy (2005) note, more research is needed on the current role and activities of the ergonomist in the course of their daily work. The ergonomist looking for new avenues of activity and attempts to stabilize a minimum homogeneity in the construction of the rules of the profession and the field of knowledge required, since the recognition of a variety in the formation of departure to the different skills and ways of intervention in the actions on working conditions and health, organization or efficiency of working systems.

1.1. The creation of the Spanish Association of Ergonomics

In the late eighties, there began to emerge in Spain a clear presence of Ergonomics in industry and in University. At that time, the first university courses were delivered, in some cases as University degrees, either as Master or as Expert courses. A highlight of this were the first two editions of the Master of Ergonomics and Working Conditions in Oviedo organized by the University of Mining Engineering in Oviedo, with ENSIDESA and the Safety Commission in the iron and steel industry (CSIS) led by Jesus Portillo. Other outstanding actions focused on an attempt to establish a framework for training in the discipline, with courses at the Higher School of Management in the “Universidad Complutense” of Madrid, “Universidad Autónoma” of Madrid and “Universidad Politécnica” of Barcelona (UPC). These actions meant a great attempt to spread this discipline and to bring it closer to other types of professionals. Nowadays, only the course taught at UPC led by Peter R. Mondelo remains, maintaining excellent reputations. In 1989, some of these pioneers of Spanish Ergonomics decided to create the Spanish Ergonomics Association (AEE).

Figure 1. Logo of Asociación Española de Ergonomía (www.ergonomos.es)

Since 1997, with the publication of the Royal Decree 39/1997, specialists have been trained under the training program given official recognition by labor and academic authorities - one of the four areas or specialties (including Occupational Health) contemplated under the preventative techniques to address occupational risks.
Therefore, Spanish ergonomists do not require to work as such anything other than that legal recognition regulated by the Royal Decree 39/1997, which states: "It will be necessary to have an official university degree and to have a minimum and appropriate training accredited by a university with a content specified in the program which is referred to in Annex VI, the development of which will last no less than six hundred hours with a proper time distribution for each training project, respecting the distribution established in that Annex ... ". The previous may explain certain skepticism about those "European ergonomists" degrees under the excuse of being necessary for ergonomists to work as such.
The training program for Ergonomics experts includes the following subjects:

- Ergonomics: concepts and objectives.
- Environmental conditions in Ergonomics.
- Workplace conception and design.
- Physical workload.
- Mental workload.
- Psychosocial Factors.

- Organizational structure.
- Characteristics of the company, the job and the individual.
- Stress and other psychosocial problems.
- Consequences of adverse psychosocial factors and their evaluation.
- Psychosocial intervention.

2. MATERIALS AND METHODS

A research about the practice of ergonomics experts in Spain was conducted, with a sampling framework of 356 ergonomists, which were associated to Regional Associations of Ergonomist professionals and to the Spanish Ergonomics Association. 356 questionnaires were sent, and 97 questionnaires were received, representing a 27.24% of the whole population of interest. This instrument is based on a conceptual model of the factors that may be relevant to the practice of the ergonomists. Specifically, it consists of 104 items that fall into the following areas: demographic, professional practice of Ergonomics in relation to university education and to working in other preventative disciplines, practice of ergonomics in relation to the used methodology, specific training received, actions for the promotion and acceptance of Ergonomics, and perception of the practice of Forensic Ergonomics. The average age of respondents was 41.62 years old (SD = 8.63). The youngest respondent was 25 years old, while the oldest was 64 years old. The gender distribution is shown in the following pie chart, Figure 2, showing 61.9% (N = 60) of men.

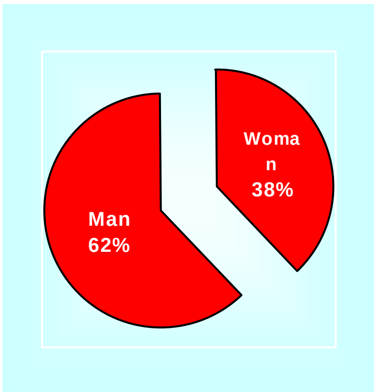

Figure 2. Gender Distribution

The Professional practice as Ergonomist for 70.5% of respondents was related to Occupational Risk Prevention functions, whereas for 8.4% of respondents works in Ergonomics together with Occupational Risk Prevention, in relation to other fields of work such as teaching, research and consulting, as shown in figure 3.

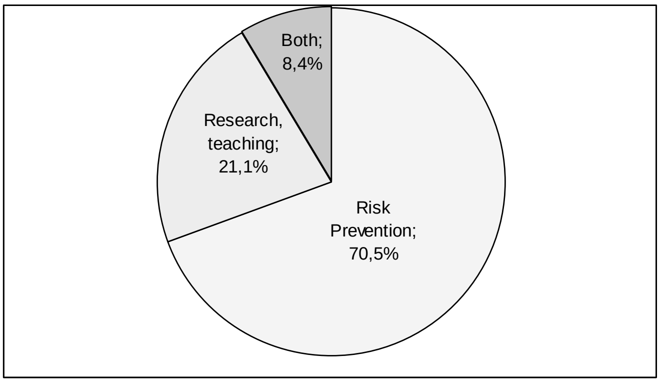

Figure 3. Professional Practice of Ergonomics

37.5% of the sample has been practicing Ergonomics professionally for more than 10 years. 57.40% of the participants work as Ergonomics specialist within an Internal Prevention Service, 40.40% work within External Prevention Services and 2.10% perform their work in the Public Administration. Generally, all Ergonomics and SocialPhsychology experts also have two other technical specialties (Occupational Safety and Industrial Hygiene), as do those experts engaged in the Health Surveillance specialty (Occupational Medicine and Nursing). Analysis of the questionnaires showed that the fields of Ergonomics and of Applied Psychology occupied over 60% of the working day for graduates in Psychology and Sociology (68.42%). The health related specialties also show this trend very clearly, as these fields occupy over 60% of their working day, 50% for medical graduates, and 30% for nurses. In the Hygiene specialty this trend was clearly not observed, with chemistry and biology experts proving to be the most active in these fields. There are 36 people who spend more than 60% of their day working in Ergonomics, which represents 39.6% of the sample. In the Safety specialty it was observed that experts with Engineering, Law, Biology and Chemistry university degrees devote greater time percentages to these fields.

However, those Occupational Risk Prevention professionals who spend more than 60% of their work time working in Ergonomics, showed statistically significant differences ($p<.05$) with respect to those who spent less than 60% of their workday. They showed a higher frequency in tasks related to work and mental health, work organization, new projects and judicial reports.

Analyzing the use of instruments and metrological equipment, the most widely used are the camera and the video camera, followed by different devices for the evaluation of environmental conditions: light meter (lighting), hygrometer (humidity and temperature) and sound level meters (noise). More specific equipment such as the goniometer (angle measurement), the HRM (heart rate measurement) or electromyography (measuring muscle activity) was not used by most of participants. It is striking that the tape measure has never been used by 63.30%. Not so strikingly 61.50% of the participants have never used lighting contrast measures.

The techniques employed for evaluating physical load to (among other goals) objectivize biomechanical aspects do not show very high frequencies. For instance, NIOSH guide is used by 19.30% of the sample, and more than half of the respondents have never implemented the Strain Index (57.30%), nor the Cirello and Snock tables (50%). Paradoxically, the greater frequency of intervention is found on those tasks that are related to occupational health, in particular to muscle and bone risk assessment (load handling, stress positions, etc..).

Participation in new projects and the application of the principles of Ergonomics design has not happened for 39.50% of respondents. Only 30.60% of the sample has participated in the design and specification of physical devices and/or the functionality of systems. Both results show the small development of Design Ergonomics and the limited involvement of ergonomists in new projects or in the design or the elaboration of specifications for Request for Proposals (RfPs) in procurement processes.

3. RESULTS AND DISCUSSION

The aim of this research has been to investigate the practice of Ergonomics in Spain from its origins. We must underline that international research in the practice of the ergonomist's profession is also still very scarce, with the exception of studies conducted in Europe by Breedveld and Dul (2005), in North America by Dempsey (2005) and more recently by Anceaux et al (2012) in France. Therefore we understand that this research represents a significant contribution to expanding knowledge on the way Ergonomics is applied. In Spain the specialty of Ergonomics and Psychosociology is linked to the prevention of occupational hazards and to the improvement of working conditions, but it gets diluted by other preventive areas that companies are obliged to apply in relation to the protection of safety and health at work. Consequently, the practice of Ergonomics in the prevention area is very limited, and its expansion depends not only on imposed actions based on new regulations or on a more rigorous enforcement of existing regulations, but also on the personal initiative of the Ergonomics specialist himself.

4. CONCLUSION

There are difficulties to extend the field of prevention of occupational risks and to expand its development in organizations. The reasons behind these difficulties are diverse and although the research points to some strategies, there are no clear ways to overcome them, recognizing the key role played by those who have decision making power, within the management of organizations and companies. Strategies must be developed to give frame to the creation of new actions for the enhancement of the professional practice and its different applications, which can be contrasted both by future European research on ergonomists, and by the advance of new practices and fields of application, like for example Forensic Ergonomics or Ergonomics Project Management.

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MISMATCH BETWEEN CLASSROOM FURNITURE AND ANTHROPOMETRIC MEASURES IN PORTUGUESE PRIMARY SCHOOLS

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Abstract

The characteristics of school furniture are strongly associated with back and neck pain, referred by school-aged children. The aim of this study was to compare furniture sizes of the 2 types indicated for primary schools, within 9 schools, with the anthropometric characteristics of Portuguese students, in order to evaluate the mismatch between them. The sample consisted of 432 volunteer students. Regarding the methodology, 5 anthropometric measures were gathered, as well as 5 dimensions from the school furniture. For the evaluation of classroom furniture, a (mis)match criterion equation was defined. Results indicated that there is a significant mismatch between furniture dimensions and the anthropometric characteristics of the students.

Keywords: *furniture, classroom, school, anthropometrics, Portuguese*

1. INTRODUCTION

The proposed activities in the classroom, such as reading, writing, observing, drawing and interpreting, are carried out with students kept on sitting position for extended periods of time, as several previous studies have found [1, 2]. In Portugal, a study found that students of the 4th year are about 70% of the time in a sitting position [3]. If it is considered that the school-age children spend about 30% of their daily time in school [4], the time they spend seated is considerable.

Recent studies reported that there are a mismatch between school furniture dimensions and schoolchildren's anthropometric measures [5, 6, 7]. This mismatch seems to be the main cause of the back, legs, arms, neck, shoulders and feet pain reported by students [7, 8]. In Portugal, about 60% of the adolescents involved in a recent study, reported having felt back pain at least once in the last three months [9]. Therefore, the school furniture seems to be primarily responsible for these constraints relating to sitting posture.

In addition to posture, there are other studies that warn about the harmful effects of improper furniture, namely at a cognitive level, such as hyperactivity, lack of interest and consequent worst learning outputs [8].
The aim of this study was to compare 2 furniture sizes indicated for primary schools, with the anthropometric characteristics of Portuguese students, in order to evaluate the potential mismatch between them.

2. METHODS

2.1. Sample and study design

The considered variables were the school furniture dimensions (seat and desk) and the students anthropometric dimensions. The sample for the anthropometric study included 432 volunteer students (216 male and 216 females) from 9 public schools belonging to the 1st cycle of the Portuguese educational system. The students aged between 7 to 10 years old, with an average of 8.5 (±1.2) years old. This sample represents a confidence level of 87,6%. It should be noted that this was a sample of convenience and so far, the measurements were taken only in the Northern part of the country. The two types of furniture used in this study were previously approved by the Portuguese Government for primary schools.

2.2. Dimensions of desks and chairs

The measures of school furniture considered for this study were those who, according to other studies [6, 7, 10], are relevant to the comparison with the anthropometric measurements of children, namely: seat height, seat depth, seat width and desk height.

2.3 Anthropometric measurements considered

The anthropometric measurements were collected using a validated anthropometric chair by a single evaluator, eliminating the error that could be introduced by the inconsistency in measurements, i.e. different measurements made by different evaluators. During the sessions, the evaluator was helped by an assistant, mainly with the task of registering the collected data.
All the measurements were taken with the subject seated in erect position in the anthropometric chair, with the knees bent at an angle of 90°, and the feet resting on a adjustable footrest. The exception to this was the stature, which was performed with the individuals standing upright and in a relaxed position, using a measuring tape attached to the anthropometric chair. During the measurement process, the individuals were barefooted and wearing shorts and t-shirt.
For this study, the anthropometric measures considered were the following [11]:

Popliteal height: measured with 90º knee flexion, as the vertical distance from the foot resting surface and the popliteal space (posterior surface of the knee);

Buttock-popliteal length: measured with 90º knee flexion, as the horizontal distance from the posterior surface of the buttock to the popliteal surface;

Hip width: the horizontal distance measured in the widest point of the hip in the sitting position;

Elbow-seat distance: taken with a 90º angle elbow flexion, as the vertical distance from the bottom of the tip of the elbow to the subject's seated surface;

Thigh thickness: the vertical distance from the highest uncompressed point of the thigh to the subject's seated surface.

2.4 Application of the measures

To evaluate the (mis)match of school furniture, considering the ergonomic principles, some compatibility criteria were defined, which establish the minimum and maximum between each furniture dimension is considered to be suitable (two-way equations) or, for situations in which only a maximum or minimum value is required (one-way).

2.4.1. Popliteal Height (PH) and seat height

Considering the anthropometric assumptions, the seat height must be adjusted to the popliteal height [12] so that the feet are perfectly laid on the floor.
There is a mismatch if the seat height is higher than 95% (high mismatch), or lower than 88% popliteal height (low mismatch) [7]. That is, the seat height must be in the range between 88% and 95% of the popliteal height (Equation 1).

$$88\%\ PH \leq Seat\ height \leq 95\%\ PH \quad \textbf{(1)}$$

2.4.2. Hip Width (HW) and seat width

In order to sit comfortably, the seat must be wide enough to accommodate subjects with wider hips [11, 12]. Thus, the match criterion is given by the Equation 2.

$$HW < Seat\ width \quad \textbf{(2)}$$

2.4.3. Buttock-Popliteal Length (BPL) and seat depth

In order to sit comfortably, the seat should also allow the subject to seat with their legs flexed at 90° (or higher) without compressing the popliteal area and, at the same time, be able to support the lumbar back. For this, the seat depth must be lower than the buttock-popliteal length [11, 12]. However, if the depth of the seat is too small for the gluteus-popliteal length (CGP), the thighs will not have the proper support. So, the compatibility criterion is according to Equation 3 [7]:

$$80\%\ BPL \leq Seat\ Depth \leq 95\%\ BPL \quad \textbf{(3)}$$

2.4.4. Elbow-Seat Distance (ESD) and desk height

The desk height is strongly related to the seat height, i.e., the desk height depends on the seat height. Thus, the desk height will be the sum of the elbow-seat distance with the seat height. Desk height (from the seat) must be between the elbow-seat distance and 3 to 5 cm below this dimension [11]. Assuming the most extreme value of this last condition, the criterion for compatibility is translated by the Equation 4.

$$ESD \leq Seat\ to\ desk\ height \leq ESD+5 \quad \textbf{(4)}$$

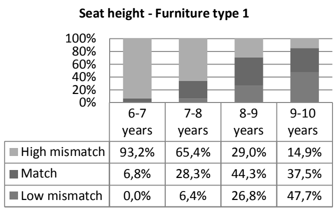
2.4.5 Thigh Thickness (TT) and seat to desk clearance

The clearance required between the seat and the desk must allow free movements of the legs and, for this, it must be equal or higher than the thigh thickness [10]. This clearance is considered to be comfortable if it exceeds the knee-height in 2 cm [7].
Based on these considerations, the match criterion is defined by the Equation 5.

$$TT + 2 \leq \text{Seat to desk clearance} \qquad \textbf{(5)}$$

3. RESULTS AND DISCUSSION

Considering the previous equations, the dimensions of the existing furniture and the children anthropometrics, it is possible to infer about the percentage of (mis)match. When two-way equations are applicable, if the furniture dimension is below the minimum value is considered to be a “low mismatch”; if it is above the maximum value it is a “high mismatch”. Between the maximum and minimum, there is the percentage of children for whom the seat is compatible (“match”).
The seat height is considered by several authors as the starting point for the design of school furniture, being the "anchor" of the school set size [10]. From the analysis of the charts in Figure 1, it is possible to infer that the seat is too high for children between 6-7 years old (with a share of more than 93% mismatch). It is within the 8-9 years old children that we have the highest % of match (~44%). In children between 9-10 years old, it turns out that the mismatch is due essentially to the fact that the seat height is too low.



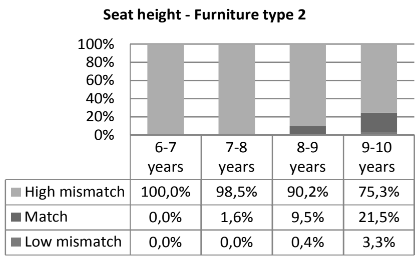


Figure 1: Percentages of match/mismatch of seat height.

According to the results presented in Figure 2, there is, in children aged 6-7 years old, a still significant % (about 60%), for which the seat is too deep, i.e. the BPH of these children is lower than the minimum value compatible with the seat depth. In this situation, there is a pressure on popliteal area that causes constriction of the blood vessels, preventing blood circulation to the legs and feet [11, 13].

The seat width has a high % of match with the width of the hips. The highest % of incompatibility is on the group between 9-10 years old. So, 11.5% of children have a width of hips higher than the seat width, which will represent a narrow seat and will result, most likely, in discomfort and restrictions on mobility [12].

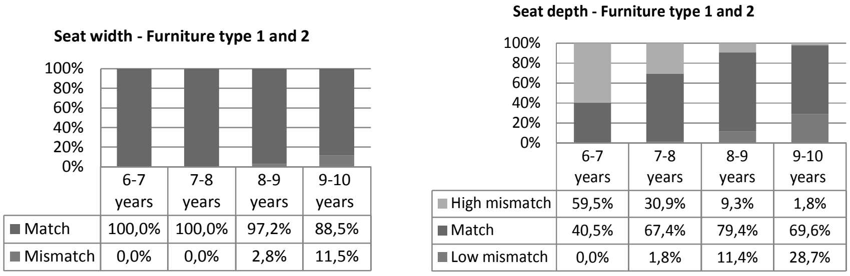


Figure 2: Percentages of match/mismatch of seat width and depth.

In this study it was found that the two types of desks used in Portuguese primary schools are too high for their users. Figure 3 shows the percentage of children whose elbow-seat distance is lower than the minimum value required for the match between this measure and seat to desk clearance.

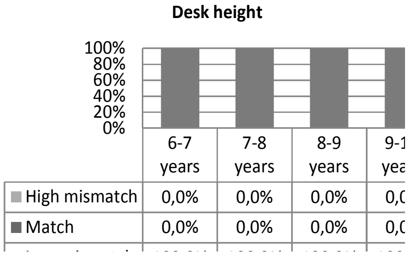


Figure 3: Percentages of match/mismatch of desk height

The clearance between the seat and the bottom of the table has more than 70% of match with the seat and desk type 1, being higher than 98.9% in the case of the seat and desk type 2, in oldest children (Figure 4).

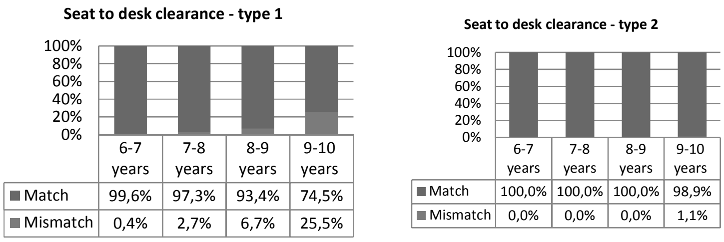


Figure 4: Percentages of match/mismatch of seat to desk clearance.

4. CONCLUSION

According the obtained data, the high values of % of mismatch between the dimensions of the primary schools furniture and the anthropometric characteristics of the user population, in particular to seat depth and height and the desk height, implies that it is urgent to introduce changes in the existing school furniture.

Of all the furniture dimensions considered relevant to the study, only the seat width and the seat to desk clearance, features high match values. This finding is similar to that of other studies, analyzed in the literature review. Note that in all situations, the furniture examined had fixed dimensions.

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STATIC ANTHROPOLOGICAL MEASURES OF MALE TRAM DRIVERS IN ZAGREB IMPORTANT FOR TRAM CONTROL PANEL DESIGN

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Abstract:

In Zagreb, the capital of Croatia, out of a total of 742 tram drivers 573 are male drivers. From the measured anthropometric measures of a sufficient and random sample of 52 male tram drivers from the entire population of 573 male tram drivers in Zagreb using statistical methods the range of normal and maximum reach of arm and the bi-acromial range of the central 90% were defined. Final results for the entire population of 742 tram drivers in Zagreb will contain ranges of anthropological measures between the fifth percentile for female drivers and ninety-fifth percentile for male tram drivers. The frequently used commands on the control panel for manual serving in the tram cab must be located predominantly within the normal reach of drivers' arms and taking into account the bi-acromial range. The same results should be taken into account during the tram control panel design or reconstruction of trams in Zagreb. The application of the presented results during the design will affect the reduction of response-reaction time and reduce the difficulty of the tram drivers' task while driving.

Key words: *male tram drivers in Zagreb, static anthropometric measures, sufficient and random sample, central 90%, control panel design*

1. INTRODUCTION

Already in 1985 during research [1] as part of the "Drive" project of the European Economic Community Michon considered that there was delay in the cognitive approach in relation to the behaviourist approach to the study of behaviour and reaction of drivers. According to Fuller's TCI model from 2005 [2], the subjective feeling of risk, instead of referring to the risk of collision, refers to the difficulty of the driving task. The difficulty of the driving task is compared by a great majority of authors (including Fuller) with mental workload. As input variables in the Fuller's TCI model, there are three standard groups of factors: "traffic environment", "transport means" and the "human factor".

The open dynamic Fuller TCI (Task – Capability Interface) model of "task demand – driver's capability" for drivers of road vehicles is also applicable for engine drivers [3] according to Figure 1, and with certain modifications and finishing it can be applied to explain the behaviour of tram drivers in a tram driver's working environment, which is the intention of the co-authors of the research below. According to Fuller [2] the task demand does not depend on its complexity, and the model is applicable, with an upgrade also to the engine drivers in Croatia according to Figure 1, and, in future studies will be applied for the analysis of behaviour of tram drivers in B&H and Croatia.

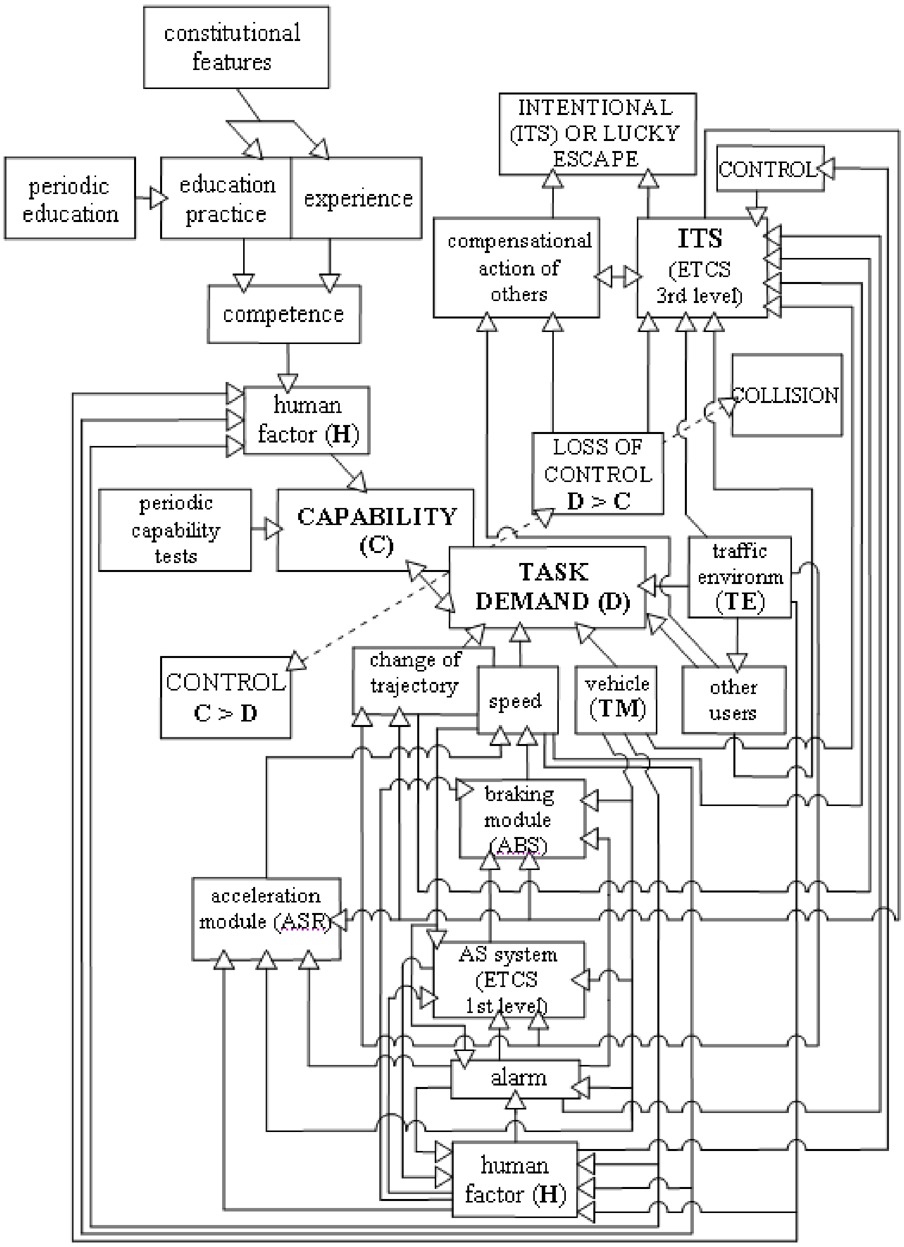

Figure 1: Dynamic open TCI model of "task demand – engine driver capability" interface in Croatia with the future development option. Source: Basic Fuller TCI model [2] adapted and modified for rail traffic in Croatia, 2012 [3]

The engine drivers' and tram drivers' task demand depends predominantly on the change of speed, unlike road vehicle drivers who can change at the same time both gears and the direction. Fuller [2], as well as the majority of scientists after 2000 recognized the fact that the choice of speed is the primary solution to the problem of keeping the difficulty of the task within the selected limits, and the limits are subject to the motivation influences.

The study of locomotive engineers' behaviour in Croatia has proven the factors of ergo assessment that affect the overall intensity of subjective disturbances from cognitive perceptions of locomotive engineers are also "transport means" factors, i.e., factors that may be closely linked to the design of the locomotive cabs [3, 4, 5]. Thus, with cab design the driver's mental workload intensity of locomotive engineers and tram drivers can be programmed. The model of Locomotive Engineers behaviour in the Republic of Croatia shown in Figure 1 is the basic Fuller TCI model [2] adapted and modified for rail traffic by Sumpor [3]. This model respects and proves the effects of "transport means" and "traffic environment" on the factors from the "human factor".

According to the open dynamic TCI model by Ray Fuller [2], the factors from the "human factor" also affect the drivers' capability as well as task demands, and among the factors of "human factors" are factors connectable to a range of typical static anthropometric measures for a sufficient and random sample of drivers from the entire population of tram drivers. The value measurements of static anthropometric measures presented in this paper have been rounded up to 1 cm. According to the instructions provided by Kroemer and Grandjean [6] 5% of the biggest and 5% of the smallest individuals of the entire population of people from the tram drivers should be excluded (in the physical dimension to which the analysis applies). According to Woodson, W. E. et al. [7], for the maximum of accepting the users' requests it is essential that the user of the transport means (operator) is included in the design at the earliest possible stage, the beginning of the development process, when the system requirements are set. According to Wilson and Norris from 2005 [8] and the guidelines of RSSB (Rail Safety and Standards Board) from Great Britain, the current priorities in research related to security and group factors "human factors" include, among other things, the evaluation of mental workload of locomotive engineers and the cab train design. The operating environments of tram drivers and the locomotive engineers are very similar (especially at lower speeds of passenger trains in the suburban traffic with no level crossings as in B&H and Croatia and with short distance between stations and road-rail crossings), because the issue of control of a vehicle predominantly comes down to timely change of speed. During the design of new trains in and new trams in the Republic of Croatia before designing of driver cab the measurements of static anthropometric measures essential for positioning the frequently and manually used commands have not been conducted.

2. METHODS AND SUBJECTS

In this study the co-authors have used the same methodology as in previous studies [9] from 2012 and [10] from 2013 to prove that the random sample is sufficient. The static anthropometric measures from Table 1 are subject to the laws of normal or Gaussian distribution. According to Kovač-Striko et al. [11] a sufficiently large sample is n > 30 from any basic set of the expected mean and standard deviation σ.

The mean arithmetic height or standing height mean $\bar{h}_{52}$ = 181.0 *cm* for the sample n = 52 male tram drivers in Table 2 was calculated according to expression (1).

$$\bar{h}_{\mathrm{n}} = \frac{h_1 + h_2 + \ldots h_{\mathrm{n}}}{\mathrm{n}} = \frac{1}{\mathrm{n}} \cdot \sum_{\mathrm{i}=1}^{\mathrm{n}} h_{\mathrm{i}} \quad (1)$$

The standard deviation of height σ_{h52} = 6.1 *cm* for the sample n = 52 male tram drivers in Table 2 was calculated according to expression (2).

$$\sigma_{h\mathrm{n}} = \sqrt{\frac{1}{\mathrm{n}-1} \cdot \sum_{\mathrm{i}=1}^{\mathrm{n}} \left(h_{\mathrm{i}} - \bar{h}_{\mathrm{n}}\right)^2} = \sqrt{\frac{1}{\mathrm{n}-1} \cdot \sum_{\mathrm{i}=1}^{\mathrm{n}} \Delta h^2} \quad (2)$$

Deviation $\sigma_{\bar{h}52}$ = 0.81 *cm* mean arithmetic height $\bar{h}_{52}$ for the sample n = 52 males tram drivers in relation to the expected mean height μ_h at basic set of the entire population of N = 573 males tram drivers in Zagreb, was calculated according to expression (3), because the basic set of the total population N = 573 males tram drivers in Zagreb is definite.

$$\sigma_{\bar{h}_{\mathrm{n}}} = \frac{\sigma_{h\mathrm{n}}}{\sqrt[2]{\mathrm{n}}} \cdot \sqrt[2]{\frac{\mathrm{N}-\mathrm{n}}{\mathrm{N}-1}} \quad (3)$$

For the added control range the standing height $\Delta h_{90\%}$ for the central 90% from Table **2**, expressions (4.1) and (4.2) by Kroemer and Grandjean [6] were obtained, which connect percentile *c*, arithmetic mean $\bar{h}_{\mathrm{n}}$ and sample standard deviation $\sigma_{h\mathrm{n}}$.

$$5.0 \cdot c = \bar{h}_{\mathrm{n}} - 1.65 \cdot \sigma_{h\mathrm{n}} \quad (4.1)$$

$$95.0 \cdot c = \bar{h}_{\mathrm{n}} + 1.65 \cdot \sigma_{h\mathrm{n}} \quad (4.2)$$

From expressions (4.1) and (4.2) follows expression (4.3) for $\Delta h_{90\%}$ *as* calculated standing height range of the central 90% of the sample.

$$\Delta \mathrm{h}_{90\%} = 5.0 \cdot c \div 95.0 \cdot c \quad (4.3)$$

3. RESULTS

Table 1 shows the results of measurements of static anthropometric measures for randomly selected n = 52 male tram drivers in Zagreb, and for all static anthropometric measures relevant for the construction of the control panel. The most important anthropometric measures in the horizontal plane of the tram cab are normal arm reach h_{ndr}, maximum arm reach h_{mdr} and bi-acromial range h_{br}. According to the results in Table 1 standing height *h* and mass *m* are included in the body mass index *BMI*. Table 1 also shows the measured amounts for reach of extended arm h_{dir} and hand length $h_{š}$.

Table 2 presents the ranges of all measured anthropometric measures Δh_{n} for the entire random sample n = 52, the ranges of all anthropometric measures $\Delta h_{90\%}$ for central 90% (calculated) and the ranges of all anthropometric measures $\Delta h_{90\%}$ for approximately central 90% (selected from the measured values).

According to results from Table 2, it has been proven that the whole random sample of n = 52 male tram drivers in Zagreb is sufficient, and that also each tram driver sample is sufficient for approximately central 90%, so that the presented refer to the central 90% of the entire male tram driver population in Zagreb.

Table 1: Static anthropometric measures for n = 52 male tram drivers in Zagreb from randomly selected sample

Resp. No.	BMI	m	h	h_{br}	h_{ξ}	h_{ndr}	h_{mdr}	h_{dir}	Resp. No.	BMI	m	h	h_{br}	h_{ξ}	h_{ndr}	h_{mdr}	h_{dir}
		kg	cm	cm	cm	cm	cm	cm			kg	cm	cm	cm	cm	cm	cm
51	29.8	87	171	42.0	20.0	46.0	**70.0**	90.0	81	25.7	90	187	41.0	**19.0**	44.0	73.0	90.0
52	30.7	105	185	46.0	21.0	48.0	81.0	94.0	82	34.0	110	180	44.0	22.0	49.0	78.0	95.0
53	29.1	105	**191**	47.0	21.0	48.0	78.0	90.0	83	24.3	78	179	46.0	20.0	47.0	75.0	87.0
54	28.4	90	178	42.0	22.0	48.0	76.0	**85.0**	85	28.4	90	178	40.0	21.0	44.0	73.0	92.0
55	26.0	75	**170**	42.0	20.0	45.0	78.0	93.0	86	26.6	75	**168**	46.0	20.0	44.0	75.0	**96.0**
56	28.7	84	171	42.0	20.0	**42.0**	**70.0**	**84.0**	87	26.5	85	179	39.0	22.0	49.0	74.0	92.0
57	28.4	90	178	46.0	21.0	47.0	75.0	92.0	88	29.4	105	189	42.0	21.0	47.0	80.0	94.0
58	29.4	105	189	44.0	20.0	47.0	78.0	92.0	89	26.3	90	185	46.0	**23.0**	**50.0**	**82.0**	95.0
59	24.5	75	175	45.0	20.0	48.0	77.0	87.0	101	38.1	114	173	47.0	20.0	45.0	71.0	86.0
60	26.3	95	**190**	**49.0**	**19.0**	47.0	78.0	94.0	102	24.8	84	184	41.0	21.0	47.0	77.0	91.0
61	27.2	90	182	39.0	21.0	46.0	74.0	90.0	103	24.9	79	178	43.0	20.0	45.0	71.0	88.0
62	31.6	100	178	46.0	22.0	49.0	78.0	93.0	104	30.8	102	182	39.0	22.0	46.0	74.0	89.0
63	27.5	95	186	43.0	20.0	47.0	76.0	94.0	106	23.7	67	**168**	43.0	**18.0**	**41.0**	**68.0**	87.0
65	24.2	75	176	41.0	21.0	47.0	71.0	**85.0**	107	30.6	99	180	**38.0**	21.0	44.0	73.0	87.0
66	28.7	86	173	44.0	21.0	**43.0**	71.0	90.0	108	30.9	100	180	**37.0**	20.0	44.0	73.0	89.0
67	23.4	80	185	39.0	21.0	48.0	**82.0**	94.0	109	23.4	81	186	45.0	21.0	46.0	75.0	89.0
68	24.9	90	**190**	43.0	21.0	45.0	**83.0**	95.0	110	24.8	84	184	43.0	21.0	48.0	79.0	91.0
70	32.3	99	175	43.0	21.0	47.0	76.0	93.0	111	37.0	120	180	40.0	20.0	46.0	71.0	**96.0**
72	31.6	108	185	47.0	21.0	**50.0**	**85.0**	92.0	112	25.9	84	180	40.0	20.0	46.0	75.0	91.0
73	29.0	92	178	**48.0**	20.0	46.0	73.0	86.0	113	25.1	85	184	42.0	20.0	48.0	75.0	93.0
74	30.9	100	180	46.0	**23.0**	**50.0**	**82.0**	**96.0**	114	23.3	84	**190**	40.0	22.0	49.0	81.0	**96.0**
75	26.0	90	186	45.0	22.0	48.0	**82.0**	92.0	117	26.9	93	186	40.0	22.0	49.0	78.0	91.0
76	31.0	95	175	41.0	**19.0**	**43.0**	71.0	**85.0**	118	27.9	103	**192**	44.0	**24.0**	**50.0**	79.0	94.0
77	31.1	110	188	**48.0**	20.0	46.0	77.0	89.0	119	26.9	89	182	46.0	21.0	48.0	81.0	**101.0**
78	27.8	90	180	**50.0**	20.0	49.0	77.0	91.0	120	28.7	92	179	42.0	21.0	46.0	75.0	91.0
79	25.2	80	178	**38.0**	22.0	45.0	75.0	93.0	121	27.5	94	185	45.0	22.0	47.0	80.0	90.0

Table 2: Ranges of anthropometric measures for all randomly selected samples of n = 52 *male* tram drivers and for central 90% (calculated) or approximately central 90% (selected from the measured values)

Anthropomet. measure	Symbol	Remark	Amount (cm)	
			n = 52	central 90%
h - **standing height** in balanced standing posture	$\bar{h}$	calculated - expression (1)	181.0	180.7
	Δh	measured for n = 52 - Table 1	168÷192	/
	$\Delta h_{90\%}$	measured and selected for n =44		171÷189
		calculated - expression (4.1,4.2,4.3)	/	**170.9÷191.0**
	σ_h	calculated - expression (2)	6.1	/
	$\sigma_{\bar{h}}$	calculated - expression (3)	0.8	/
h_{br} – **shoulder width**, or **biacromial range** in the area of shoulder joints	$\bar{h}_{br}$	calculated - expression (1)	43.2	43.0
	Δh_{br}	measured for n = 52 - Table 1	37÷50	/
	Δh_{br90}	measured and selected for n = 45	/	39÷47
		calculated - expression (4.1,4.2,4.3)	/	**38.1÷48.3**
	$\sigma_{h_{br}}$	calculated - expression (2)	3.1	/
	$\sigma_{\bar{h}_{br}}$	calculated - expression (3)	0.4	/
h_{ndr} – **normal arm reach** or **working distance**, from elbow to the tip of the longest finger	$\bar{h}_{ndr}$	calculated - expression (1)	46.6	46.7
	Δh_{ndr}	measured for n = 52 - Table 1	41÷50	/
	$\Delta h_{ndr90\%}$	measured and selected for n = 44	/	44÷49
		calculated - expression (4.1,4.2,4.3)	/	**43.1÷50.1**
	$\sigma_{h_{ndr}}$	calculated - expression (2)	2.1	/
	$\sigma_{\bar{h}_{ndr}}$	calculated - expression (3)	0.3	/
h_{mdr}– **maximal arm reach** or **length of reach**, from shoulder joint to the tip of the longest finger	$\bar{h}_{mdr}$	calculated - expression (1)	76.2	75.7
	Δh_{mdr}	measured for n = 52 - Table 1	68÷85	/
	$\Delta h_{mdr90\%}$	measured and selected for n = 43	/	71÷81
		calculated - expression (4.1,4.2,4.3)	/	**69.7÷82.6**
	$\sigma_{h_{mdr}}$	calculated - expression (2)	3.9	/
	$\sigma_{\bar{h}_{mdr}}$	calculated - expression (3)	0.5	/
h_{dir} – **reach of extended arm**, from the tip of the longest finger to the most protruding part of the back	$\bar{h}_{dir}$	calculated - expression (1)	91.2	91.1
	Δh_{dir}	measured for n = 52 - Table 1	84÷101	/
	$\Delta h_{dir90\%}$	measured and selected for n = 43	/	86÷95
		calculated - expression (4.1,4.2,4.3)	/	**85.4÷96.9**
	$\sigma_{h_{dir}}$	calculated - expression (2)	3.5	/
	$\sigma_{\bar{h}_{dir}}$	calculated - expression (3)	0.5	/

Table 3: Comparison of the mean amount ratio arm's length and standing height for the citizens of the Republic of Croatia

	Female:		Male:	
Subjects:	Tram drivers in Zagreb	First years students of graduate study of FPZ in Zagreb	Tram drivers in Zagreb	Locomotive engineers from all over Croatia
The total number of subjects n in the random and sufficient sample	36	34	52	50
Total population N	169	55	573	1410
Age range (years)	30÷55	22÷26	29÷64	28÷53
The average attainment of the age (years)	45.5	24.0	47.2	44.9
Mean height value $\overline{h}$ (cm)	166.6	170.4	181.0	180.4
Standard deviation σ_h (cm)	4.9	5.8	6.1	6.2
A range of sample height Δh (cm)	155÷177	160÷182	168÷192	165÷194
Calculated height range for the central 90% - Δh90% (cm)	158.5÷174.8	160.8÷179.9	170.9÷191.0	170.2÷190.6
Mean value of ratio of arm's reach and height h_r/h	0.42	0.42	0.42	0.42
Correlation coefficient R for evaluating of linear function $h_r = h_r(h)$	0.61	0.73	0.63	0.69
Year of measurement	2013	2013	2013	2012

Source: 2013 authors' complemented own research and results of past research taken from 2012 [3]

According to the harmonic analysis of Muftić et al. [12, 13] the ratio of arm's reach and standing height is the harmonic number h_r/h=25/64=0.39. According to the results of measurements for 2012 and 2013 from Table 3 of the random and sufficient sample n > 30 due to the size of the studied population N, this ratio is always for the citizens of the Republic of Croatia h_r/h=0.42 irrespective of gender, occupation, and attainment of age, with the correlation of mean strength for $0.5 < R < 0.79$. As expected, the function of dependence $h_r = h_r(h)$ was closer to the linear dependence (R = 0.73) for younger respondents, female students of the average age of 24.

By comparing the mean height value for female tram drivers in Zagreb (adult females) and female students of the first years of graduate study at FPZ, the basis of only one hypothesis from the scientific literature [14] has been partly confirmed:

- Female students have a greater mean height than adult females (in Zagreb), because the height of women starts to decline relative to the attainment of age after the age of 25,

- Due to the influence of the socioeconomic factors the female students are expected to have additionally increased average height in relation to their peers of the same age who are not students; this need to be proved yet by concrete measurements.

3. DISCUSSION

The most frequently used commands for manual serving in tram cab are: "dead man" function, brake module, accelerator, horn or bell, direction indicators, commands for setting the points, and commands for manipulation of the doors in passenger area.

New tram cabs in Zagreb have no leg-serving commands.

Figure 2 (left) and Figure 3 (right): Model TMK 2200 produced by Crotram manufacturer's consortium in Croatia which operates in Zagreb

Figure 2 and Figure 3 show tram control panel in the new tram that runs in Zagreb. Multi-purpose controller for the left arm in Zagreb is designed for group-related commands in connection with the changing of the speed: accelerator, brake modules, and "dead man" function.

According to Figures 2 and 3 the position of a multi-purpose controller in a new tram cab in Zagreb is too much to the left and too much to the back, in relation to the male subject which is closer to the upper limit of the range for the central 90% of male tram drivers (h = 173.0 *cm)*:

- outside of the range of normal arm reach,
- outside of bi-acromial range (shoulder width),
- outside of the field of vision of the tram drivers without turning their head.

Simultaneously with this study, the authors of this paper and all researchers participating in the national scientific project "Cognitive Ergonomics in the Function of Traffic Safety Increase" have studied which factors are also the dominant and important factors of subjective disturbance from the tram drivers' cognitive perception, from the groups "transport means" and "traffic environment", for a random sample of male and female tram drivers in Zagreb.

4. CONCLUSION

In this paper, it has been proven that the random sample of male tram drivers from Zagreb is sufficient for determination of specific anthropometric measures needed for tram control panel design. Results include the centiles that are between 5% and 95%, i.e. central 90% of the randomly selected and sufficient sample, i.e. central 90% of the entire population of male tram drivers. Designing of driver cabs and control panels in trams, without taking into account the measurement results and the calculation of the range of the most important anthropometric values in the central 90% from a random and sufficiently big sample of all drivers, may be the reason of anthropometric lack of suitability of the working space of the driver cab for the central 90% of tram drivers from the total population of Zagreb. Since the factors from the group "human factor" are input factors in the open dynamic TCI model of drivers' behaviour, and factors from groups "transport means" and "traffic environment" influence the "human factor", inadequate design of tram cab may also result in increased physical efforts in the static seating working position (amount of lumbar moment of the drivers depends on the body mass index - *BMI*), increased perception-response time of tram drivers in the circumstances of the need to change the speed, and may be the reason for the occurrence of the subjective feeling of workload from the drivers' cognitive perception. This paper has proven the dependence of the standing human height on the age, gender and occupation. The final results for the entire population of 742 tram drivers in Zagreb will contain ranges of all important anthropological measures between the fifth percentile for female drivers and the ninety-fifth percentile for male tram drivers. The group-related commands such as multi-purpose controller for manual serving are very good solutions for commands associated with the choice of speed, because the choice of speed is the primary solution of the problem of keeping the difficulty of task within the selected limits. However, in new tram cabs in Zagreb, the multi-purpose controller is outside of the bi-acromial range, and it is not within the normal arm reach.

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STATIC ANTHROPOLOGICAL MEASURES OF FEMALE TRAM DRIVERS IN ZAGREB IMPORTANT FOR TRAM CONTROL PANEL DESIGN

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Abstract:

In Zagreb, the capital of Croatia, out of a total of 742 tram drivers 169 are female drivers. The adaptation of tram control panel to a large share of 23% of female drivers in the total population of tram drivers cannot be resolved with an ergonomic seat with eight levels of adjustment. From the measured anthropometric measures from a sufficient and random sample of 36 female tram drivers of the entire population of 169 female tram drivers in Zagreb using statistical methods the range of normal and maximum arm reach and the biacromial range of the central 90% were defined. The final results for the entire population of 742 tram drivers in Zagreb will contain ranges of anthropological measures between the fifth percentile for female drivers and ninety-fifth percentile for male tram drivers. The frequently used manually served commands on the control panel in the tram cab must be located predominantly within the normal reach of the drivers' arms and taking into account the biacromial range. The same results should be taken into account during the tram control panel design or reconstruction of trams in Zagreb. The application of the presented results during the design will have impact on reducing the response-reaction time and on reducing the difficulty of the tram drivers' task while driving.

Key words: *female tram drivers, sufficient and random sample, anthropometric measures, central 90%, control panel design.*

1. INTRODUCTION

The difficulty of the driving task is compared by a great majority of authors with mental workload. Intense feeling of fatigue from cognitive perception of drivers, according to Ashton and Fowler [1], may be reason for occurrence of errors and may affect the perception-response time. The open dynamic TCI model by Fuller [2] was designed for road traffic, for simultaneous changes in direction and speed. TCI model of "task demand – driver's capability" is applicable for engine drivers [3], and with certain modifications and finishing it can be applied to explain the behaviour of tram drivers in a tram driver's working and traffic environment. For low speeds suburban traffic for passenger trains and trams is very similar, because there is short distance between stations and road-rail crossings. The difference in the driving trajectory between rail and tram traffic is the following: in rail traffic the points are set from the local center, while in the tram traffic the points are set manually from the tram cab by the tram driver. According to the open dynamic TCI model in Figure 1, the selection of vehicle speed is determined by human factors. The task demand does not depend on its complexity, and the drivers' task demand depends dominantly on the change of speed for all drivers [2]**.** The factors from the "human factor" also affect the drivers' capability as well as task demands, and among the "human factors" are factors connectable to a range of static anthropometric measures for a sufficient and random sample of tram drivers, from the entire population of male and female tram drivers. When the driver's capability exceeds the task demand (C>D), the task is easy. When the driver's capability and the task demand are equal (C=D), the drivers act on the borders of their capability and the task is very difficult, and only at that moment the subjective risk becomes equal to the objective statistical risk. When the driver's capability is lower than the task demand (C<D), then the task is per definition simply too difficult and the drivers cannot handle it.

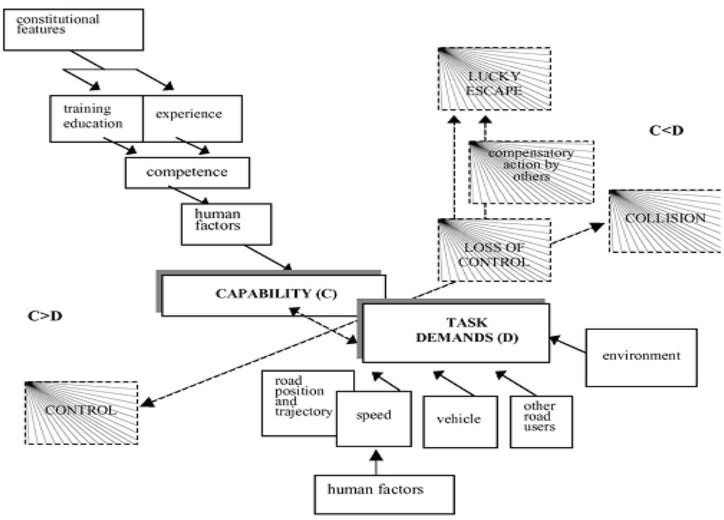

Figure 1: Open dynamic TCI model of "task demand – driver's capability" interface
Source: Taken from **Fuller, R.**, 2005 [2]

Besides, currently in Zagreb, in the year 2013 there are six different types of trams running with five different control panels. The public transportation operator in Zagreb, ZET, does not prescribe a standard which commits manufacturers of trams for the Croatia market to standardize the control panels, so that all the frequently used commands for manual serving (module accelerator, brake module, "dead-man" function, horn or bell, commands for setting the points, direction indicator commands and door manipulation commands) in all the trams would always be on the same side of the control panel and served by the same hand. According to Wilson and Norris from 2005 [4] and the guidelines of RSSB (Rail Safety and Standards Board) from Great Britain, the current priorities in research related to security and "human factors" include, among other things, the evaluation of mental workload of locomotive engineers and the cab train design. Identical rules can be applied to the design of tram cab.

2. FEMALE STATIC ANTHROPOMETRIC FACTORS

Anthropometric variables are polygenetic factors, and their distribution is the result of multiple influences, factors of genetic and non-genetic origins, according to Jurum-Kipke et al. [5]**.** Phenotype is the result of interaction of genotypes and many factors of environmental systems. Thus, the phenotype variations of some entity populations are the sum of genotype variations and variations of the ambient systems that govern in the ambient of the observed entity population, as can be seen from expression (1).

$$F_v = E_v + G_v \quad (1)$$

where: F_v – symbol of phenotype variation,
E_v – variation of ecological factors, and
G_v – genotype variation.

According to Jurum-Kipke et al. [5], numerous anthropometric studies that refer to the definition of the so-called static anthropometric measures show also the differences that result from the constitutional differences between people, both regarding gender and age, and regarding the body constitution. According to Ujević et al. [6], age is also a significant factor of body stature. The whole development of body dimensions reaches its peak towards the end of teenage or in early 20s of men, while women reach this development a few years earlier. After maturity the body dimensions of both genders begin to decrease with age which is illustrated in Figure 2.

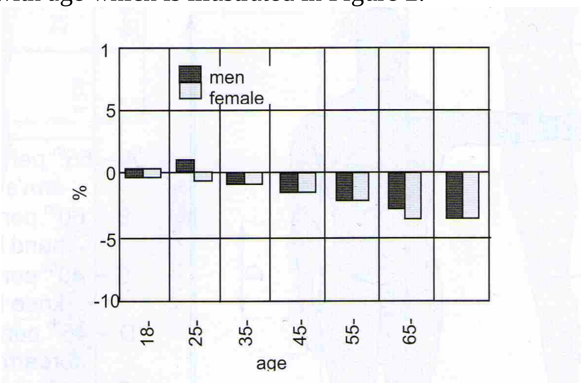

Figure 2: Relative changes in body stature depending on age and gender, for men and women at the age of 18 to 79
Source: Taken from Ujević, D. et al., 2009 [6]

According to Ujević et al. [6] socioeconomic factors also have a significant influence on body stature. Since a socioeconomic factor affects the possibility of higher education, it follows that the studies of students almost always indicate that they are taller than those who are not gaining higher education. Table 1 gives comparative overview of the standard static anthropometrical measures for female population according to measuring year, occupation and age. The coauthors' measurement results from Table 1 confirm that with age the mean height of the female population decreases after the age of 25. According to that, female students of the first years of the Faculty of Traffic and Transport Sciences at the graduate study are statistically among the highest groups in the entire female population in Zagreb, which proves the scientific literature hypothesis according to which the socioeconomic factors have a significant impact on further elevated body stature.

Table 1: Comparison of anthropomeasures for female respondents in Zagreb, according to year of measuring, occupation (socioeconomic factors) and age.

Female respondents in Zagreb:			Tram drivers in Zagreb	Students of the first year graduate study at FPZ in Zagreb
Total of respondents from random sample *n*			36	34
Total population *N*			169	55
Age	Range (year)		30÷55	22÷26
	Average (year)		45.5	24.0
Mean height $\bar{h}$ (cm)			166.6	170.4
Standard deviation for height σ_h (cm)			4.9	5.8
Height sample range Δh (cm)			155÷177	160÷182
Calculated range of height for central 90% $\Delta h_{90\%}$ (cm)			158.5÷174.8	160.8÷179.9
Body mass range *m* (kg)			55÷135	52÷85
Mean value of hand length and height ratio h_r/h			0.42	0.42
Mean value of shoulder width and height ratio h_{br}/h			0.22	0.22
Measuring year			2013.	2013.
BMI	Range (kg/m^2)		19.5÷43.6	18.1÷30.1
	Average (kg/m^2)		26.7	21.7
BMI	Normal body mass *BMI* = ***18.5-24.9***	*n*	17	31
		%	47.2 %	91.2 %
	Overweight *BMI* = ***25-29.9***	*n*	12	2
		%	33.3 %	5.9 %
	Obese *BMI >30*	*n*	7	1
		%	19.5 %	2.9 %
	Overweight and obese *BMI >25*	*n*	19	3
		%	52.8 %	8.8 %

The mean value of height for female tram drivers in Zagreb $\bar{h}$ = *166.6 cm* during the year 2013 from Table 1, in relation to the mean value of height for the entire population of adult women in Croatia $\bar{h}$ = *163.0 cm* according to Ujević et al. [6] from 2005, suggests a possible phenotypic effect of slight increase in height for the female population between the years 2005 and 2013. According to Kovač-Striko et al. [7] a sufficiently large sample is $n > 30$ from any basic set of the expected mean and standard deviation σ. However, it is necessary to verify the results from Table 1, by taking measurements of a larger sample of women, including female respondents from all Croatia outside the City of Zagreb.

3. REQUIRED NUMBER OF RESPONDENTS TO DETERMINE THE NORMAL AND MAXIMUM REACH OF ARM

A random sample of $n = 36$ respondents (as for $n = 32$ respondents in the approximately central 90%) are fully adequate to describe the entire population of $N = 169$ female tram drivers in Zagreb, all calculated under the assumed expressions (2), (3) and (4) for the evaluation of the sample [7]. According to Kroemer and Grandjean [8]

5% of the tallest and 5% of the smallest individuals of the entire population of people from the tram drivers should be excluded (in the physical dimension to which the analysis applies). It is necessary to include the centiles that are between 5% and 95%, i.e. approximately central 90% of the randomly selected and sufficient sample, i.e. the entire population.

The mean arithmetic height or standing height mean $\bar{h}_{36}$ = *166.6 cm* for sample *n = 36* of female tram drivers in Table 3 was calculated according to expression (2).

$$\bar{h}_n = \frac{h_1 + h_2 + ...h_n}{n} = \frac{1}{n} \cdot \sum_{i=1}^{n} h_i \tag{2}$$

The standard deviation of height σ_{h36} = *4.9 cm* for sample *n = 36* of female tram drivers in Table 3 was calculated according to expression (3).

$$\sigma_{hn} = \sqrt[2]{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(h_i - \bar{h}_n\right)^2} = \sqrt[2]{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \Delta h^2} \tag{3}$$

Deviation $\sigma_{\bar{h}36}$ = *0.7 cm* mean arithmetic height $\bar{h}_{36}$ for sample *n = 36* of female tram drivers in relation to the expected mean height μ_h at basic set of the entire population of *N = 169* female tram drivers in Zagreb, was calculated according to expression (4), because the basic set of total population *N = 169* of female tram drivers in Zagreb is definite.

$$\sigma_{\bar{h}_n} = \frac{\sigma_{hn}}{\sqrt[2]{n}} \cdot \sqrt[2]{\frac{N-n}{N-1}} \tag{4}$$

For the added control range the standing height Δh_{32} for the central 90% from Table 3, expressions (5.1) and (5.2) by Kroemer and Grandjean [8] were obtained, which connect centile *c*, arithmetic mean $\bar{h}_n$ and sample standard deviation σ_{hn}.

$$5{,}0 \cdot c = \bar{h}_n - 1{,}65 \cdot \sigma_{hn} \tag{5.1}$$

$$95{,}0 \cdot c = \bar{h}_n + 1{,}65 \cdot \sigma_{hn} \tag{5.2}$$

From expressions (5.1) and (5.2) there follows expression (5.3) for the $\Delta h_{90\%}$ *as* calculated standing height range of the central 90% of the sample.

$$\Delta \mathrm{h}_{90\%} = 5{,}0 \cdot c \div 95{,}0 \cdot c \tag{5.3}$$

Table 2 shows the results of measurements of static anthropometric measures for randomly selected *n = 36* female tram drivers in Zagreb, and for all static anthropometric measures relevant for the construction of the control panel. The value measurements of static anthropometric measures presented in this paper have been rounded up to 1 cm. In the same way as in this chapter, during the year 2012 in B&H (Sarajevo), the static anthropometric measures were measured for male tram drivers by Sumpor et al. [9].

Table 2: Static anthropometric measures for $n = 36$ female tram drivers in Zagreb from randomly selected sample

Resp. No.	*age*	*BMI*	m	h	h_{br}	$h_{š}$	h_{ndr}	h_{mdr}	h_{dir}
			kg	cm	cm	cm	cm	cm	cm
64	48	29.0	79	165	36.0	17.0	40.0	67.0	81.0
69	50	25.4	75	172	**43.0**	20.0	47.0	76.0	87.0
71	50	26.0	70	164	37.0	19.0	39.0	69.0	84.0
80	47	31.8	92	170	39.0	**21.0**	45.0	71.0	**90.0**
84	54	**43.6**	**135**	**176**	**50.0**	20.0	**48.0**	**78.0**	**92.0**
105	36	24.4	68	167	34.0	19.0	40.0	70.0	78.0
116	45	33.2	85	160	34.0	17.0	40.0	**62.0**	81.0
301	45	26.2	74	168	37.0	18.0	45.0	67.0	86.0
302	51	30.1	85	168	37.0	19.0	46.0	73.0	84.0
303	43	27.7	80	170	39.0	18.0	40.0	68.0	81.0
304	48	24.3	67	166	36.0	17.0	43.0	71.0	83.0
305	48	30.5	84	166	37.0	18.0	39.0	66.0	81.0
306	**30**	**19.5**	**55**	168	34.0	18.0	46.0	76.0	85.0
307	40	36.7	101	166	36.0	17.0	46.0	73.0	87.0
308	46	26.1	79	174	41.0	20.0	43.0	77.0	84.0
309	49	22.1	64	170	41.0	20.0	43.0	68.0	85.0
310	49	27.3	70	160	41.0	18.0	41.0	66.0	78.0
311	38	23.9	65	165	34.0	17.0	46.0	74.0	83.0
312	43	20.4	61	173	35.0	17.0	44.0	71.0	82.0
313	48	23.7	70	172	34.0	18.0	43.0	71.0	81.0
314	49	19.6	56	169	36.0	18.0	40.0	70.0	78.0
315	38	23.1	63	165	36.0	19.0	40.0	67.0	81.0
316	48	22.0	60	165	36.0	18.0	44.0	73.0	81.0
317	44	36.3	**105**	170	**43.0**	20.0	43.0	70.0	87.0
318	45	24.6	77	**177**	**32.0**	19.0	**48.0**	**80.0**	87.0
319	**55**	21.5	**55**	160	36.0	19.0	**38.0**	68.0	79.0
320	51	23.1	60	161	**30.0**	17.0	39.0	68.0	81.0
321	51	24.1	68	168	38.0	18.0	**38.0**	63.0	83.0
322	51	27.2	75	166	34.0	18.0	40.0	67.0	81.0
323	46	28.8	72	**158**	38.0	**16.0**	**36.0**	**62.0**	**74.0**
324	43	26.6	64	**155**	33.0	**16.0**	39.0	65.0	80.0
325	38	23.3	62	163	37.0	19.0	40.0	65.0	81.0
326	43	29.3	77	162	**43.0**	20.0	41.0	67.0	82.0
327	48	24.6	67	165	39.0	20.0	42.0	65.0	80.0
328	41	24.2	70	170	36.0	19.0	40.0	70.0	82.0
329	39	29.7	80	164	38.0	18.0	41.0	63.0	**71.0**

Table 3 presents the ranges of all the measured anthropometric measures Δh_n for the entire random sample $n = 36$, the range of all anthropometric measures $\Delta h_{90\%}$ for central 90% (calculated) and the range of all anthropometric measures $\Delta h_{90\%}$ for approximately central 90% (selected from the measured values).

Table 3: Ranges of anthropometric measures for all randomly selected samples of *n = 36* female tram drivers and for central 90% or approximately central 90%

Anthropometric measure	Symbol / meas. unit	Remark	Amount for *n = 36*	Amount for central 90%
h - **standing height** in balanced standing posture	$\bar{h}$ / cm	calculated - expression (2)	166.6	166.6
	Δh / cm	measured for *n = 36* - Table 2	155÷177	/
	$\Delta h_{90\%}$ / cm	measured and selected for *n = 32*	/	160÷174
		calculated – expression (5.1,5.2,5.3)	/	**158.5÷174.8**
	σ_h / cm	calculated - expression (3)	4.9	
	$\sigma_{\bar{h}}$ / cm	calculated - expression (4)	0.7	
h_{br} – **shoulder width**, or **biacromial range** in the area of shoulder joints	$\bar{h}_{br}$ / cm	calculated - expression (2)	37.2	36.6
	Δh_{br} / cm	measured for *n = 36* - Table 2	30÷50	/
	Δh_{br90} /cm	measured and selected for *n = 30*	/	33÷41
		calculated - expression (5.1,5.2,5.3)	/	**31.0÷43.4**
	$\sigma_{h_{br}}$ / cm	calculated - expression (3)	3.8	
	$\sigma_{\bar{h}_{br}}$ / cm	calculated - expression (4)	0.6	
h_{ndr} – **normal arm reach** or **working distance**, from elbow to the tip of the longest finger	$\bar{h}_{ndr}$ / cm	calculated - expression (2)	42.0	42.1
	Δh_{ndr} / cm	measured for *n = 36* - Table 2	36÷48	/
	$\Delta h_{ndr90\%}$/cm	measured and selected for *n = 31*	/	39÷47
		calculated - expression (5.1,5.2,5.3)	/	**36.9÷47.1**
	$\sigma_{h_{ndr}}$ / cm	calculated - expression (3)	3.1	
	$\sigma_{\bar{h}_{ndr}}$ / cm	calculated - expression (4)	0.5	
h_{mdr}– **maximal arm reach** or **length of reach**, from shoulder joint to the tip of the longest finger	$\bar{h}_{mdr}$ / cm	calculated - expression (2)	69.4	69.2
	Δh_{mdr} / cm	measured for *n = 36* - Table 2	62÷80	/
	$\Delta h_{mdr90\%}$ / cm	measured and selected for *n = 32*	/	63÷77
		calculated - expression (5.1,5.2,5.3)	/	**61.9÷76.8**
	$\sigma_{h_{mdr}}$ / cm	calculated - expression (3)	4.5	
	$\sigma_{\bar{h}_{mdr}}$ / cm	calculated - expression (4)	0.7	
h_{dir} – **reach of extended arm**, from the tip of the longest finger to the most protruding part of the back	$\bar{h}_{dir}$ / cm	calculated - expression (2)	82.3	82.3
	Δh_{dir}/ cm	measured for *n = 36* - Table 2	71÷92	/
	$\Delta h_{dir90\%}$ / cm	measured and selected for *n = 32*	/	78÷87
		calculated - expression (5.1,5.2,5.3)	/	**75.6÷88.9**
	$\sigma_{h_{dir}}$ / cm	calculated - expression (3)	4.0	
	$\sigma_{\bar{h}_{dir}}$ / cm	calculated - expression (4)	0.6	

4. DISCUSSION AND CONCLUSION

In this paper, it has been proven that the random sample of female tram drivers from Zagreb is sufficient. The final results for the entire population of 742 tram drivers in Zagreb will contain ranges of anthropological measures between the fifth percentile for female drivers and ninety-fifth percentile for male tram drivers. Disregarding ranges of anthropological measures for the entire population of tram drivers simultaneously with inadequate design of tram cab can influence negatively the increase of the drivers' perception-response time, as well as the drivers' subjective perception of workload. By comparing the results of the measured range of height for adult female population (female tram drivers in Zagreb) and female students of the first year of the FPZ graduate study in Zagreb, it was detected a possible cumulative effect of socioeconomic factors on the increased height of students, together with the influence of age (the average age of female students is 24 and females reach relative maximum height until the age of 25). The measurement results from 2013 have confirmed the hypothesis of the possible phenotypic variation of anthropometric measures for the entire female population since the last measurement in Croatia in the years 2005 and 2006, according to the medium height of female population. Due to the possible value changes of anthropometric factors for the female population, while designing a tram cab it is necessary to conduct one's own recent measurements on a random and sufficient sample of respondents. The results in this paper show a higher share of 52.8 % overweight and obese female tram drivers compared with female students by the value of the body mass index *BMI*. The amount of lumbar moment of drivers in the static sitting position dominantly depends on the *BMI*, when frequently used commands for manually serving are incorrectly spaced within a maximum arm reach.

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ANALYSIS OF ANTHROPOMETRIC SIZES OF CHILDREN AMONG SEVERAL NATIONAL POPULATIONS AGED FROM 3 TO 5 YEARS

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Abstract:
This paper presents and compares the results of three anthropometric studies conducted on female and male children aged 3, 4 and 5 years in Bosnia, Croatia and Turkey. Measurements were carried out in Bosnia and Herzegovina by experts of the Technical University of Bihać, in the town of Bihać, while measurements in Croatia were carried out in Zagreb by experts of the Faculty of Textile Technology, University of Zagreb. Measurements were carried out in public and private nursery schools, and a total of 286 children were measured in Bihać, while in Zagreb 812 children were measured. In the area of Turkey measurement was performed in the city of Trabzon and the number of measured children of 286 was the same number as in the city of Bihać. The paper compares estimates of basic parameters such as children's body weight (kg), children's body length (cm), children's chest circumference (cm) and body height in a sitting position (cm). Some relevant comments on the values in all three countries, Bosnia, Croatia and Turkey are given.

Keywords: *children, anthropometry, comparison of dimensions in Bosnia and Herzegovina, Croatia and Turkey*

1. INTRODUCTION

Anthropometric measurements of the human body have been developed for various reasons since ancient times. Performed anthropometric measurements of the population indicate morphological values and developmental characteristics and diagnosis of the health status of certain populations [1-4]. On the basis of anthropometric data certain standards in different industries are defined. Anthropometric measurement is important in designing products in the furniture industry, mechanical engineering, transport equipment industry, especially passenger cars, buses, railway carriages, aircraft, protective clothing and footwear, consumer goods, etc. Application of anthropometry in ergonomics and design of furniture is of great importance because it significantly increases the productivity of workers and ensures their safety and health at the workplace. For these reasons, the design and construction of furniture in the workplace required characteristics of users, and in particular anthropometric dimensions [5-8]. In designing a product it is necessary to know the dimensions of the body of potential users. Man of the modern world spends half of his life passively sitting, a quarter of life lying, and only the remaining quarter in movement. These positions indicate the importance of a systematic and interdisciplinary approach to the solution of structural types of furniture for sitting and lying. When sitting it particularly relates to a specific user populations of furniture for sitting at work, such as groups of students, office workers and people of specific occupations in which the body has the same long-term position. Nursery infants and teenagers typically spend 30-78% of their time sitting. Harper [10] established the importance of furniture especially constructed for the bodies of children and for different positions and activities children occupy during sitting. Anthropometric measurements of children aged 3, 4 and 5 years are used to design tables, chairs, beds, mirrors, TV stands, hangers and other furniture [9-10]. It is known that there are serious ergonomic problems in schools that may be associated with a lack of anthropometric data and their application. The main subject of this research is to obtain reliable and accurate anthropometric measures of male and female children which would be used for designing furniture [11]. Differences in body measurements of different populations in different geographical areas are evident. It results from this fact that one product of the same dimensions is not suitable for different peoples.

2. METHODS AND SUBJECTS

The data were obtained from 286 children of normal health who actively visit public and private nursery schools of Bihać (Bosnia and Herzegovina) [2], Zagreb (Croatia) [6] and Trabzon (Turkey) [7]. Nursery schools were selected randomly, and children's access to the measurement was on a voluntary basis. Nursery schools that were involved in the project had children from different social and economic conditions. All measurements were performed in 9 nursery schools in the area of Bihać. Anthropometric measurements were performed in Zagreb nursery schools that were randomly selected, and 812 children aged from 3.5 to 5.4 years were measured [11]. In Turkey, measurements were taken in 16 nursery schools in the area of Trabzon on children aged 3, 4 and 5 years [7]. In Bihać 22 anthropometric dimensions of children were measured, as shown in Figure 1, whereby 12 dimensions were measured in a standing and 10 dimensions in a sitting position. In addition to standard measuring equipment such as measuring tape and sliding caliper, the universal adjustable anthropometric chair designed at the Technical University of Bihać, and the goniometer was used. The chair is adjustable for different dimensions on which vertical and lateral profiles are built in. Modifications are possible using the built-in bolts and platform for the correct measurement of different dimensions. Weight was measured using scales.

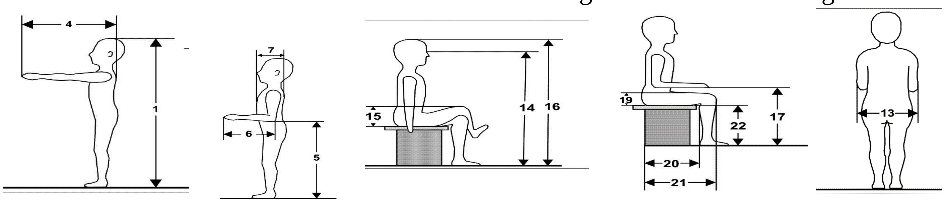

Figure 1. Anthropometric measurements taken in a standing and sitting position

The data for each measured child were entered in the measurement list on the basis of which a database with all relevant data was created.

3. MEASUREMENT RESULTS

Based on the results of measurements in both studies basic statistical anthropometric data of children of the town of Bihać in Bosnia and Herzegovina [2], the children of the city of Zagreb in Croatia [6] and the province of Trabzon in Turkey [7] were obtained. In the following figures and tables basic characteristics of measurements are shown.

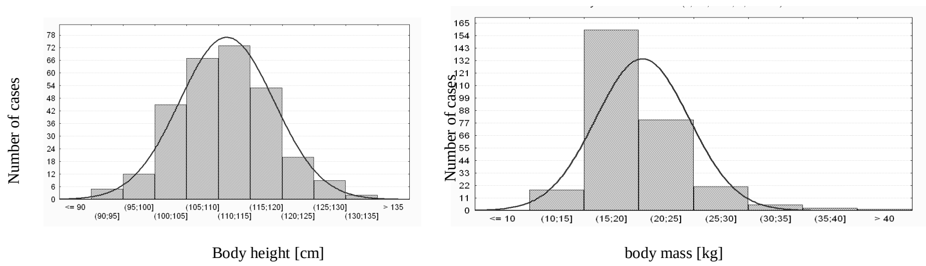

Figure 2. Distribution of the values of children's body height and body mass aged from 3 to 5 years in the area of Bihać

If we make the distribution on the basis of gender and compare the data from Bihać and Croatia, we obtain the following information:

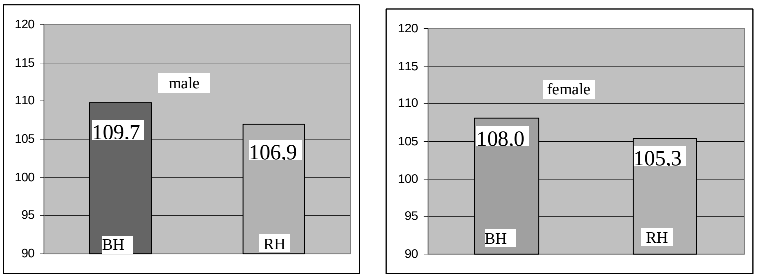

Figure 3. Comparison of the body height of children aged from 3 to 5 years in Bosnia and Herzegovina and Croatia

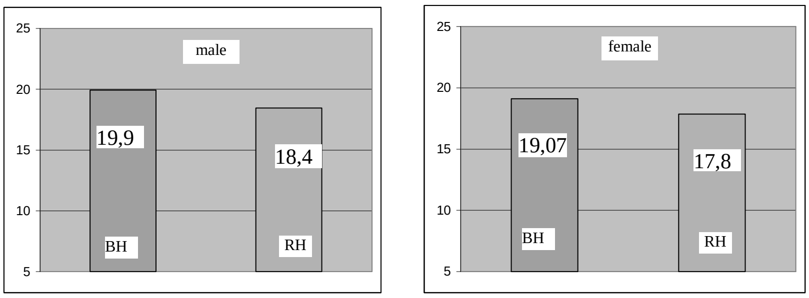

Figure 4. Comparison of body mass of children aged from 3 to 5 years in Bosnia and Herzegovina and Croatia

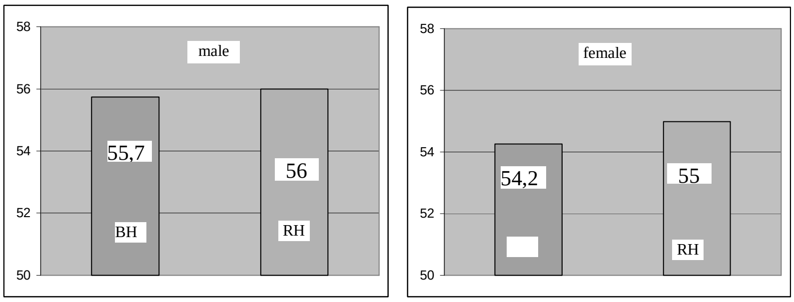

Figure 5. Comparison of chest circumference of children aged from 3 to 5 years in Bosnia and Herzegovina and Croatia

From the previous analysis, which is shown in Figures 2 to 5, can be concluded that the differences are quite small which is understandable; however, concerning body height and body weight a slightly more distinctive difference is to be observed. Thus, we see that children of Bosnia and Herzegovina, both male and female, are for about 3 cm taller than children of Croatia of the same age and are about 1 kg heavier. Concerning waist and chest circumference, differences are only slight. The measurements of anthropometric sizes of children in nursery schools were made in the Municipality of Bihać. It was the first anthropometric measurement made in Bosnia and Herzegovina. Tables 1, 2, 3 and 4 show estimates of basic parameters of the distribution of specific sizes for children in Bosnia and Herzegovina, Croatia and Turkey using the results in [4,6,10].

Table 1. Estimate of basic parameters of the distribution of children's body height (cm)

COUNTRY	*Age/years*	*N*	*Arithmetic average*	*Standard deviation*	*RANGE Min.*	*RANGE Max.*
BOSNIA AND HERZEGOVINA	3.0-5.0	286	111.0	6.43	92.5	134.0
CROATIA	3.5-5.4	812	110.3	6.4	86.5	135.5
TURKEY	3.0-5.0	286	104.13	6.35	84.6	113.6

Table 2. Estimate of basic parameters of the distribution of children's body mass (kg)

COUNTRY	*Age/years*	*N*	*Arithmetic average*	*Standard deviation*	*RANGE Min.*	*RANGE Max.*
BOSNIA AND HERZEGOVINA	3.0-5.0	286	20.25	3.75	13.0	30.5
CROATIA	3.5-5.4	812	19.35	3.4	10.0	34.0
TURKEY	3.0-5.0	286	-	-	-	-

Table 3. Estimate of basic parameters of the distribution of children's chest circumference (cm)

COUNTRY	Age/years	N	Arithmetic average	Standard deviation	RANGE Min.	RANGE Max.
BOSNIA AND HERZEGOVINA	3.0-5.0	286	56.17	4.16	48.5	72.5
CROATIA	3.5-5.4	812	56.70	3.64	46.2	75.0
TURKEY	3.0-5.0	286	-	-	-	-

Table 4. Estimate of basic parameters of the distribution of children's body height in a sitting position (cm)

COUNTRY	Age/years	N	Arithmetic average	Standard deviation	RANGE Min.	RANGE Max.
BOSNIA AND HERZEGOVINA	3.0-5.0	286	87.00	7.45	77.0	100.0
CROATIA	3.5-5.4	812	90.30	7.82	81.0	105.0
TURKEY	3.0-5.0	286	81.15	7.68	69.3	93.0

Tables 1,2,3 and 4 provide estimates of basic parameters of the distribution of parameters such as: children's body mass (kg), children's body length (cm), children's chest circumference (cm) and children's body height in a sitting position (cm). From the previously presented tables it is evident that in children from the area of Bihać all anthropometric dimensions are greater than the dimensions among children of Trabzon. For some sizes the difference is negligible, while in some other sizes, such as body height in a standing position, body height in a sitting position, the difference is quite apparent in all three countries. From the results it can be concluded that children aged 3-5 years from the area of Bihac have all anthropometric measurements greater than the children of the same age from the area of Trabzon, and smaller compared to children of Zagreb, and when it comes to mass the children of Bihac have the greatest mass, followed by the children of Zagreb and of Trabzon. It follows from above that children' body height, and of course of adults depends on climate and geographical position.

4. CONCLUSION

From the previously presented analysis of the data obtained it can be concluded that the anthropometric measures of children of Bosnia and Herzegovina are greater than of the Turkish children of the same age. If we could take a few measures and the difference express as a percentage, we would find that children of Bihać are by 6.87% higher than the children of Trabzon. Also, body height in a sitting position was greater in children of Bihać by 7.2%. From the results it can be concluded that children aged 3-5 years from the area of Bihać have all anthropometric sizes greater than the children of the same age from the area of Trabzon, and smaller than the children of Zagreb, and when it comes to mass the children of Bihać have the greatest height and mass, followed by the children of Zagreb and of Trabzon. It follows from above that children's body sizes, and of course of adults, depend on climate and geographical position. On this basis, the clothing, footwear and furniture were designed for this population of different dimensions, ie, for children of Bosnia and Herzegovina, Croatia and Turkey. It is desirable to harmonize space dimensioning with associated anthropometric sizes of people so that they are adapted to human beings as much as possible. By making anthropometric measurements every few years, it is possible to improve and facilitate the conditions that impede and endanger health. Using anthropometric data to determine the relationship of the human body and the working space increases the quality, comfort and safety of the workspace.

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DESIGN OF RAIN PROTECTIVE MATERIALS WITH SATISFACTORY COMFORT- RELATED PROPERTY

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Abstract
Resistance to water penetration is the most important quality of materials that should provide adequate rain protection. At the same time, those materials need to be breathable in order to evacuate the perspiration away from the skin and from the garments. Within the meaning of all above mentioned, this paper focuses at the design of two-layered materials and investigation of their water vapour resistances.The results indicated that the samples produced from polyurethane that comes from the copolimer of polyester/polyeter have at least 6 times lower water vapour resistance than those produced from the base of hydrophilic polyester. Because of higher differences in obtained values, this is an important fact that should be taken into account when designing a product that will assure the optimal wear comfort.

Keywords: rain protective,knitted fabric, polyurethane,water vapour resistance

1. INTRODUCTION

In the last decades, a significant increase in the emphasis is placed on comfort of textiles, as well as their protective functions. The attention was paid on complex legislation and regulation of the workplace, as a result of the opinion that it is no longer acceptable for humans to experience discomfort or to incur injuries. A consequence of all staten resulted in development and exploatation of new fibres, fabric structures, finishing processes and clothing systems whose purpose is to provide improved protection, whilist maintaining comfort, efficiency and well-being [1].

1.1. Protective clothing

Protective clothing is defined as clothing that is used principally because of the special performance or functional characteristics, rather than their aestetic and decorative function. Therefore, such garment should in the first place protect the wearer from different environmental conditions, as well as the effects that may result in injuries or even worse. The personal protective textiles can be classified according to different end-use functions that refer to the optimal protection, such as thermal, flame, chemical, mechanical, biological, electrical, etc. The classification of protective materials is given on the Figure 1 [2].

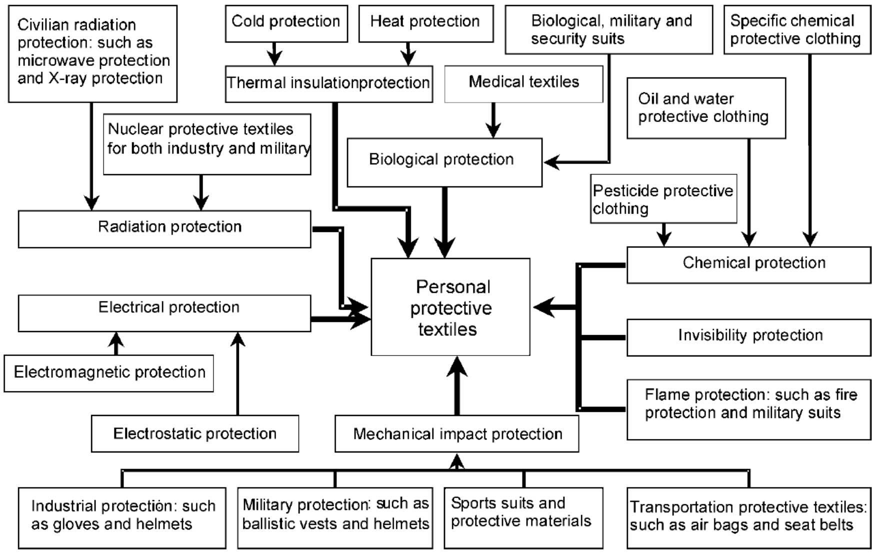


Figure 1: The classification of protective clothing

1.2. Rain protection

Resistance to water penetration is the most important quality for an adequate rain protection. Breathable garments evacuate the perspiration away from the skin and from the garments. When too much humidity has accumulated in the clothing, condensation occurs and the skin feels clammy. In cold atmospheric circumstances, one risks to cool down too quickly. Otherwise in warm circumstances, the rhythm of the heart will increase and after some time there is a risk of heat stress.

Water vapour resistance is a measure of the garment's ability to allow water vapour to pass through the fabric. According to EN 343 [3], the classification of materials in class 1 (water vapour resistance > 40) indicates high resistance or low breathability, while class 3 (water vapour resistance ≤ 20) indicates high breathability or ability to transport moisture (Table 1).

Table 1: Classes of materials according to R_{et} values

Class	1	2	3
Water vapour resistance (R_{et}), m^2PaW^{-1}	$R_{et > 40}$	$20 < R_{et > 40}$	$R_{et < 20}$

The Table 2 shows the effect of the water vapour's penetration ability on the recommended continuous wearing time at different working temperatures. The data specify the maximum recommended wearing time for a complete outfit (jacket and trousers) without a warm lining. The presented values are applicable at a medium physical load M = 150 W/m^2, for an average man, at 50% relative humidity and wind speed v_a = 0.5 m/s. Effective ventilation openings and/or breaks can extend the wearing time.

Table 2: Recommended wearing time

Class		1	2	3
Water vapour resistance (R_{et}), m^2PaW^{-1}		$R_{et > 40}$	$_{20 <} R_{et > 40}$	$R_{et < 20}$
		Recommended wearing time, minutes		
Temperature of working environment in °C	25	60	105	205
	20	75	250	-
	15	100	-	-
	10	240	-	-
	5	-	-	-

1.3. Moisture in textile materials

The ability of fabric to bind the moisture from the environment is a significant precondition for the establishment of thermophysiological comfort. In support of the fact that the fabric's ability to absorb and transfer moisture is essential for the determination of material comfort, are the results of research showing that even a small share of moisture in textiles (3-5%) leads to the formation of discomfort [4]. In addition, due to the accumulation of moisture in the material, the thermal insulation of clothing is reduced by 2-8% [5]. For the transfer of water vapour through the textile structure are significant the following mechanisms: water vapour diffusion and absorption and desorption of water vapour in the fiber.

Diffusion of water vapour through the textile structure can be realized through the cavities in the textile structure that are filled with air, or between the fibers [6]. For structures that are made of hydrophilic fibers, diffusion takes place in two stages. The first phase takes place by diffusion Fick's law, and the second, much slower phase, takes place with regard to the relationship between the concentration gradient and the flow of water vapour [7]. Specifically, both hydrophilic fibers absorb water vapour, it leads to their swelling what reduces the size air-filled spaces between the fibers and thus the diffusion process slows down.

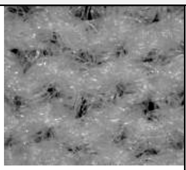
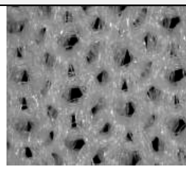
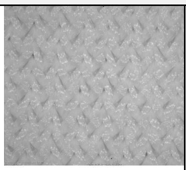
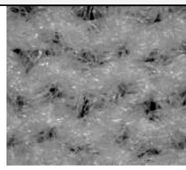
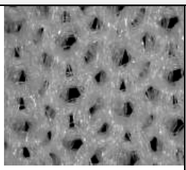
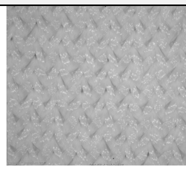
Hygroscopic textile structures bind water vapour from humid air that is above the surface of the skin that sweats and release it in the dry air. The amount of water vapour that the material can bind, depends on the type of fiber and humidity of atmospheric air. If the dry textile material is located in areas with humid air, the fiber absorbs water in a way that binds molecules from the air and transfers them into its core. Otherwise, when the material is wet or damp, the release of molecules takes place while the material dries. Over the time, the equilibrium of moisture content in the material and in the air establishes, while the difussion of the water molecule is still going on in both directions The chemical fibers (in particular fibers produced of synthetic polymers) have significantly reduced ability to absorb in relation to the natural fibers. In such fibers, due to poor holding capacity of moisture from the atmosphere and from the surface of the body, the machanism of adsorption on the surface of fibrous materials has a significant role.

2. EXPERIMENT

2.1. Materials and structural properties

Six knitted fabrics with different structures (designations PU1 – PU6) were designed to observe the differences of water vapour resistance. They were all 2-layered, consisted of knitted fabric that served as supstrate (either single jersey, interlock or locknit) and polyurethane coating. All samples were coated under the same conditions, on the same coating line, with two polyurethane coatings: from the base of hydrophilic polyester and copolimer of polyester/polyeter. Polyurethane was applied to the knitted fabric using the transfer procedure.

Table 3: Investigated materials and their properties

Layer	Structure of knitted fabric	Mass (gm^{-1})	Thickness (mm)	Structure of knitted fabric	Mass (gm^{-1})	Thickness (mm)
	PU1			PU2		
Supstrate	 Single jersey	110	0,68	 Interlock	109	0,50
Coating	Copolimer of polyester/ polyeter	77	0,16	Copolimer of polyester/ polyeter	77	0,16
	PU3			PU4		
Supstrate	 Locknit	279	0,77	 Single jersey	110	0,68
Coating	Copolimer of polyester/ polyeter	77	0,16	Base of hydrophilic polyester	81	0,16
	PU5			PU6		
Supstrate	 Interlock	109	0,50	 Locknit	279	0,77
Coating	Base of hydrophilic polyester	81	0,16	Base of hydrophilic polyester	81	0,16

Preliminary measurement of resistance to water penetration using the hydrostatic pressure test [8] showed that the values for all designed samples are higher than 20 000 Pa, what makes them adequate for the production of rain-protective clothing.

The results of mass and thickness for used substrates are given in the table 3. The mass of polyurethane coating, as seen from the same Table was either 77 or 80 g/m^2 and thickness 0,16 mm.

2.2. Measurement of water vapour resistance

The water vapour resistance of produced materials (both knitted fabric substrates and coated knitted fabrics) was measured using the sweating guarded hotplate (SGHP) produced by Measurement Technology Northwest. The SGHP simulates processes occurring next to the human skin, i.e. the transfer of heat and water vapour from the skin, through the layers observed, to the environment [9]. During the tests of water vapour resistance, the sweating guarded hotplate was placed into an air conditioned chamber where the following conditions were established and maintained: 35°C and 40% relative humidity of the air. The velocity of airflow was 1 m s^{-1}.

3. RESULTS AND DISCUSSION

The results of measured water vapour resistance for designed materials PU1-PU6 are given on the Figure 2.

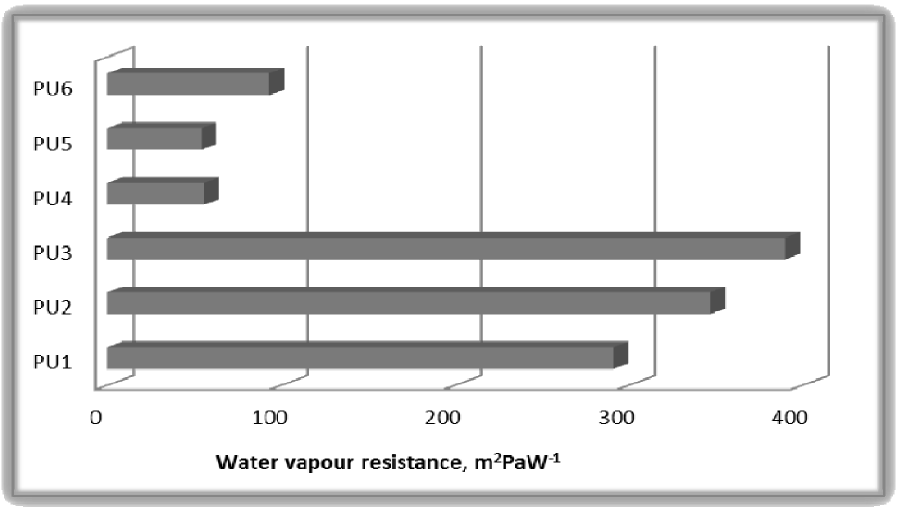


Figure 2: Water vapour resistance of investigated materials

There is a wide range of obtained values of water vapour resistance for investigated materials, i.e. 48 - 346 m^{2}PaW^{-1}. It is well seen that a type of coated polyurethane has significant and dominant influence to the total value of heat resistance. In this way, the samples produced from polyurethane that comes from the copolimer of polyester/polyeter (materials PU4-PU6) have resistances ranging from 54 to 80 m^{2}PaW$^-$

^{1}, while those produced from the base of hydrophilic polyester have values that are at least 6 times higher. The staten has confirmed that the materials coated of polyurethane from the base of hydrophilic polyester indeed significantly contribute to higher breathability of clothing item. Considering the obtained values and classification given in the Table 1, all samples are in the class 1 (Ret > 40) what indicates high resistance to the transfer of water vapour and, at the sam time, low breathability. The reccomended wearing time for outfits made of such materials should be up to 240 minutes if the temperature of working environment is 10ºC, or less for warmer environments (Table 2). The lowest values are obtained for the fabric that consists of interlock substrate and coating on the base of hydrophilic polyester. Therefore, a design of future materials with optimal breathability should be based on the named structure. The influence of substrate type is also well seen. In both groups of materials that were coated with different polyurethane type, the highest value of water vapour resistance is obtained for material that has a locknit substrate (mass of 279 gm^{-1} and thickness of 0,77 mm).

5. CONCLUSION

In this investigation are measured materials that were designed to differ in fabric supstrate and type of coating, but to be functional and to give approximately the same resistance to water (rain) penetration. The presented investigation indicated that a type of coated polyurethane has significant and dominant influence to the total value of heat resistance. In this way, the samples produced from polyurethane that comes from the copolimer of polyester/polyeter have at least 6 times lower water vapour resistance than those produced from the base of hydrophilic polyester. Because of higher differences in obtained values, this is an important fact that should be taken into account when designing a product that will assure the optimal wear comfort.

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MEASURING THE THERMAL INSULATION CHAMBER WITH INFRARED CAMERA

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Abstract
Infrared thermography is a method of contact-free temperature measurement providing temperature distribution on the surface of the observed object. Today it is widely applied in almost all branches of human activity. The advantage of infrared thermography is that it is a method whose application does not disturb in any way the current state of the object. The results of the thermogram analysis can be obtained as the value of temperature, temperature distribution as a line or histogram display of certain temperature interval defined by the percentages of the thermogram. In this paper the infrared camera is used for testing the thermo insulating element on the subject. The measurements were conducted in three states: in deflated and inflated state and subject without thermo insulating element. Tests have shown that the thermal insulation element has good insulating properties.

Keywords: *Infrared camera, thermo insulation, isothermal distribution*

1. INTRODUCTION

Infrared thermography is a contact less measurement method for determining the temperature distribution on the surface of objects by measuring the intensity of radiation in the infrared region of the electromagnetic spectrum. Thermography term derives from the Greek words *therme* - heat and *grafein* - write. This means that thermography implies that after the measurement a permanent record of the measured values remains. This entry is called a thermogram. Every body in its environment emits electromagnetic radiation, whose intensity depends primarily on the body surface temperature. If a body temperature is higher than about 600 ° C, human body radiates visible light, ranging from dark red to lighter shades, as the temperature rises. At lower temperatures, radiation is invisible to the human eye and is called the infrared (lat. infra - below) [1]. Since infrared radiation emitted all bodies depending on their temperature, following the blackbody radiation law, thermography allows you to "watch" environment without visible illumination. The amount of radiation increases with temperature, therefore thermography allows to see changes in temperature (hence the name of thermography). Seen by thermographic camera, warm objects stand out well compared to the colder background, humans and warm-blooded animals become easily visible in relation to the environment, day and night.

The radiation heat is the heat transfer mechanism that exclusively depends on the temperature of the body and the condition of its surface. All body temperatures above 0

K radiate heat. Unlike the conduction and the convection, radiation does not require a material medium to take place and does not depend on the temperature gradient media. In the electromagnetic waves spectrum, thermal radiation exists in the wavelength range 3-400 nm - ultraviolet (UV) radiation, from 0.4 to 0.76 μm - visible light, and especially in the wavelength band 1-1000 μm - infrared radiation [2].

2. THE WORKING PRINCIPLE OF THERMAL CAMERA

Thermographic system consists of the infrared (IR) camera and thermogram processing unit (PC). In the IR camera is integrated optics, infrared radiation sensor, the unit for converting an electric signal in the video, the monitor and card storage. The computer is used for processing of IR images by specific software and the data it retrieved from the card which is located in the camera, Figure 2. How the characteristics of electromagnetic radiation are equal to the entire electromagnetic spectrum, the used optics in IC devices in form is similar to that of photographic equipment, but different in material from which it is made. The materials used for making the lens must be transparent to infrared radiation, namely, germanium, zinc sulfide, zinc selenide for infrared longwave radiation and silicon, sapphire, quartz or magnesium for midwave IR radiation [3].

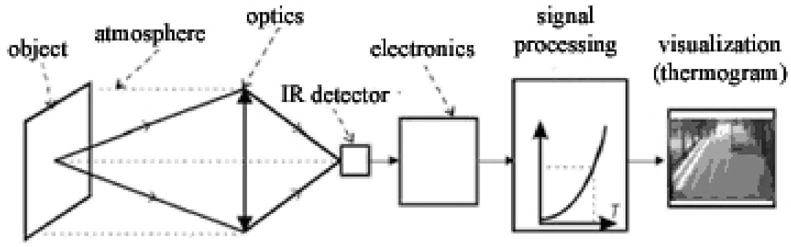

Figure 2: Schematic representations of thermal camera [4]

2.1. Application of infrared thermography in the field of textile engineering

In the field of textile engineering is the most widespread application of thermography in the examination of insulating properties of clothing. The method used to gain insight into the distribution of temperature on the surface of the skin in different environmental conditions and in different clothing sets. As the skin temperature is one of the important indicators of the heat exchange between body and environment, the temperature distribution on the skin is an essential factor for the evaluation of thermal comfort. The first line examines is the clothing worn during extreme low and high temperatures, such as protective clothing (e.g. firefighting clothing) and wear for special purposes (e.g. military and police uniforms). Thermography also serves to evaluate the performance of clothing for personal use [5]. The attempt was to use this method for evaluating the apparel fit and clothing pressure on the body and influence the activities by varying intensity on the temperature distribution [6]. In the area of fabrics testing, thermography is used for damage assessment and electroconductive woven textile [7], etc.

Advantages and disadvantages of thermography

Advantages of thermography are numerous, as follows:
• Displays a visible image so that they can compare temperatures over a large area
• Capable to capture moving targets in real time
• Can be used to measure inaccessible and dangerous places
• Can be used to find defects in metal parts
• Can be used for better vision in dark areas.

Limitations and disadvantages of thermography are the following:
• Thermal cameras are expensive
• Recordings are difficult to interpret in the case of objects with inhomogeneous temperature
• Precise measurement of interfering uneven emissivity and reflection from other surfaces
• Most cameras have ± 2% accuracy or worse, and are not as a precise as contact method
• They can directly observe only the surface temperature.

3. EXPERIMENT

For testing with thermal camera was purchased VarioCAM ® HR camera (Figure 3), firm Infratec GmbH. With the camera is purchased computer software suite IRBIS ® 3 Professional for thermal image analysis. Table 1 shows the characteristics of thermal imaging cameras.

Figure 3: VarioCAM ® HR thermal camera

VarioCAM ® HR camera displays, on your screen in real time, a clear image of the heat distribution of the object being viewed. Laser pointer has the function of marking a particular (central) point on the object to locate the exact place from which the temperature value to read. The screen shows the temperature distribution of various shades of color, and the numerical value of the minimum and maximum temperatures of objects displayed on the display device.

Table 1: Technical specifications of VarioCAM ® HR camera

Spectral range	(7.5 ... 14) μm
Detector Detector format (pixel)	microbolometer Focal Plane Array, uncooled (384 x 288) or (320 x 240)
Temperature measurement range	(-40 ... 300) °C, optional 1,200 °C
Measurement accuracy	± 1.5 K (0 ... 100) °C; ± 2 % (< 0 bzw. > 100) °C
Temperature resolution 30 °C	Better than 0.08 K ili 0.05 K (premium Mode)
IR-frame rate	50/60 Hz
Standard lens (object field)	25 mm (30 x 23)° or (25 x 19)°
Image storage	SD card
Dynamic range	16 Bit
Interfaces	PAL/NTSC-FBAS, S-Video, RS232, FireWire (IEEE 1394)
Power supply	Standard, off the shell Li-Ion battery (quick rechargeable, with status display)
Operation temperature, encapsulation	(-15 ... 50) °C, IP54
Dimensions	(133 x 106 x 110) mm
Weight	1.5 kg (complete system)

3.1. Recording the thermoinsulating chamber with thermal camera

The measurement of thermoinsulating chamber with thermal camera was conducted in a darkened room in order to minimize the impact of light reflection. The measurement distance from the camera was one meter. The first shooting was recorded without thermoinsulating chamber and to the front, rear and lateral sides. Then the subject clothe on a thermoinsulating chamber. The next recording was carried out after half an hour after the subjects clothe thermoinsulating chamber. Filming was also conducted in all three sides (front, rear and lateral sides). Then in the thermoinsulating chamber is inflated the pressure of 50 mbar and again waited for half an hour before the new recording. The described process of recording is graphically shown in Figure 4.

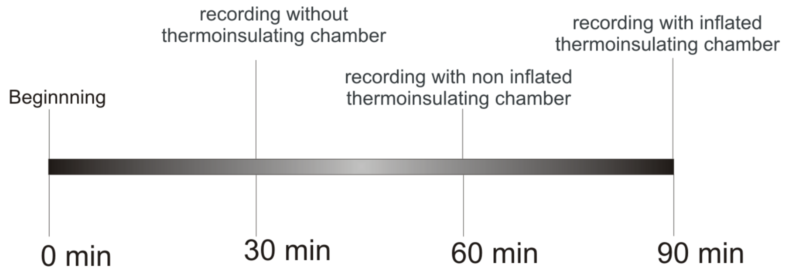

Figure 4: The recording process with thermal camera

4. RESULTS

Figures 5-7 shows isotherms measurements made with thermal camera. The isotherms are divided into six ranges.

a.	b.	c

Figure 5: Isotherms of front parts: a. without thermoinsulating chamber a, b. with non inflated thermoinsulating chamber, c. with inflated thermoinsulating chamber

a.	b.	c.

Figure 6: Isotherms of back parts: a. without thermoinsulating chamber a, b. with non inflated thermoinsulating chamber, c. with inflated thermoinsulating chamber

a.	b.	c.

Figure 7: Isotherms of lateral parts: a. without thermoinsulating chamber a, b. with non inflated thermoinsulating chamber, c. with inflated thermoinsulating chamber

5. DISCUSSION

To test the thermoinsulating chamber is used high-resolution thermal camera VarioCAM ® hr, and the obtained thermal images are processed in the software package suite IRBIS ® 3 Professional. With above mentioned equipment the recording of the thermoinsulating chamber is made on subject in non inflated and inflated state (the pressure in the insulated chamber was 50 mbar), and a subjects torso without thermoinsulating chamber.
The assaying of thermal images, it is clear that there is a significant difference in the temperature distribution throughout the torso of subject without thermoinsulating chamber and subject who carry an inflated thermoinsulating chamber. Looking at the temperature distribution along the torso of subject who wears inflated thermoinsulating chambers are observed higher temperatures in the upper chest and back area. The reason for this is that these parts of the heat insulating chamber better fit the body of examinee,

while the lower parts of the thermoinsulating chamber touch the body of the examinee smaller, and in this zone there is free flow of environment air. Further analysis shows that the temperatures observed in the areas of the body even more when the examinee carries the non inflated thermoinsulating chamber.

It is interesting to note the temperature difference in the face of the examinee in three mentioned cases (without thermoinsulating chamber, with non inflated and inflated chambers). In subjects with inflated chambers the face temperature is the lowest, while at the same subjects without thermoinsulating chamber is the highest. The above suggests that thermoinsulating chambers have good insulating properties and held body heat and therefore there was no need to further activate the body's mechanisms for regulating body temperature via the bloodstream.

6. CONCLUSION

Infrared thermography is used today in nearly all branches of human activity. There is a growing use of thermal imagers in the field of textile and apparel industry, especially in testing of protective clothing and clothing for special purpose. Good application of the thermographic camera is a non-contact measurement and quick response, and the bad is influence of emissivity and geometry of an object. This paper shows the temperature distribution of thermoinsulating chamber for thermal adaptive clothing in non inflated and inflated state (the pressure in the chamber was 50 mbar).

Acknowledgement

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PROBLEMS OF CONSTRUCTING FURNITURE ACCORDING TO ERGONOMIC REQUIREMENTS

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Abstract

In this article we are going to deal with the problem of constructing wood based products. We will mention the rules and regulations at construction and at the preparation of those constructions to be ready for the production process. At the end of the work paper, we sill mention the problems of the construction of the furniture within the three groups of furniture products.

Keywords: C*onstruction of the furniture, Recommendation for furniture construction and problems of construction within an ergonomic recommendation*.

1. INTRODUCTION

Ergonomic furniture is any furniture item that is designed to allow someone to use the furniture without suffering from repetitive stress injuries. Those who design furniture ergonomically follow a set of scientific principles that people use the furniture in a way to remain healthy, while maximizing performance. Ergonomic, also called human engineering, is the study of how the human body works and interact with objects.

Designers and manufacturers take into account how anthropometry, posture, and repetitive motion affect the user to come up with viable solution for furniture design and space design.

Since people come in many shapes and sizes, anthropometry as study of measurement of the proportion, size, and weight of the human body help in designing ergonomically suitable products for men, women or children.(5)

Good ergonomic design takes into consideration seated, standing, reaching or moving posture for avoiding stress on the user's back, buttocks arm muscles or feet.

All of the mentioned factors go into creating efficiently designed and constructed furniture for people to function better and be more productive. Long term damage to the human body or related injuries can be minimized or avoided.

All the principles of furniture construction are designed according to the ergonomic recommendations and presented in the following point.(6)

2. CONSTRUCTION OF WOOD BASED PRODUCTS

The word “structure” has its roots in the Latin “construere”, which translated means to build, create, edit, design, etc. Design of the products represents the first stage of the manufacturing process and all of the other further phases such preparation, drafting and final product manufacturing are directly depending on design.
Furniture production is based on a technological process that is accurate and predefined manufacturing process of a product, semi finished product, or part of the product.
Manufacture of furniture an integrated process consisted of: production planning and evaluation of production programs, procurement of raw material, drying, cutting, machining, assembling of products parts, surface treatment, assembling of products, product packaging, its internal and external transportation.

Requests for furniture are:

- Functionality
- Structural requirements suitable for development of structure that should be characterized by rational use of raw material, durability, strength, firmness, techno logicality and reliability in application.
- Technological requirements that are influenced by the type of production and state of the technological process.
- Technology – economic requirements that determine cost-effective products, technical control requirements, and all other processes till the final customer.
- Esthetic requirements that determine unity of esthetic and functionality of product characteristic. The esthetic of furniture is reflected in harmonic line components of the product, some product groups, and their relationship with the interior and architecture.(4).

Easy operations in designing today are enabled by using the 3D software. A big advantage of the software is speed and constant possibility of introduction changes into the project that makes it easier for manufacturers and resellers.
Most software packages are 3D, because it is practically a new generation of software package for designing. Engineers in this way can create virtual models of their projects and products. This significantly speeds up the process of work, because they are able to control more. Using 3D software, we can drastically reduce the number of production errors, which may occur when viewing tolerance and therefore significantly reduce production costs. This way we avoid great waist while the process of design becomes a competitive advantage.
Constructing is a complex of different technical, theoretical, experimental, and information process that takes a place in a social, economic, technical and technological environment. The task of constructing process is to create optimal product under the given circumstances within the shortest possible time and with the least cost.
There are two different types of constructing:

1. Construction as the subject of design
2. Constructing as the method of artistic representation of construction that comply with the rules and standards of technical drawing, manual methods or computer programs.

The subject of design in the wood industry refers to the final products, which are made of wood and wood materials. Besides wood material, in the preparation of the final products are also used non-wood materials such as metal, glass, fabric, leather, ceramic, plastic, and similar. Constructing activities occur within business system in two places. In subsystem development function where exists as separate function exists. In the process of product development, designing makes one of the phases in the concretization of new product, which is the technological processing or redesigning. The second location is in the production under sub-function of production preparation or immediate products making.

In the constructing phase of wooden product, comes to the fore the ability and creativity of designers to use the acquired knowledge in solving technical problems using standards, alternative solution, catalogues of similar products, catalogues with elaborated variants of shaped constructions etc. and to optimize the solution to the limitation of materials, technology and economic. In addition to knowledge of constructing rules, the constructor which use computer for performance of constructing phase needs to know technical design as well.

Phase of construction begins in the product development process based on conceptual solutions designed and used to complete the documentation of the product development or prototype product. Technological processing of the constructor-technologist defines the factors necessary to produce samples used for construction, grading and testing of quality factors. Decisions during constructing stage affect all other stages of the product life cycle and have a major impact on production costs, especially the new products.

Research of constructing process showed that inside of same exists intuitive (unscientific) and discursive (scientific) way of thinking in solving constructive problems and decision making.

- Intuitive way is based on empirical (experience), without basic scientific knowledge, research experiments, calculation, and logical conclusions.
- Discourse methods are based on the results of scientific research experiments, calculations and logical conclusions.
- Systematic or methodical constructing allows it to develop algorithmic process and solves by use of electronic computers.

Research is mainly carried out in three directions:

- Finding new methods
- Developing new methods by combining the known methods
- Improvement of known methods due to efficacy

2. SOME EXAMPLES OF CONSTRUCTION OF WOOD BASED PRODUCTS

The design process and its involving in the furniture industry as well as the development technologies of its production affect the construction of product.

As a result of technology development, the techniques were also modified.

Continues changes of furniture appearance based on creativity of designers work make influence significant towards construction process in certain furniture units.

The majority of wood workers are artisans, rather than designers in the modern sense and the furniture production world.(1).

The furniture industry would continue to construct familiar objects and products, using the same basic tools, methods and materials. But certain fashionable workshops and factories are producing innovative designs for client wealthy enough to pay for, what we call today 'development costs'. Since these innovations have to be tried and tested for certification, before they become part of the workshop or production repertoire, they need to be approved by construction engineers.

Design created to be constructed into functional furniture is not easy to construct and prepare for production. As we know from studies of anthropometry, in order to be functional, most products and items of furniture has to relate in some way to the human body.

However, anthropometry and ergonomic – the statistical sciences concerned with comparative study of the human body and how it relates to its environments, defined most of the needed conditions. But, to satisfy these conditions and recommendations in one hand and in the other to construct the product which will satisfy the quality of the product within modern recommendation and standards, you have to take care of both recommendations and construct a wood based product which will be producible in production process.

Hereby, we present few examples of the problems with which construction engineers are facing in factories.

First, we present so called near-perfect back rest chair

Figure 1: The near – perfect back (ergonomic back rest) chair

The ergonomic typist chair is designed to be comfortable for people of any stature and a draw-leaf table is an example of compactness coupled with flexibility. But, a chair mainly must support the user in such positions that he or she can function comfortable.

If the chair has arms, sit-downs and gets-ups will be without difficulties. It must be strong enough to bear the weight of the person yet light enough to be moved without effort. (3).

To construct the chair that would be reasonable comfortable for the majority of population, designers base their work on standard dimensions, but to confirm precise height, shape and angle of chair's components, it may be necessary to make a mock-up of the critical elements or to test and modify certain details as work progress.

The following elements 'as example' for chair construction should be respected:

1. Padding, because it improves chair comfort
2. Seat width, provides generous clearance
3. Seat angle which usually slopes slightly backwards
4. Seat depth, not deep to press on the back of the legs or to relieve the discomfort
5. Angle of back rest which should be adequate
6. Position of back rest which should support the middle portion of the user's back
7. Arm height which supports the forearm at the comfortable level

8. Seat height, the front rail should be acceptable not to press on the backs of the thighs uncomfortable

The above mentioned elements should be strongly respected on the construction of the chairs. The problems here are not the recommended dimensions but their accurate implementation inside of the production process with all types of machines in manufacturing lines. If they are not constructed correctly, they create uncomfortable consequences on the user's body.(3).

The table construction, need no more than a flat surface supported at a height that is convenient for dinning, studying, typing or serving tables. They have experimented with table tops to assure the best shape and size to accommodate the average needs of users, and its type of work or usage in different places and ambient.

Figure 2: Specific table construction – Jual Curve curved coffee table

The third type of construction is construction of storage-unit of furniture. When we speak about storage-unit of furniture, we refer to wardrobe, bureau, bookcase, or dresser which indicates their function and also their place in the house or other premises. In furniture production we classify them in shelves, drawers, and cupboards, in whatever combination provides the most convenient and effective use of space either for kitchen, bedroom, office or elsewhere. The basic principle of construction here is to use recommended dimensions that allow an average (height and weight) size person to reach the top shelf or gain access to the back of a cupboard without stretching. The built-in storage units are special construction where "modules" that are bolted side by side or the hall frame in one unit and the inner construction are adopted to the needs of user as well as the front doors with different materials to build in.

Figure 3: Storage unit – Alterton furniture Regence slim cabinet

Hereby we want to mention that presently construction of all types of furniture is supported with very well developed software or computer programs implemented in CAD/CAM systems. Software's for furniture design and construction are developing rapidly to the level of including plug-ins for generating built-in units furniture pieces and sets.

3. CONCLUSION

From the above mentioned material we can conclude the following:

1. The construction of wood based products is affected by rapidly developing technologies for the production of final products.
2. The basic principles of construction methods of wood based products are clearly defined and mostly respected in the preparation of materials for production and the construction process itself.
3. The need for functional furniture made the construction process more difficult where the constructor should carefully take in consideration the recommended elements of different regulations and standards for certain products especially concerning ergonomic.
4. The three mentioned groups of products (chairs, tables, and the storage units) have certain recommended elements of construction to be assured during the construction process and the preparation for its production.
5. Different software's were developed as for designing needs as well as for construction needs for most products where all of the recommended elements from different regulations and standards are already integrated in the software's themselves.
6. Ergonomic and anthropometry as specific sciences affected the construction process of all types of products planned for human usage. The recommendations of the researches are carefully built in all regulations and construction process. Using ergonomic principles can improve performance and reduce injuries at the usage of furniture.
7. At last to construct the ergonomic design it is not so easy and not enough to follow only the standards recommendations, built a multidisciplinary process which assure comfortable product and product which will be produced with high quality and safety in usage and processing.

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OFFICE TASK LIGHTING

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Abstract
The lighting of three office workplaces, which are located on different sides of the building, were measured. Measurements were performed with respect to different times of the day, and with respect to weather conditions. Measurements showed that the time of the day and weather conditions affect the amount of lighting in individual workplaces. The results obtained were compared to the recommended lighting levels according to HRN EN 12464-1:2008 and HRN EN 12464-2:2008.

Keywords: *lighting, office jobs, local lighting, general lighting*

1. INTRODUCTION

Today, office employees spend most of their working hours working on computer systems. Working on computer systems is uniform, with high repeatability of movements and requires a high degree of mental concentration, and exact psychomotricity with normal reaction times to tactile (0.09 s), visual (0.15 s) and acoustic stimuli (0.12 s). Working movements are extremely short and quick with a demanding degree of movement coordination and vision concentration due to work on a computer system. High degree of vision concentration requires good lighting of the workplace with scattered light intensity of 500 lx at least according to BS EN 12464-1:2008 which defines lighting of workplaces as indoor workplaces [1].
Therefore, the lighting of the work place with a computer system is one of the important factors of the work environment which gains increasing attention. Adequate lighting results in increased productivity, higher quality of work because it allows accurate, fast and easy observation, improves concentration and prevents fatigue.
As a rule we have natural day light in the workplace. Its amount depends on the level of lighting of outdoor places and the size of the area permeable to light.
Lack of natural lighting of indoor places is complemented by artificial lighting that is designed as a system of general lighting, i.e. by light sources that are set to light up a room, or a combination of the general system with an additional source for specific areas or locations in this indoor space [2].

The contrast between the screen and the paperwork should be in a ratio 1:3 to 1:10, and luminance contrast between dark characters and the background of the monitor screen should amount to 1:5 to 1:7. The most efficient measure from an ergonomic point of view is the adequate position of the screen in relation to the lights, windows and other surfaces. Thus, it is best that the light is at the right angle to the desk. In case it is located in front of or behind the desk, direct (light in front of the table) or indirect glare (light behind the desk) would result. It is preferable to set lampsin parallel or laterally to the median plane of the worker's desk. Lighting fixtures that are located directly above the worker's desk will cause a blurred printout of characters on the screen [3]. Today, the office lighting producing large amounts of horizontal direct light is avoided because it creates reflection. The angle of the luminous flux should not exceed 45° from the vertical, and luminous flux must be directed either downward or upward. Additional lighting is used in workplaces where work is demanding, and it is important that there is no glare or reflection.

2. EFFECTS OF LIGHT ON THE HUMAN BODY

Man primarily collects information visually since the eye is the most important sense that handles up to 80% of all information. Working on computer systems is performed with the required visual control that is achieved by transferring and / or eyesight concentration, whereby a stimulus is given in the regulatory human system based on visual perception as an input to activate the muscle system to make a decision about the creation of a movement. When working on a computer system it is necessary that the worker has very good sensory abilities of sense organs of vision that are related to visual acuity as the ability of noticing details and parts which would require near visual acuity [4].

During working hours it is possible that about 30 000 transmissions of the central line of vision occur between the light-template, gray keyboard and dark screen resulting in an adaptation jump because the human eye can constantly adapt to changes in color and light (contrasts). Different distances of the screen, keyboard and template from the eyes require sharpening eyesight - accommodation adjustment of the eye.

Long eye strain caused by poor lighting and glare in the visual field leads to the occurrence of visual fatigue that manifests as a painful irritation of the eyes, double visual images, headache, reducing the possibility of accommodation, reduced visual acuity, contrast sensitivity and speed of perception. As a result of visual fatigue productivity, quality of work and increase in the number of operational errors are reduced.

Due to poor lighting of the workplace the consequence is an unfavorable posture of the worker attempting to reduce the distance of his eyes from the screen which causes an increase in the angle of curvature of the spine and an increased flexion of the head. Therefore, favorable lighting of the workplace and working environment is very important for the working position.

3. EXPERIMENTAL PART

To test the intensity of lighting of office tasks, three workplaces in the Operations Department of Finances in a particular enterprise were selected. Measurements were carried out for three days in a period of three hours in different weather conditions. Lighting was measured n a Multinorm M16201 device with a connected radiant flux meter. Measurements were made in three offices where only day lighting coming through the windows, and general lighting were measured. The measured values were analyzed using a computer program Excel. The results obtained by measurements were compared with minimum required lighting of workplaces while working on a computer in the office in accordance with standard HRN 12646-1:2008.

4. RESULTS AND DISCUSSION

Measurements of the intensity of light were taken in three different offices for three days in a period of three hours. The first (RM1), Fig. 1a and the second (RM2), Fig. 1b, workplace is located on the west side, and the third (RM3), Fig. 1c, workplace is located on the east side of the building. During measuring the first day was overcast, while the second and third day was sunny.

1a	1b	1c

Figure 1. Workplaces RM1 (1a), RM2 (1b) and RM3 (1c)

Figure 2 shows the lighting level with general lighting for the first day (overcast). The lighting of RM1 and RM2 was lower than 500 lx almost half of the working hours, and only about 14,00 hours the lighting exceeded 500 lx, whereas the lighting of the third workplace was in conformity with the recommendations of standard HRN EN 12464-1:2008.

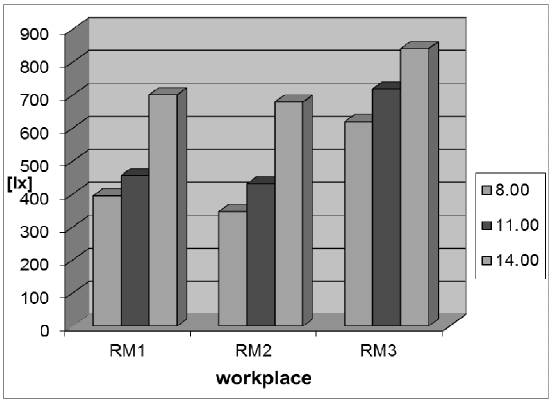

Figure 2. Level of lighting of the workplaces with general lighting on the first day

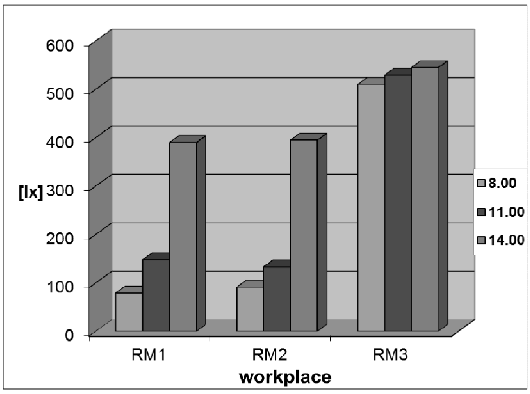

Figure 3. Different kinds of lighting of workplaces without general lighting on the first day

Figure 3 shows the level of general lighting without lighting for the first day (cloudy); it can be seen that the lighting on the RM1 and RM2 failed, while the RM3 met the requirements.

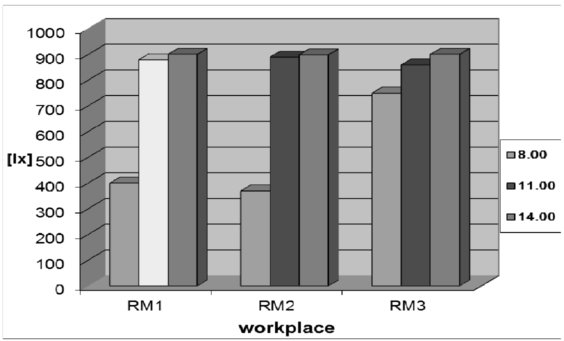

Figure 4. Lighting level in the workplaces with general lighting on the second day

Figure 4 shows the lighting with general lighting on the second day (sunny); it can be seen that in the morning the RM1 and RM2 lighting did not comply, while the RM3 met the requirements of necessary lighting.

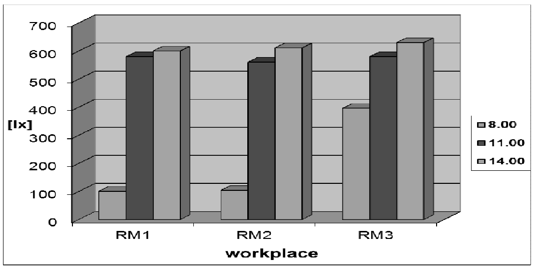

Figure 5. Lighting level in the workplaces without general lighting on the second day

Figure 5 shows the lighting level without general lighting where it is evident that in the morning the lighting of all three workplaces did not comply with the requirements, while about 11, 00 o'clock it met the requirements and ranged 500-650 lx.

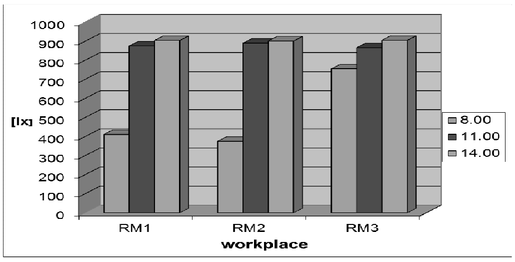

Figure 6. Lighting level in the workplaces with general lighting on the third day

Figure 6 shows that the level of lighting of the workplaces with general lighting was below 500 lx in the morning on the third day (sunny) in the workplaces RM1 and RM2, while the lighting level in the workplace RM3 was above 500 lx all the time.

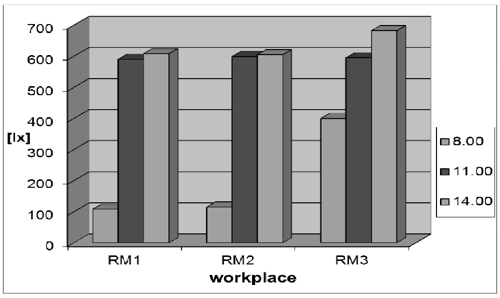

Figure 7. Lighting level in the workplaces without general lighting on the third day

Figure 7 shows the level of lighting of the workplaces without general lighting, which indicates that in all three workplaces the lighting was under 500 lx and did not meet the requirements necessary in the morning, while it met the requirements for the rest of the time.

5. CONCLUSION

The level of lighting office tasks affects the position of the office in relation to the cardinal directions, and weather conditions as external factors, and the location and amount of general lighting and / or additional local lighting in the workplace [5].
In two observed offices (RM1 and RM2) it was noticed that the lighting level without general lighting and with general lighting does not meet the requirements of necessary lighting of 500 lx. The lighting of the third office (RM3), which is located on the east side, does not meet the requirements of necessary lighting without general lighting only in the morning hours, whereas it meets these requirements with general lighting.
Considering the results of the measurements it is proposed to introduce additional local lighting of workplaces that would achieve less eye fatigue of employees, higher productivity and better concentration.

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ERGONOMIC CRITERIA FOR THE DESIGN OF PACIFIERS

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Abstract: *Pacifiers are everyday companions for babies and toddlers. The general safety requirements to reduce the risk of accidents with pacifiers are described in EN 1400-1:2002-12. This paper describes an analysis of the anatomical, physiological or psychological needs of the users based on literature search, screening of design solutions and interviews with parents and specialists in pediatric dental surgery, pediatric dentistry, speech therapy, postpartum care and breastfeeding counseling. As a result, essential ergonomic design criteria for pacifiers are described which complement existing safety requirements and are meant to increase the usability of pacifiers.*

Keywords*: Pacifier, safety requirements, ergonomic task analysis, ergonomic design criteria, usability*

1. INTRODUCTION

Pacifiers (also called dummies, binkies or soothers) are everyday companions for babies and toddlers in most of the developed countries. Parents give these artificial molded teats to calm and soothe babies when they are in bad temper. Pacifiers are also used to help infants to fall asleep or to overcome stressful or painful moments. In a worldwide survey 1996-1997 the International Child Care Practices Study found, for babies of 3 months of age, pacifier usage rates of 12.5% (Japan) to 71% (Ukraine) [1].

Pacifiers have been developed out of two kinds of forerunners: The hard teething rings and the soft sugar tits (also sugar-teats or sugar-rags), small fabric bags filled with sweet breads, honey or similar. It can be assumed that pacifiers have been industrially produced since the end of the 19th century, the first US patent for a “nipple-holder” has been granted in 1899 [2], an “artificial nipple” aiming to protect sore nipples in 1845 [3].

Today’s pacifiers have artificial molded teats mostly out of silicon or latex and shields out of diverse plastic materials. They are consumer products with a high demand on product safety, among other reasons because they are used by a high risk user group, potentially unattended babies and toddlers. The international standard EN 1400-1: 2002 specifies general safety requirements for materials, design, packaging and labeling of pacifiers and include requirements for the manual [4]. The standard refers to the European directive on general product safety 2001/95/EC [5] and includes specific design guidelines for the ventilation holes in the shield and the fixation of the teat in the shield, respectively ring or knob. Figure 1 shows the most important and visible basic design elements of a pacifier according to the European standard EN 1400 [4].

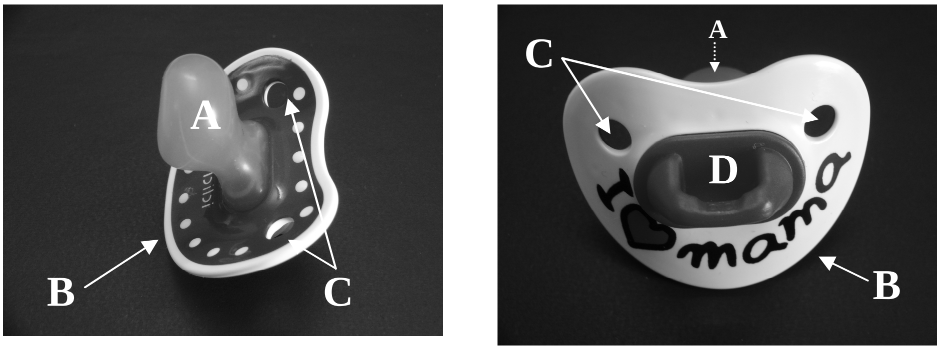

Figure 1: Basic design elements of a pacifier [4]: Teat (A), shield (B), ventilation holes (C), and ring or knob (D). Model: bibi® Latex, 0-12 months, Lamprecht Ltd, Switzerland.

Whereas the European directive [5] refers to “safety and health of persons” the European standard EN 1400 [4] refers solely to “general safety” and aims to reduce accidents related to pacifiers.

This paper aims to complement existing design guidelines for pacifiers with ergonomic recommendations – design goals focusing on the basic needs and well-being of the user and usability of the product.

2. METHODS

Ergonomic design criteria or design goals have been developed following a classical approach for product ergonomic analysis in three steps, inspired by Ramsey [6] and Bullinger & Solf [7]. The first step was the analysis of product and product environment, the second step was the definition of user requirements, and the third step was the development of corresponding ergonomic design criteria. During these three steps literature search, analysis of existing design solutions and expert interviews have been conducted.

The ***literature search*** has been conducted between September 2012 and March 2013. Base of the literature search has been in a first step the *Web of Science* and *Google scholar*. In a second step the search has been extended on non digitized literature within the Swiss library network NEBIS. Key words were among others: pacifier, dummy, binky, soother, non-nutritive sucking, and child development.

The ***analysis of existing design solutions*** focused on actually available pacifiers in the Swiss market for the age groups +/-2 month till 36 month. Overall 47 pacifiers from seven producers AVENT (Philips Electronics UK Ltd.), bibi® (Lamprecht Ltd.), Chicco (Artsana S.p.A.), Difrax (Difrax BV), MAM (Bamed AG), Nûby$_{TM}$ (Luv n’ care® Ltd.), and NUK® (MAPA GmbH) have been included in the analysis.

The ***expert interviews*** included four experts with a minimum of 12 years of expertise in the field. These experts covered the domains of pediatric dental surgery, pediatric dentistry, speech therapy, logopaedics, postpartum care, and breastfeeding counseling. The face-to-face interviews followed a protocol with personal introduction of 5-10 minutes, introduction to product ergonomics of 10 minutes (aims & benefits, ergonomic product analysis, ergonomic design principles, the role of the ergonomist in product design processes), and an open discussion of 50-100 minutes (including general role of pacifiers for the domain, specific recommendations for pacifiers and pacifier use, effects of pacifier use on human development, need of the child and the parents, and specific feedback on design solutions).

3. RESULTS

3.1. Product environment

The screened literature misses the fundamental characteristics of an ergonomic approach as it is described by Dul and colleagues [8] (systems approach, design driven and with performance goals and well-being goals). However, the extensive list of positive and adverse health effects found, served as base for the analysis and the interviews. Domains where adverse and positive health effects are intensively discussed in the literature include pediatric nursing [8]&[9], clinical pediatrics [10], general medicine [11], orthodontics, and dentofacial orthopedics [12]&[13]. Among the positive effects the prevention of Sudden Infant Death Syndrome (SIDS), a positive effect to the emotional and psychological development of the child (soothing, control gaining …), and the effectiveness as an adjunctive pain relief are mentioned most often. Next to accidents with pacifiers or pacifier related injuries (choking, broken teat, separation of pacifier parts), most mentioned negative health effects are: negative effects on oral health and dentition (anterior open bite, posterior crossbite, and narrow intercuspid width), negative impact on breast-feeding and speech development, increased evidence of inflammation of the middle ear (otitis media), allergies (mostly latex allergies), skin irritations and infections (source of bacteria) as well as potential for compulsive use (pacifier addiction). Most of the above mentioned effects are still controversially discussed within different contexts and among the different disciplines or domains. However, in most discussions, there is – even among the different disciplines and even among non ergonomists – consensus that frequency, type, intensity and duration of the use of pacifiers have an impact on health risks or health benefits [8]&[12].

Not only the literature search, but also the interviews showed an unexpected variety of different views on pacifiers and the use of pacifiers. Reasons for this are the dynamics and the individuality of child development from premature babies (-2 month) to toddlers of 24 month [13]. It’s important to note, that during child development some of the child’s demands to his pacifier will change continuously or gradually, others will change at a moment’s notice. Another reason could be found in the temporal segregation of the different specialists, as they typically focus on specific aspects and conduct their interventions in clearly defined development phases or age groups, e.g. breastfeeding counseling age -2 to +2 month, logopaedics for children above 24 month, pediatric dentistry for children above 36 month.

Taking in account the above findings an important part of the found ***variety of design solutions*** on the market can be explained. Three different concepts of teats, seven different concepts of shields and ventilation holes and multiple concepts for rings or knobs could be found.

3.2. Basic functions of a pacifier

From an ergonomic point of view, we define the basic function as the core function that is essential for the user of the product. For pacifiers two different use phases with two different but interlinked basic functions could be assigned:

- Learning phase (first weeks and months). The primary function of the pacifier is to support the child in ***learning efficient motor patterns*** for the nutritive and non-nutritive-sucking. Ideally effective motor patterns of the sucking movements of the tongue, the jaw and the facial muscles are well coordinated with the nasal breathing and the swallowing. At the age of 6 months the learning phase is completed for most children. An intelligent design of pacifiers supports and encourages the child to learn and optimize an efficient motor pattern.
- Application phase. The primary function of pacifier use is the ***calming effect*** of an undisturbed, often rhythmic sucking. The transition from learning phase to the application face runs fluently and individually. The primary function in application phase is to satisfy the natural sucking need as an everyday companion of the child. Actual benefit is the calming effect of the non-nutritive sucking.

3.3. User requirements – main human aspects for the design of pacifiers

Classic ergonomic analysis of a product is based on anatomical, physiological and psychological aspects. Ramsey [6] described 37 different aspects that should be considered. Of these 37 aspects the following eight can be rated as of particular relevance for pacifiers:

1. Anthropometry or body mass, in particular the exterior mouth (upper and lower lips, nose and chin) and the inner mouth (upper jaw with arched palate, tongue).
2. Body motions and forces, in particular the movements and forces of the tongue during sucking.
3. Climate, in particular the thermal insulation of the shield.
4. Tactile perception, in particular the perception of shield and teat by the body surface of the child during sucking and at rest.
5. Motor development, in particular the coordination of sucking motion with swallowing and breathing (coordination of patterns).
6. Feedback, in particular the tactile response of the pacifier to the movement of the tongue during sucking.
7. Motivation, in particular the role and motivation of the parents, but also the motivation of the child.
8. User behavior, in particular the way the pacifier is used and in what situations the pacifier is used (e.g. individual desideratum of pacification).

A more detailed description of user requirements must, among others, take in account the above mentioned dynamics and individuality of child development.

3.4. Ergonomic design criteria

Nine ergonomic design criteria in form of design goals for the pacifier shield and the pacifier teat have been developed in order to fulfill the basic functions in an effective way and in order to reduce the known health risks.

At rest and during the natural sucking movements of the child, the ***shield of a pacifier*** should:

- absorb the suction forces during sucking and evenly spread the remaining forces over the outer mouth region (lips and facial muscles),
- provide a support for the upper and lower lips and allow a vacuum during the closing of the mouth,
- do not affect the child's nose or chin (pressure points on the chin and nasal septum) in rest position and normal range of motion during motion,
- not have exposed or protruding edges or engagement surfaces, so that the pacifier cannot be easily stripped off by simple movements such as grazing movements in the normal range of motion of the arms, and
- avoid that the pacifier may accidentally access or be sucked in the trachea of the child.

At rest and during the natural sucking movements of the child, the ***teat of a pacifier*** should:

- pick up the suction forces of the child and forward them to a certain extent to the shield (counter-pressure on the lips),
- give the tongue enough resistance (surface area, volume, surface friction) to transmit the tongue movements to the pacifier,
- allow the widest possible closure of the teeth at rest and during the natural sucking and sucking movements (small shank), and
- absorb – to a certain extent – the suction and pulling forces of the tongue and the lower jaw.

4. DISCUSSION AND CONCLUSION

Pacifiers are everyday companions of children and – on the first view – seem to be simple products and easy to design. However, literature review and interviews with experts in the field of medicine and care show a waste variety of specific demands and recommendations for pacifier design and use. This situation makes it difficult for producers and designers of pacifiers to get a grip on ergonomic aspects of the product.

By collecting the main risks and the main benefits of pacifier use that are discussed in the literature and among experts in the field, and by discussing these aspects with a focus on the needs of the parents and the child, two basic functions of pacifiers could be extracted. Additionally, by analyzing existing product design solutions and the product environment, a prioritization of the numerous anatomical, physiological and psychological (human) aspects that have to be taken into account in the design process could be achieved. As a result of this ergonomic product analysis, following a classical approach, nine essential ergonomic design criteria for pacifiers could be described. These ergonomic design criteria or design goals are of general matter and give space and freedom to designers and producers. The aim is to complement essential safety criteria of the European standard for pacifiers EN 1400 [4] with essential ergonomic design requirements. Further work will focus on more detailed age-related ergonomic design guidelines for pacifiers.

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ADVANCED ACCESS TO DETAILED WORKPLACES DESIGN USING THE PRINCIPLES OF ERGONOMICS

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Abstract

The authors present a progressive approach to detailed workplaces design with using of ergonomic principles. This methodology was developed by CEIT Digital Factory division and Slovak Ergonomic Society. Is already actively using in practice by the implementation of industrial projects, under name CEIT ErgoDesign. In this methodology are used modern digital tools, non-contact scanning, stereoscopic, virtual and augment reality and also a modern ergonomic analysis with using a software tools. It is a comprehensive ergonomic design of workstations using either reactive or proactive ergonomics. It is a complex of multidisciplinary solutions for design of individual workstations using modern technology. This methodology has been developing and verifying for several years and is constantly updating with a new areas.

Keyword: ergonomic, detailed workplace design, evaluation of ergonomics, digital factory

1. INTRODUCTION

By ergonomic solutions we have primarily to protect a health, prevent diseases and eliminate the possibility of accidents. The doctor is a man, who has treated if the problem occurred and ergonomic engineer is a man, who would just prevent ergonomic health issues related to their work operations. Designing workplaces, their assessment and optimization for the purpose of humanizing work, while increasing productivity, have historically been time consuming and require a great deal of effort to achieve a comprehensive solution analyst projection ergonomic design. Missed while feedback that before the implementation of solutions to help reveal its shortcomings. Now we can handle such a task within a much shorter time and with high efficiency, flexibility and accuracy and above all with a great view of the man who is still a major component of the work process.

2. PROGRESSIVE APPROACH TO DETAILED WORKPLACES DESIGN

CEIT (Central European Institute of Technology) in collaboration with Slovak Ergonomic Society, were created own methodology for detailed design of workplaces, four years ago. Its logic and function has been verified on a lot of projects aimed at optimizing the assembly and production sites in a virtual 3D environment using ergonomic tools digital enterprise. This unique design uses modern tools such as 3D laser scanning, an interactive layout planning production with the use of its system, digital design workplaces and work environments Siemens Tecnomatix, including comprehensive ergonomic analysis, and so on. This progressive approaches to provide customers with quality solutions, which eliminate the ergonomic deficiencies during both the digital model. At the same time are eliminated the deficiencies in the design work, material flow, quality, productivity and so on. Methodology developed for the establishment remained open to further development and improvement. Its basic structure could be summarized in 2010 into three points of the framework, and to obtain input data processing – creating the project, solution design layout of workplaces.

3. EXPANDING OF ACCESS METHODOLOGY CEIT ErgoDesign2012

To our approach we added a new field this year. It ensures the complex multidisciplinary design solutions for individual workstations using modern technology. CEIT ErgoDesign 2012 characterized in detail the input data for the database project. It was created a separate module of the analysis, which was supplemented by area evaluation of spatial conditions, area evaluation of the working environment and area evaluation of physical activity, which has been filled with new ergonomic analysis. In the module of draft solutions were characterized by specific outcomes and were independent of the other modules in the form of analysis solutions. This section includes three major new areas. Among other things, evaluation of labor productivity and its changes in the design and verification of real-world using augmented reality. The original three modules CEIT ErgoDesign expanded to six modules and new name of methodology is CEIT ErgoDesign 2012 (figure 1).

3.1. Getting input data

In the methodology is the first step after the request for the project of the existing collection of real input data and verification. When collecting data, it is essential to obtain information and documents from the company. Under the verification understand and retrieve data values of project can be completed and verify the truth and accuracy of the data from the company where the project is implemented. Individual data collected can be divided into four groups. In the first group we obtain installation and technical procedures, information on production benefits, performance standards, and the organization breaks, characterizing manufacturing or assembly system and the organization of work. In the second group are identified characteristics of the environment and its components. The company provides a complete 2D layout of the workplace. This information will be specified in detail and verified by 3D laser scanning work and its various components as required.

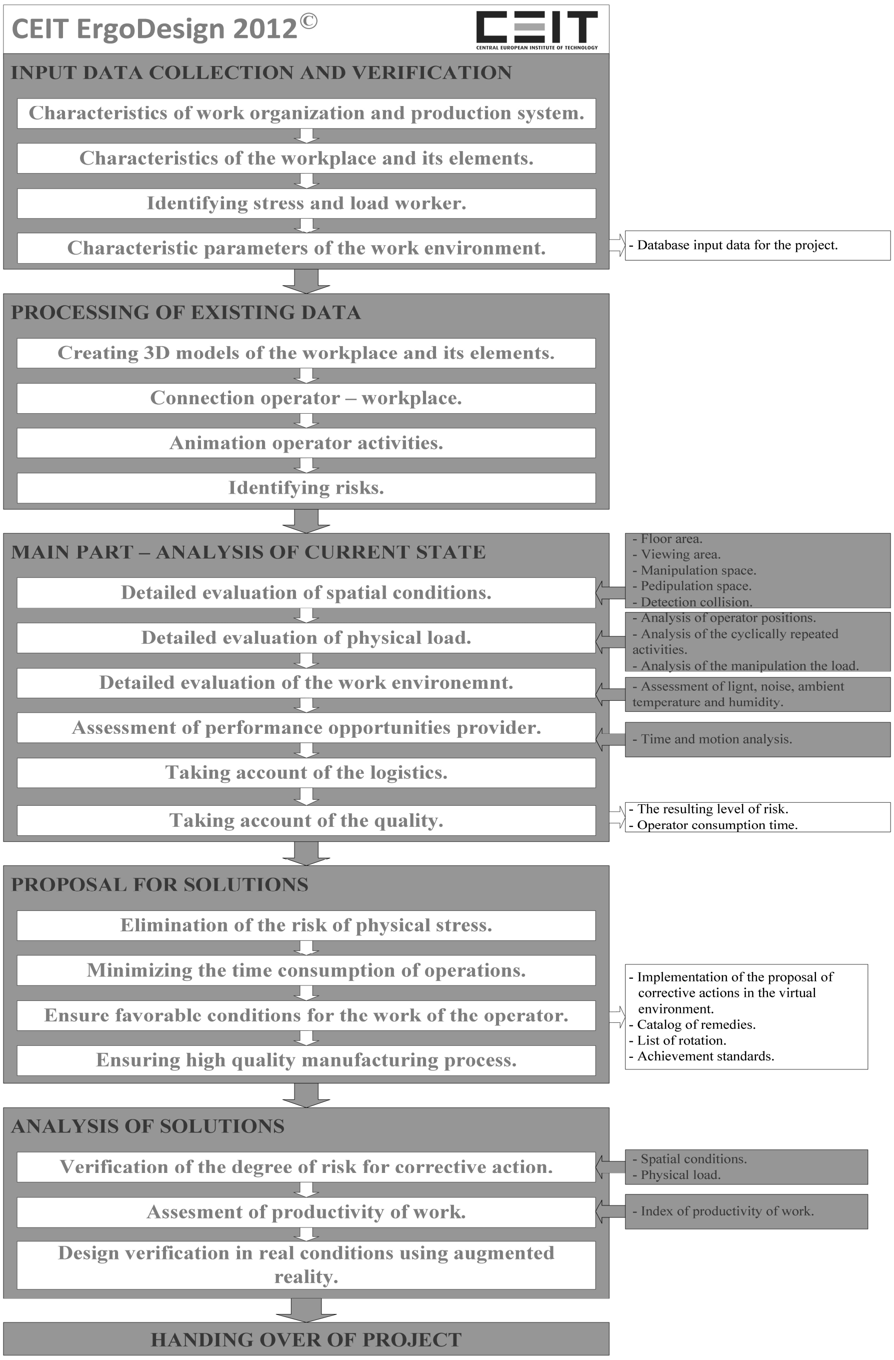

Figure 1: CEIT ErgoDesign (Smutná, 2012)

It is used while contactless laser scanner [1], [2]. The third group is characterized by a subjective state of stress for workers using the modified Nordic Questionnaire. Data that is collected through this questionnaire allows to analyze the characteristics of the reference file employees, incidence, intensity and localization problems and musculoskeletal system, subjective evaluation factors and working conditions for employees and the characters and factors that may affect incidence and degree of difficulty workers. They are then used to test of the real physical activity, whether conventional digital load cell, or advanced support tools as ErgoPAK by which we obtain the current strength in tension, compression, manual handling limits etc. Information on the position can be obtained using a stereoscopic video. Stereoscopic records are now one of the newest features that have been applied to the field of ergonomics [3]. Its using is primarily in the analysis of the real situation in terms of workplace stress analysis operator. Industrial stereo recording is carried out through a set of cameras from different points at the same workplace. For high quality stereo recording is necessary to take into account a large number of parameters commonly available 3D camera is not set [4]. The result is a spatial perception of the operator´s workplace, which allows accurately track and analyze movements of real operator. This technology is an alternative to motion capture techniques or to use CAVE (virtual cave technology). The fourth group is the need to collect sufficient data characterizing parameters of the working environment. In this area, we focus mainly on lighting noise, temperature and humidity.

3.2. Processing of existing data

Using database, we get the first module of input data for the project. The second module of our approach is focused on processing the collected data. In the first step is from 3D laser scanning workstation modeled workplace. It is also modeled in the digital space the individual components, for example desks, chairs, shelves, pallets, containers, assembly parts, etc [5]. After insertion of modeled components in the digital workplace are models deploys according to the real situation. It is then inserted DHM – Digital Human Model, to the virtual workplace and it can be realized an animation of operator actions. They are using stereoscopic records, manufacturing and assembly processes. Very important step of second module is an identification of negative risk factors. Thanks an output of Nordic Questionnaire and also stereoscopic videos is prepare a list of potential risk factors at work. It´s actually a record of risk assumed of the working space, physical activity and work environment. These risks are followed procedure in the third module and verified by the scientific method to determine the rate of one for every defined risk.

3.3. Analysis of current situation

This section is devoted to the evaluation of ergonomics, operator performance with respect to logistics and quality. The detailed evaluation of the spatial conditions is animation model operator actions and inventory of potential risk factors at work inputs for detailed evaluation of spatial conditions. Using the tools of modern ergonomics, software options, we determine whether the risks relating to the working environment very seriously. They are evaluated the total space requirements for the workplace provider, free floor space not built, transition lanes, dimensional relationships between operators – the workplace and workplace elements. We assess the viewing,

manipulation, pedipulation space and detect possible collision conditions in the workplace in relation man – an element of the workplace.
The detailed assessment of physical activity is necessary to use force characteristics. These are the forces measured by the type of activity. Individual analyzes are selected according to whether the handling of loads, cyclically repeated actions or static load, or due to business need to evaluate energy expenditure and so on. These include analysis RULA, OWAS, REBA, Low Back Analysis, Static Strength Prediction, Snook and Ciriello, Key Indicator Method, NIOSH and etc.

In accessing the physical work environment factors not realize evaluation of lighting, noise, temperature and humidity in the workplace. This module, like others, is open and we plan to complete the measurement and evaluation of other factors in the working environment. The necessary data are primarily from measurements of the parameters of the working environment. Processed data are then compared with the current legislation, which allows you to take the final inventory of risk factors in the working environment. This statement is further supplemented by the fact that the protective equipment used to these risk factors is sufficient.

3.4. Analysis of current situation

After receiving and processing data, identifying risks, and after verification using spatial assessment of conditions, physical activity and work environment you can go to the design of remedial measures. Summarize the individual final inventories of negative firs factors. These are incorporated into a final catalog of remedies and of course the remedies for which it is possible to implement a 3D model to work. Catalog of remedies is a document given to the submitter of the project. This catalog contains a list of risks with their detailed descriptions, degree of risk analysis after application of physical stress. References to legislation and proposals for corrective measures, of course, a risk measure for possible application of these measures. By individual remedies we can eliminate the risks of physical stress, minimize the time consumption and provide favorable conditions for operators. All solutions are implemented with regard to logistics and quality, and we provide high quality manufacturing process. The fourth module outputs include proposals for corrective measures implemented in the virtual environment, the catalog of remedies with the resulting level of risk, leaves rotation performance standards. Of course, by the nature of these solutions are complemented outputs of other options.

3.5. Analysis of the solution

After a realization of draft a remedial action is necessary to carry out the verification of the level of risk for corrective action, where detailed assessment of spatial conditions and physical strain after application of these measures in a virtual environment [7]. Remedies of the work environment, we verify by current legislation. In this section, operator performance is evaluated and then change in labor productivity. The input for this phase is already created 3D animation model operator. At the same time, are entering stereoscopic videos that allow tracking of economic movements. Then is followed a selection of a suitable system MTM or UAS, evaluation of operator performance capabilities of the original state, and then the proposed state. The resulting value of labor productivity is obtained by the time data of the operation of the implemented method of pre-defined times. Finally, it is necessary to quantify labor productivity [6]. To verify this design can be used in labor productivity index. If the principles of ergonomics to design remedial measures for one workplace, it is necessary to analyze the consumption time worker in his activities at the workplace. As part of the project and assess the overall productivity designed for all workplaces.

4. CONCLUSION

It is necessary to emphasize that CEIT ErgoDesign 2012 is an innovative approach to design and evaluation of healthy and productive workplaces. It is not sufficient just to use the system run, on the contrary, it is necessary to continuously improve, innovate and implement new models, technologies, research findings, and develop the system for the benefit of businesses and their employees. The application of augmented reality in this approach not only has a unique meaning for man – the operator, but for the company itself, in the form of better output in less time and with greater efficiency.

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TO BYPASS OR NOT TO BYPASS: AN EXAMPLE OF WORKERS' CONFLICT OF INTERESTS IN A MANUFACTURING COMPANY

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Abstract

Bypassing and disabling safety systems are generally viewed as illegal behaviours of shop floor workers and a major cause of industrial accidents. Some analyses of work settings have been demonstrating the reasons for such acts. The aim of this paper is to show, through an example collected during an ergonomic intervention, the conflict of interests that workers can be subjected to, when carrying out a bypass act. It is argued that understanding and taking these conflicts into account is a critical condition for safer and healthier work environments.

Keywords*:* *Ergonomic, Intervention, Safety Systems, Design, Safety, Work*

1. INTRODUCTION

Manipulative actions in machinery, or bypassing acts, are commonly observed in work settings. In their routines, shop floor workers deliberately do such acts, including disabling, bridging and removing protective devices and safety systems. Bypassing and tampering protective devices is considered a major cause of occupational accidents in industry, including fatal ones. A German interdisciplinary research project [1] interested in such issue concluded that the dimension of tampering is extensive: its results show that one third of all the protective devices in metal-working companies are temporarily (23%) or constantly (14%) manipulated.

The underlying reasons why workers bypass protective devices are diversified. This can be motivated by a freely access and easily removal of switches [2]. Also, employees may not have been adequately informed about possible risks [2] and they can underestimate the heightened hazard caused by the manipulation [3]. The bypassing may be tolerated in plants [2] and there are few negative consequences for the manipulator [3].

Other reasons can motivate the bypassing actions: a bad design of the machines that lead to a poor view of the process; malfunctions can result in repeated interruptions of production and excessive delays before operation can be resumed; and in some cases, specific operating modes, such as set-up, troubleshooting, reconstructions and automation mode, cannot be applied without any manipulation action [2,3]. It is argued that the bypassing of protective devices can be avoided only if machines are designed in such a way that the defeating offers no benefits, i.e. there are no incentives [4].

Some studies have been pointing that bypassing has not been adequately addressed in the field of Occupational Safety and Health – OS&H [3,1]. In most cases, the part which bypasses the function is considered responsible, but this definition of responsibility does not go far enough [2]. It is evident the lack of studies concerning other types of motivations for bypassing acts, specially the ones considered to be “outside” the scope of OS&H.

The aim of this paper is to contribute to a broaden discussion about the motivations and interests that can lead workers to perform bypassing acts. To achieve such goal, an example is presented. It reports the occurrence of an incident during a manufacturing process that forced its interruption. The workers acted to solve the incident, doing bypassing to resume the production.

After the description of the case, a discussion will be presented. But before, it is important to highlight that this constitutes an analysis of a single case. The bypassing acts are polemical, and many other interests can exist in manipulative actions. What is defended is that such cases shall be analyzed individually. Again, the intention here is not to create a generalization, but, from the example given, to encourage the discussion about other motivations and interests that may encourage manipulation in machinery.

2. MATERIALS AND METHODS

The described example was observed during an ergonomic intervention, conducted in a manufacturing company and focused on a specific processing machine. The Ergonomic Analysis of Work Activity [5] was the main method applied. Field studies enabled the research party to familiarize with the technical process, progressively winning the workers trust [6]. It also assisted in mapping the workers activities, including their actions and their visualization and communication needs [7].

The collected data was granted through a systematic observation of the work activities done and the machine routines. Open and semi-structured interviews, spontaneous and concurrent verbalizations, were also used as data-collection techniques.

While the incidentes were occurring, data were being recorded: the time of the occurrence, the number of workers involved in the correction, the actions performed by each one, the communications established, and so on. Then, the workers were questioned about what they have done, why they have carried such actions, the frequency of the specific occurrence or similar situations, etc. Data collection also included the analysis of relevant documents available, like company specs, work instructions and safety procedures.

The field research lasted for seven months, comprised between November 2010 and June 2011. It took around 41 data-collecting days, each day consisting of approximately 6 hours of direct contact with the workers and the routines of the machine. As the company works in rotative shifts, all the shift groups were involved in the research.

3. RESULTS

The study focused on the calendering process, an intermediary process of tire manufacturing. It produces continuous sheets from rubber compounds incorporated onto reinforcing materials. The calendering process is an important step in the production of tires, because the quality of the sheets is critical to the tire performance.

3.1. Brief description of the equipment

The calendering machine, a calender, is a heavy-duty machine equipped with three or more chromeplated steel rolls, which revolve in opposite directions, in specific speeds [8]. Besides the steel rolls, a number of other accessory equipment ensures the production process and measurement and control systems guarantee the quality of the final sheets.

3.2. The textile fabrics calendering process

The calendering of textile fabric uses rayon, nylon and polyester fabrics as reinforcing materials. The process is initiated with the placing of the textile fabric rolls in the unwinding station. From there, the edge of the fabric is spliced, either to a fabric already in processing, or to the set-up liner. Then, the fabric is pulled, until it reaches the calender rolls, where it will be impregnated with rubber on both sides. On this journey it goes through several rolls, whose main objectives are: (i) to direct the path of the fabric along the machine; (ii) to balance the tension of the fabric; (iii) to promote the opening of the weft (expander roll); (iv) to center the fabric for a correct feeding of the calendering; (v) to heat the tissue, avoiding the presence of moisture, which hampers the adherence of the layer of rubber.
After passing through the calender rolls, the sheet goes over cooling drums, and over the accumulator system, until it reachs the winding station (wind-up station), where it will again be winded into spools again, using a liner fabric. The, the sheet is cut, and sent to storage, where it should remain for up to two hours before being used in the next stage of manufacture of the tire.

3.3. The incident

A thread from the textile fabric in the calendering process, grips to the rolls of the acessory system of the equipment, and it is continuously wraped, therefore it frays the fabric successively.

Local of occurrence: The incident can occur in one of the rolls of the accessory equipment (a total of 35 rolls).

The causes of the incident: The incident may occur due to the presence of loose wires or due to a damaged weft. In order to minimize it, the supplier company applies an adhesive protecting layer on the edge of the fabric and covers the fabric spools with a plastic shield. The wires can also be loosened during the splice of the fabric spools. A careful splicing during the set-up between the spools can avoid the incident, as stated by a worker:

“a bad splice can make a tire turn into waste…”

As the spools are carried by fork-lift trucks, the fabric can also be damaged during the transportation.

Time and frequency of occurrence: The incident generally occurs at the beggining of the calendering of the spool, when the splice gets tensioned and therefore subject to split, or when the most external fabric of the spool, therefore more subject to be damaged during transportation, is being calendered. The machine workers know the incident very well, as they reported:

> *"these things happen…it happens once per month…but also it depends on the fabric conditions…"*

The consequences to the production: The frayed fabric cannot be calendered, once it does not fit the quality specification. Moreover, productivity is reduced due to the time spent fixing the situation.

The procedure to deal with the incident: The worker must stop the machine and call the maintenance staff.

3.4. The bypass action to correct the incident

Throughout this research, three of such occurrences were observed. As soon as the incident was observed, the workers intervened immediately to fix it. After identifying the area of the incident, they disconnected the machine, to secure a minimal material loss.
Concerning one specific occurence, the situation took place in a roll of the accumulator system, situated inside a protective fence. Despite the existence of a door on the fence, it is constantly locked. The machine worker was not allowed to have the key, so he jumped over the barrier.
In another case, the incident occurred in a roll also located inside the protective zone. However, in this occurrence, it was possible for the worker to reach the place, even staying outside the fence. This way, the worker laid down on the floor and stretching himself under the fence, he reached the zone and cut the rolled threads.
Another occurrence was also observed in the heating drums, located inside a closed cabinet to avoid thermal losses. However, in this case, it is a place the workers have free access to, the positions required to cut and remove the threads were very unconfortable, due to limited space. This is worsened because it is an area with high temperatures, what also increases the burning risks.
In all occurrences, by the end of the removal of the threads, the worker left the place and resumed the calendering.

4. DISCUSSION

In all the incident occurences, the workers' decision was not to follow the procedure and solve the problem. In all of them, the bypassing was performed without further consequences. The incident was solved and the calendering process status was resumed in a few minutes.
The actions performed by the workers can be initially viewed as an infringement of the company procedures, as the workers must call the maintenance staff. Also, the

bypassing implied the arising of unforeseen risks: physical barriers, designed to ensure the workers safety, became a new source of risks; and the need to adopt extreme positions may have an impact on the workers' health.
A closer analysis of the bypassing actions demonstrates that workers were also motivated by interests that may seem to be outside the domain of OS&H. Three of them will be presented.

4.1. Maintenance organizational structure

If the worker calls the maintenance staff to solve the problem, the production remains interrupted until the responsible is available to come and solve the problem. As stated by one worker, this may imply waiting up two hours. The worker stated:

> "*Can you imagine if we have to call the engineering team at every malfunctioning? Until somebody comes…*"

It is important to understand that the maintenance staff has an amount of tasks to accomplish, sometimes bigger than their capability. It is not rare to find such situations in industrials settings, in which the maintenance organizational structures are insufficiently dimensioned or poorly managed, regarding the real demands of the production.

4.2. Process productivity and wages

The greater the processing time to solve the incident and return to the normal production, the more production time is lost. This consequently represents a reduction of the amount produced by the shift, which in turn can imply a wage reduction, once the workers receive rewards according to the amount produced by the shift.
This would have consequences not only for the machine workers of that shift, once not only the machine workers are paid according to the production volume, but also for their supervisors. Also noteworthy is the company pressure to fulfill the production goals and the incentives to competition among the work shifts, like the monthly reports presenting the production levels achieved by each work shift.

4.3. Punishment and tolerance

Doing the bypassing action, the worker is in noncomplaiance with a company's procedure and can be punished by doing it.
Bypassing actions with no further consequences are commonly tolerated, except in the cases in which accident with greater severity happens. Generally, after such cases, companies tend to increase the number of warnings, procedures and safety barriers.

5. CONCLUSION

The bypassing acts and manipulations in machinery are more common than what is usually estimated. In this paper, it was presented an example of an incident and a bypassing act done to solve it. Then, some aspects, regarding the workers' conflicts of interests in such situations, were discussed.

Conflicts of interests like the ones presented can be identified in similar cases. They are generally outside the OH&S scope. Nevertheless, a broaden analysis demonstrates that sometimes they may not be. It is defended that such issues have a direct influence in the workers decision for doing bypassing acts or not.

It is argued that understand these conflicts and take them into account is a condition to promote safer and healthier work environments. Otherwise, the safety systems will continue being bypassed.

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AUTOMATIC TRAIN OPERATION AND ITS IMPACT ON THE TRAIN DRIVER WORKLOAD

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Abstract: *Over the past decade number of automatic train operated lines is worldwide significantly increased. This is the result of numerous advantages of its application related to traffic control and energy saving issues. One of significant advantages of its application is improvement of train driver cognitive ergonomics which is an important factor for improvement of train and traffic control efficiency. In this paper experiences with automatic train operation and its impact on the train driver workload will be discussed.*

Keywords: *automatic train operation, train driver cognitive ergonomics, traffic control efficiency*

1. INTRODUCTION

Automatic Train Operation (ATO) refers to a system that guides the train automatically by the information provided by an automatic train protection (ATP) system [1]. It is an operational safety enhancement device used to help automate operations of trains which insures partial or complete automatic train piloting and driverless functionalities.. Mainly, it is used on metro railway systems which are easier to ensure safety of humans but it is also used on other kind of railway systems. Most systems elect to maintain a train driver to reduce risks associated with failures or emergencies.

Its onboard subsystem is responsible for the automatic control of the traction and braking effort in order to keep the train under the threshold established by the ATP subsystem. Its main task is either to facilitate the driver or attendant functions, or even to operate the train in a fully automatic mode while maintaining the traffic regulation targets and passenger comfort. It also allows the selection of different automatic driving strategies to adapt the runtime or even reduce the power consumption.

Its wayside subsystem is in charge of controlling the destination and regulation targets of every train. The wayside ATO functionality provides all the trains in the system with their destination as well as with other data such as the dwell time in the stations. Additionally, it may also perform auxiliary and non-safety related tasks including for instance alarm/event communication and management, or handling skip/hold station commands.

There are various degrees of automation (or Grades of Automation, GoA) which are defined according to which basic functions of train operation are responsibility of staff, and which are the responsibility of the system itself. According to the International Association of Public Transport (UITP), there are five Grades of Automation (GoA) of trains:

- GoA 0 corresponds to on-sight train operation, similar to a tram running on street traffic.
- GoA 1 corresponds to a fully manual train operation where a train driver controls not only the starting and stopping of a train but also the operation of train doors and handling of emergencies or sudden train diversions. This is a typical grade of automation for most conventional railway system (e.g. railway system in Croatia is GoA 1)
- GoA 2 corresponds to a semi-automatic train operation (STO) where the starting and stopping of a train is automated but a standby train driver remains in the driver's cab to prompt the train to start, to control the operation of train doors, to manually operate the train if needed and to handle emergencies. Many ATO systems in the world are of grade GoA 2.
- GoA 3 corresponds to a driverless train operation (DTO) where a train can start and stop itself but a train attendant may be present to operate the train doors and to manually drive the train in case of emergencies.
- GoA 4 corresponds to an unattended train operation (UTO) where the starting and stopping of trains, as well as operation of train doors and handling of emergencies are fully automated without any regulatory requirement of staff present in the trains

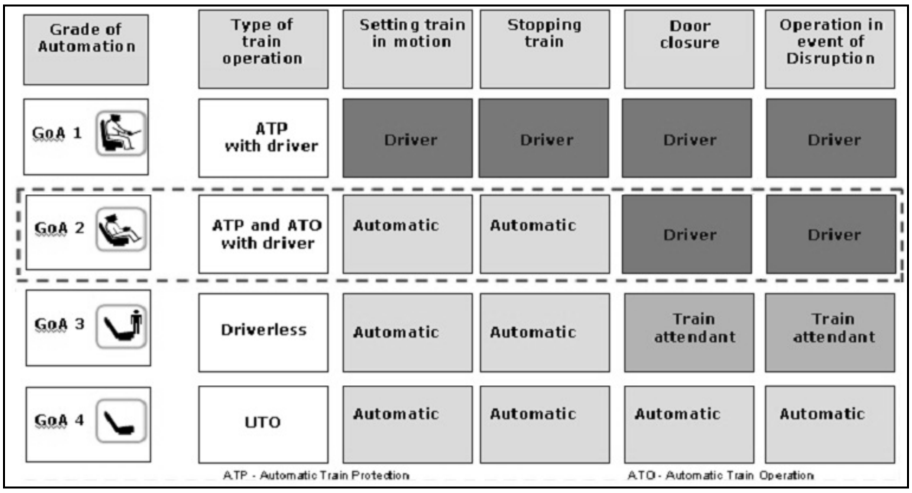

Figure 1 Grades of automation according to basic functions of train operation [2]

This paper refers to GoA2 ATO systems which are used on many railway lines around the world.

2. THE PURPOSE AND EXPERIENCES WITH AUTOMATIC TRAIN OPERATION

The increase of demand for transport service in rail traffic stipulates higher ratio of consumed infrastructure capacity [3]. A number of approaches (e.g. building new lines, optimizing the length of block sections etc.) could bring increased capacity but are accompanied by an increase of investment. Therefore, new approaches for increase of railway capacity while minimizing the railway operating cost are sought for, enabling a better use of the existing infrastructure by real-time optimization of railway operations. Hence currently two approaches have been developing, real time timetable rescheduling and optimisation of train operation. In the case of conventional railway lines real-time rescheduling plays a key role in improving of railway network capacity and ATO is widely applied in high-speed railway and metro railway systems. Compared to the conventional mixed-traffic lines, high-speed lines and metros have less heterogeneity in train types and stable timetables and increased train computing power. Hence the high-speed lines and metros focus more on the train optimization (e.g. energy efficient train operations) so far, whereas the conventional line makes more efforts in infrastructure optimization.
However, the separation of optimization between infrastructure and train operation is only an interim state. In the very near future, conventional rail lines will be updated with new systems, high-speed lines will no longer be dedicated lines but mixed with conventional lines, while metros are predicted to involve more rescheduling because of the increasing disturbances in the rush hour. On top of that the strict limits between metros and mainline railways tend to disappear [4]. In that case integrated approach will be used.

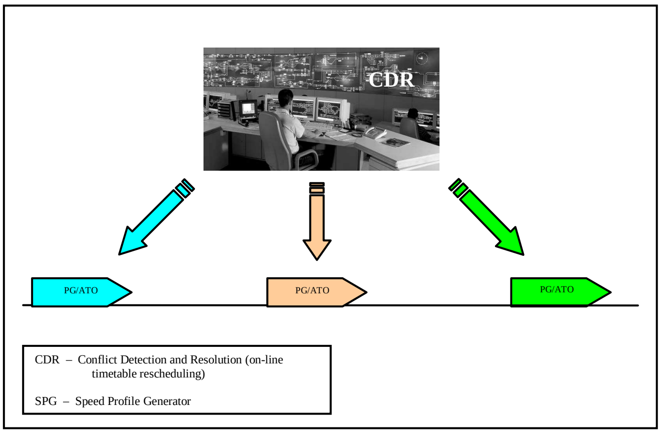

Figure 2 Integrated rail traffic optimisation approach

The primary task of ATO is to realize automatic train speed control to ensure trains operated as planned. The output depends on specific ATO automation level, either direct commands to the train system as full automation or the advisory information to the driver as semi-automation.

3. IMPACT OF AUTOMATIC TRAIN OPERATION ON THE TRAIN DRIVER WORKLOAD

The increase in traffic intensity and complexity of the railway system demands new methods for real-time traffic control. Considering the main problems of modern railway traffic, improvement in its efficiency in the first place can be achieved by improvement of execution reliability and stability of timetable [5]. Thus, the aim of the speed regulation task is to control the train traffic in order to realise the current plan as well as possible and to save energy at the same time, while considering the constraints given by the safety system and the operational procedures.

With the aim to successfully accomplish this task train drivers can be supported with train driving support systems usually called Driver Advice System (DAS). The use of these systems allows online response on timetable perturbations which can decrease efficiency of railway operations. This has a positive effect on the flexibility of train control process which can result in improvement of railway traffic management efficiency [6]. Beside that a very important advantage in use of these systems is an energy efficient train driving by their influence on trains speed profile. Namely, it is known that speed profile of the train plays an important role in its energy consumption and by that it affects on its running time which determines its driving strategy.

While driving the train the driver's primary goals are to:

- Maintain safety (safety duties take priority over all other duties)
- Maintain the schedule of the service (to ensure, as far as possible, that the train runs to time and any avoidable delay is prevented).
- Additional driving initiatives (improving energy efficiency of service) [7].

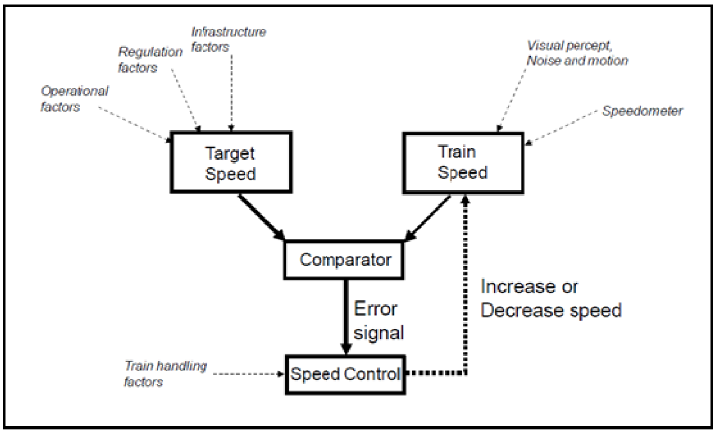

Figure 3 Cognitive Task Analysis of the Driver's Train Speed Control Activity [7]

The basic problem in usage of this system is how to present DAS information in the cab. The presentation of the information should aim to communicate the advisory information to the driver in a robust manner and in a way that minimises any disruption to the driver's other activities. It should not mask or otherwise compromise the

presentation of safety critical or higher priority information provided by other cab instruments, and should not itself be masked by the general environment of the train cab. There are three basic approaches for the presentation of DAS information to the train driver, visual, auditory and combined.
By visual approach the problem is that the train driver, in order to receive complex visually presented information, should direct central vision to the location of the instrument and during this period the driver is unable to acquire other visual information (other than through the less acute peripheral vision). Besides, train driving is a visually demanding activity and the driver must already monitor a number of different in-cab instruments (especially the speedometer, which must be regularly consulted), and monitor the track ahead for signs, signals and track obstructions. Additional visual activities, such as monitoring the DAS, are reducing the amount of time available for existing visual activities, and may disrupt performance of many of safety critical tasks. Furthermore, many of the existing auditory alerts and events in the train cab are safety critical – alarms and verbal communication with the dispatcher and some discrete auditory events may be missed or misinterpreted, reducing the robustness of the communication. Therefore, continuous tones will interfere with other auditory events and would not be acceptable to a driver. Furthermore, auditory information is restricted to a smaller range of coding levels that the human operator can distinguish and associate with different meanings. This limits the complexity of the information that can be communicated and makes the auditory presentation less robust. Speech may be regarded as a special case of auditory information as it can deliver complex information that the driver can readily understand. These speech displays are still presenting discrete information that may be subject to masking and may be missed or misunderstood by the train driver [7]. All this results in bad impact on the train driver ergonomics and requires the application of a new approach in train operation.
A possible solution for this problem represents automation of train operation processes. The main purposes of automatic train operation are to avoid the negative impact of human operations on traffic safety, to improve capacity of railway line and to enable energy efficient train operations. Thereby, the primary task of ATO is to realize automatic train speed control to ensure trains operated as planned. Hence primary purpose of ATO systems of grade GoA 2 is to help train driver to perform this task.

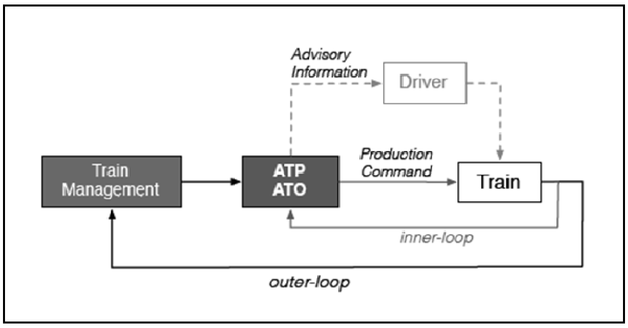

Figure 4 Comparison of DAS and ATO control loops [4]

This kind of ATO system relieves the driver of many functions and delivers high accuracy in producing services according to the timetable, thereby giving him more time to watch for abnormal conditions in such typically closed circumstances.

Comparing to DAS supported train operation appliance of the GoA 2 increases the amount of time available for other, more important, operational visual activities and improves performance of many safety critical tasks during the train operation.
In normal conditions i.e. if there is no disruption in traffic, this grade of ATO system performs all the functions of the train driver, except for door closing. The driver only needs to close the doors, and if the way is clear, the train will automatically proceed to the next station.

3. CONCLUSION

The main purposes of automatic train operation are to avoid the negative impact of human operations on traffic safety, to improve capacity of railway line and to enable energy efficient train operations. By the comparison of GoA2 ATO and conventional DAS supported train operations it can be concluded that appliance of this grade of automatic train operation could respectively improve train driver ergonomics by significantly reduce of the train driver workload. This can result in higher efficiency of railway operations by avoiding the negative impact of human operations on traffic safety, improving of railway line capacity and to enabling more energy efficient train operations.

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AIRCRAFT MAINTENANCE PERSONNEL`S WORK SPACE DESIGN

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Abstract:
Aircraft maintenance is defined as preservation, inspection, overhaul and repair of an aircraft, including replacement of parts. Maintenance tasks have to be done very carefully and accurately, therefore maintenance personnel`s work space has to be adequate for personnel to maintain aircraft. Regulation for aircraft maintenance states that work space shall not distract personnel from carrying out maintenance inspection tasks. This paper deals with investigation of physical dimensions of work space during small training aircraft maintenance, according criteria contained in MIL- STD1472, which analyze and evaluate the human engineering aspects of equipment design. Specific areas are analyzed including space required for standing and seated operations; standard and special console design; compartments, stairs, ladders and ramps; entrance and exit through doors, etc. Results of measurements will be presented and discussed.

1. INTRODUCTION

Humans are an integral part of aircraft operation and maintenance. Environmental factors such as temperature, vibration, pressure, humidity, noise, time of day, amount of light and G-forces can affect human working performance and maintenance tasks. Maintenance tasks have to be done very carefully and accurately, therefore maintenance personnel`s work space has to be adequate for personnel to maintain aircraft. EASA (European Aviation Safety Agency) regulations for aircraft maintenance named PART 145 PART 145 [1] defined working environment conditions such as temperature, lighting, noise, ventilation, etc., but there is no precise definition and dimensions of maintenance personnel's work space. MIL-STD1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities provided quantitative requirements and a detailed design of work space [2].

2. INTERNATIONAL REGULATIONS RELATED TO WORKSPACE OF MAINTENANCE PERSONNEL

2.1. EASA PART 145

EASA regulations for aircraft maintenance named PART 145 (European Aviation Safety Agency - PART 145[1] defined working environment conditions including aircraft hangars, component workshops and office accommodation. The working environment must be such that the effectiveness of personnel is not impaired. PART145 defined that :

1. Temperature must be maintained such that personnel can carry out required tasks without undue discomfort.
2. Lighting is such as to ensure each inspection and maintenance task can be carried out in an effective manner.
3. Noise shall not distract personnel from carrying out inspection tasks. Where it is impractical to control the noise source the maintenance personnel have to be provided with necessary equipment to reduce excessive noise during maintenance. This is the most important condition connected with this article.

Where a particular maintenance task requires the application of specific environmental conditions different to the foregoing, then such conditions are observed. Specific conditions are identified in the maintenance data. The working environment for line maintenance is such that the particular maintenance or inspection task can be carried out without undue distraction. Therefore where the working environment deteriorates to an unacceptable level in respect of temperature, moisture, hail, ice, snow, wind, light, dust or other airborne contamination, the particular maintenance or inspection tasks must be suspended until satisfactory conditions are re-established.

2.2. MIL-STD 1472

MIL-STD 1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, provide principles and methodology that are used to integrate the human into the design of equipment to achieve mission success [2].
The goal of this integration is to optimize effectiveness, efficiency, safety and reliability of the operation and maintenance of equipment. The quantitative nature of criteria contained in MIL- STD1472 aids in analyzing and evaluating the human engineering aspects of equipment design.
In a document DOD-HDBK 743, anthropometry of the U.S. Military Personnel are contained data obtained by actual measurement of representative population samples of military personnel. As an example, DOD-HDBK 743, shows that only 5% of the persons (male and female) were less that 60 in tall (1.52m), and that 95% were 73.1 in tall (1.86m), or less. Therefore, for human engineering purposes, the design must be able to accommodate personnel who are between 60 and 73.1 in tall [2].
Physical dimensions of the work space must be adequate for personnel to operate and maintain equipment. Specific areas analyzed include space required for standing and seated operations; standard and special console design; crew compartments, stairs, ladders and ramps; entrance and exit through doors and hatches and surface colors. The key to optimizing work space is to design the space around the person, rather than designing the space and then putting the person in it. By designing around the person, costly redesign efforts resulting from insufficient work space can be avoided.

3. DESCRIPTION OF AIRCRAFT MAINTENANCE FACILITY

The flight training organization as a part of Faculty of Transport and Traffic Sciences, University of Zagreb, named Croatian Aviation Training Center (or in Croatian *Hrvatsko zrakoplovno nastavno središte* – HZNS further in the paper) uses its own aircraft maintenance facility which is located within the Lučko Airport, 11km southwest of Zagreb. The facility consists of a maintenance hangar and additional facilities. The total ground floor area of the aircraft maintenance facility is 1092.4 m^2, Fig. 1.

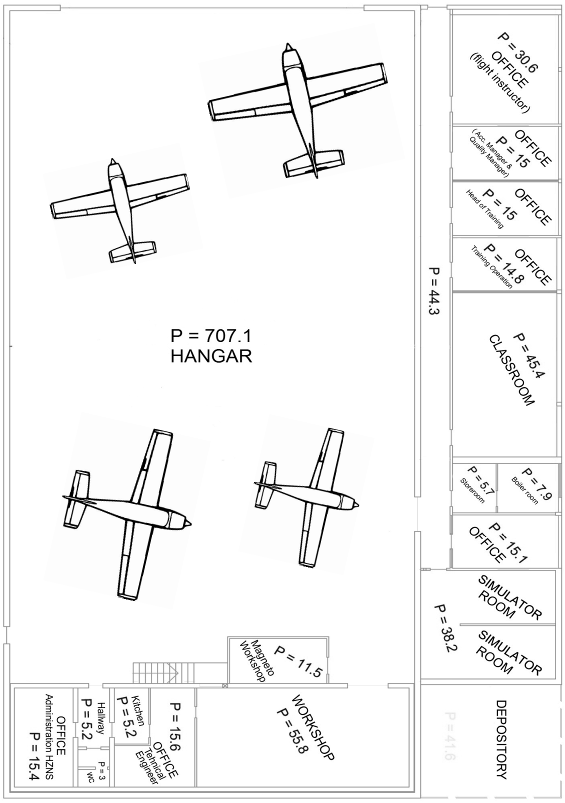


Fig. 1. Aircraft maintenance facility [3]

The hangar is used mostly for all the necessary tasks, such as maintenance, repair, assembly and storage of aircraft. Offices are used by HZNS employees, and classrooms and simulators are used mostly by training students. The aircraft maintenance facility is used for base and line maintenance of small training aircraft such as Cessna 172, Piper 34 and Diamond Katana DV20. Line maintenance includes minor repairs and modifications which do not require extensive disassembly and can be accomplished by simple means. Base maintenance includes major scheduled maintenance (or checks) which are described in the maintenance program. Training aircraft is maintained after every 50 flying hours. Duration of maintenance work after 50 flying hours is 8 to 10 man hours, while maintenance after 100 flying hours generally takes 16 to 20 man hours.

An aircraft during typical base maintenance is presented on Fig. 2.

Fig. 2. Aircraft on maintenance in the HZNS facility (*courtesy of HZNS hangar supervisor Damir Donković, 2011*.)

The maintenance facility is well illuminated by natural and artificial lighting. Offices and hangar facilities are heated by a central heating system. The maintenance facility is provided with all necessary plumbing, electrical, telephone, fax, internet and other utilities required for normal operation of HZNS. The paper [4] presents that the noise levels in all areas of the maintenance facility were satisfactory regardless of the level of noise that is generated on the aircraft during its maintenance. In this paper, maintenance personnel body dimensions and work space dimensions during aircraft base maintenance regarding HZNS technicians are presented.

5. MEASURED ANTHROPOMETRY AND MAINENANCE PERSONNEL WORK SPACE DIMENSIONS

There are four technicians in HZNS that perform maintenance on aircraft in the fleet. Standard anthropometry according to MIL- STD1472 is used as a form for measuring, figure 3.

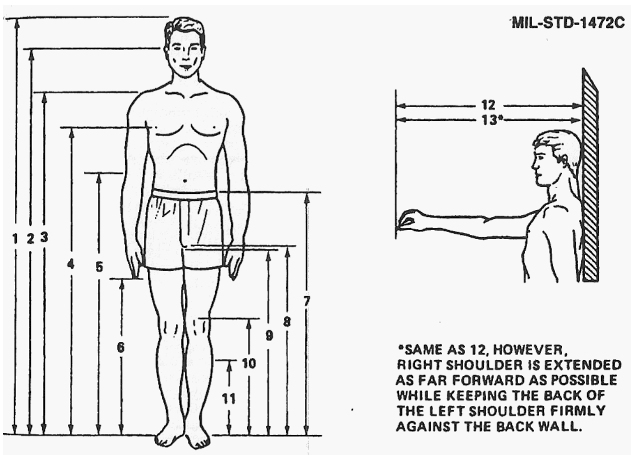


Fig. 3. Standing body dimensions [2]

Standing body dimensions for HZNS technicians in centimeters are shown in a Table 1.

Table 1. Standing body dimensions for HZNS technicians in cm

		Tech 1	Tech 2	Tech 3	Tech 4
1	Stature	171	173	182	165
2	Eye height (Standing)	158	157	173	155
3	Shoulder (acromiale) height	139	142	153	138
4	Chest (nipple) height	124	125	136	123
5	Elbow (radiale) height	103	105	118	106
6	Fingertip (Dactylion) height	61	68	69	65
7	Waist height	105	106	107	96
8	Crotch height	79	77	83	77
9	Gluteal furrow height	78	76	82	76
10	Kneecap height	54	54	56	57
11	Calf height	37	37	47	42
12	Functional reach	82	83	84	70
13	Functional reach, extended	93	97	100	82

As seen in Table 1, all technicians are between 165 and 182 cm tall. Therefore, for human engineering purposes, the physical dimensions of work space must be adequate for personnel to operate and maintain the aircraft and each maintenance task have to be easy to perform.
Measurement of workspace has been conducted during maintenance tasks on a single-piston engine aircraft Cessna 172, Fig. 4. The Cessna 172 is the most frequently used single-piston engine training aircraft, often used in flight training organization fleets.

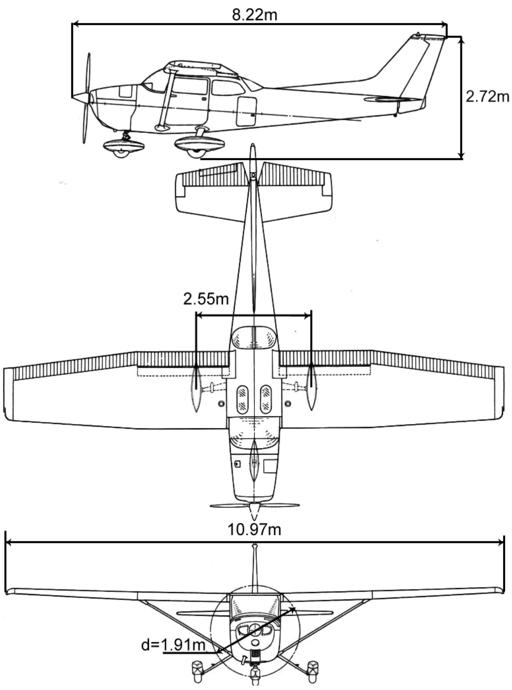
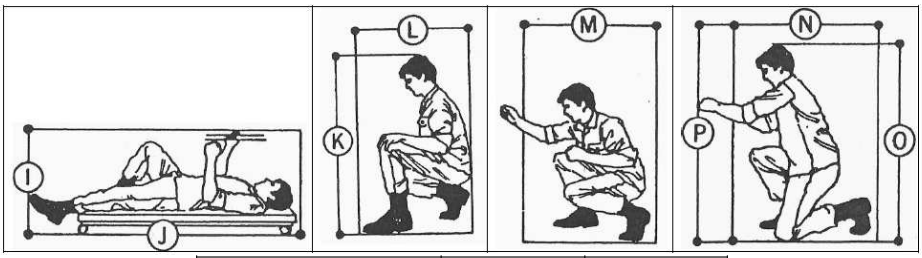


Fig. 4. Cessna 172 aircraft [5]

Figure 5 presents typical body positions during maintenance and preferred work space dimensions according to MIL-HDBK-759A [2].



	minimum	preferred
I. height	51	61
J. lenght	186	191
K. height	122	-
L. width	68.5	91
M. width	66	102
N. width	106	122
O. height	142	-
P. opt. work point	-	68.5

Figure 5. Body positions during maintenance and work space dimensions

6. CONCLUSION

Regarding the dimensions of maintenance personnel and preferred dimensions of work space during maintenance of C172, it can be seen that all dimensions of the maintenance work space outside the aircraft are satisfactory for these maintenance personnel. For technician no. 3. in table 1, it is very difficult to maintain the interior, the pilot cabin, and under the aircraft, due to his dimensions. For these maintenance tasks, work has to be done by other available personnel.

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ERGONOMIC AND CUSTOMIZED FOOT ORTHOSES MANUFACTURED WITH 3D PRINTERS

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Abstract
A study was undertaken in order to manufacture an ergonomic and customized foot orthotic insole using 3D scanning techniques and 3D printer. The shape of the customized foot insole was determined using 3D scanning technology, 3D reconstruction of foot and 3D image processing in order to design the foot insole and to avoid the abnormal position and motion of foot during gait. The foot orthoses obtained by 3D scanning are expected to improve gait comfort and effort, improve foot-loading characteristics and reduce fabrication time and cost compared to manual customized foot insole fabrication techniques. The paper describes the 3D scanning method approached, processing phases, and manufacturing of a customized foot insole. The correct design and fabrication of customized foot insole determine patient comfort, acceptance, and restoration of normal foot functions.

Keywords: *3D scanning technology, 3D image processing, 3D printer*

1. INTRODUCTION

The manual methods for creating customized foot orthoses have many drawbacks including the time-consuming and imprecise process which may affect the comfort of prostheses or ortheses. The use of the new computer aided technologies is often faster and decreases the amount of practitioner time required for conception and manufacturing of ortheses.
Prostheses and ortheses manufacturing with computer aided technologies may include next main phases in connection with image processing and fabrication [1,2,3]:

- 3D data acquisition of anatomic surface geometry;
- 3D digital model reconstruction;
- Fabrication using Rapid Prototyping.

I.1 Scanning

A lot of different techniques can be approached with 3D scanning. Each technique has its own advantages, limitations and costs. Most known 3D scanning techniques use: Coordinate Measuring Machines (CMM); 3D ultrasound devices; CT-Scanning devices; MRI - Scanning devices, Laser scanners; Scanners with structured light; Photogrammetric scanners, Radio frequency (millimeter wave) devices. There are a lot of modern commercial solutions for anatomic surface scanning without penetration under the skin:

- Laser scanners;
- Structured light scanners;
- Video cameras and markers;
- Stereo photogrammetry;

I.2 3D model reconstruction;

Computer programs (known as scanning software) are used in scanning techniques to perform 3D digital construction. The main goals of the 3D scanning and reconstruction software are to import the photos from the scanning device, to eliminate the artifacts and to transform the data into 3D digital model.

I.3 Fabrication by Rapid Prototyping

CAD/CAM and Rapid Prototyping are tools for the rapid manufacturing of customized prostheses and orthoses. 3D printing is a low-cost alternative to traditional rapid prototyping for fabricating customized components. 3D printing is a process of making 3D solid components from digital models using additive techniques and creating by laying successive layers of material.

A foot orthosis is a functional device designed to correct and optimize foot functions and is commercially available under the name “foot insole”. Foot orthoses can help a lot of specific foot conditions [3,4]: Underpronation, Overpronation, Ankle Sprains, Flat Feet, Arch Pain etc. The paper describes the work phases used from data acquisition, to image processing and fabrication of a customized foot insole. The ergonomic characteristics of the used devices and of the work phases of fabrication are revealed.

2. TECHNICAL REQUIREMENTS

The most important aspects of a foot orthosis are the orthosis design and the quality of the insole material. The foot insole is the interface between the human foot and the shoe. The design and fit of insole determine patient acceptance, comfort and energy expenditure. The manual method for designing insoles requires a skilled prosthetist and time consuming phases [4, 5] as in Figure 1. Final alignment of the prosthesis was performed using visual gait analysis and patient feedback.

Figure 1: Traditional method for forming foot insoles

Manual fabrication has a direct influence in the quality and in the operational costs. The prosthesis is geometrically irregular obligating the prosthetist to make adjustments. These adjustments increase substantially the fabrication time and costs and sometimes cause traumas to the patient.
A structured light scanner was used to develop a 3D digital image of the foot of a patient. These 3D scanners project patterns of light on the foot of a patient using a video projector and the cameras record the distorted pattern. They usually use several pairs of cameras, with the images sent to software that calculates the binocular disparities between corresponding points in each pair of images. The 3D geometry is inferred using stereoscopy. The images are sent to software that calculates the binocular disparities between corresponding points in each pair of images and reconstructs the 3D model.
The fabrication of foot orthosis was performed with a cost effective 3D printer working with fibers.

3. RESULTS

In the first step, data acquisition is accomplished using noncontact 3D scanner (Artec MH) with structured light (Figure 2). The scanner projects a structured light onto the foot of a patient. The Artec MH 3D Scanners use video camera technology with structured light and capture a multitude of frames.

Figure 2. The Artec MH scanner

The frames are combined automatically (in the scanner software) into a single 3D mesh, in the 3D reconstruction step. The mesh represents the 3D surface model of the foot (Figure 3 left).

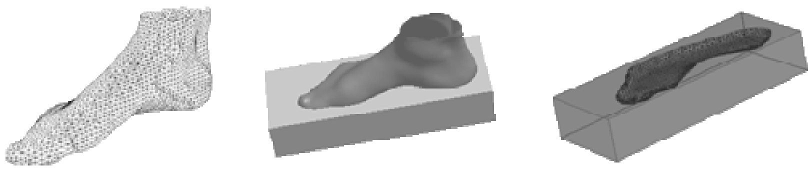

Figure 3. The 3D model of the foot (left), foot imprint process (center) and final imprint (right)

In order to obtain the foot imprint, the 3D surface model of the foot (Figure 3 left) was combined with the 3D model of a surface box. Figure 3 (center) shows the 3D foot model overlapped with the model of a box. The 3D foot model was then subtracted (Boolean operation) from the 3D box model. After the foot subtraction, the 3D shape of the foot was imprinted in the box model (Figure 3 right). Boolean operations with 3D surface models may be performed with 3D graphic software like Studio Max, Blender (free software), AutoCAD (special add on) etc. In order to manufacture a foot insole which properly fits a foot of a customer, the foot angles of the customer's foot (Figure 4) are measured.

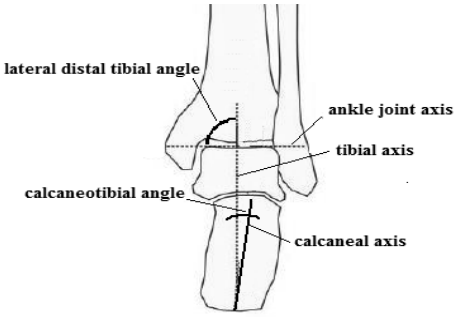

Figure 4. Foot angles and axes (view from rear)

The foot angles are of the most critical information in custom-made manufacturing of foot insoles. The angles of inclination of a human foot are measured by an orthopedist, physiotherapist, artificial-limb orthotist, shoe fitter etc. while the foot is being examined by touch. Modern measurement methods include different technologies based on image recording.
The orthotic technician has to include in the foot insole model all dimensions, angles (as in Figure 4), adjustments and details as prescribed by the podiatrist in order to restore faulty foot function.
Also, technician has to fit the foot insole and the shape or the last (straight, inflared or outflared) used by shoemakers in the manufacture of shoes. Final shape of foot insole has to be saved in STL format. Final modifications can be done with different editing functions in any 3D modeling software.
In the final step, the 3D model of the foot insole was transferred to the software of a 3D printer, BFB 3D type (Figure 5) in order to convert CAD model to 3D print data.
The BFB 3D Touch printer has multi-material free forming capabilities, 3D printing volume of 275x275x210mm³, and 125µm layer thickness. This printer is one of the most affordable 3D printers in its category and is on the market.

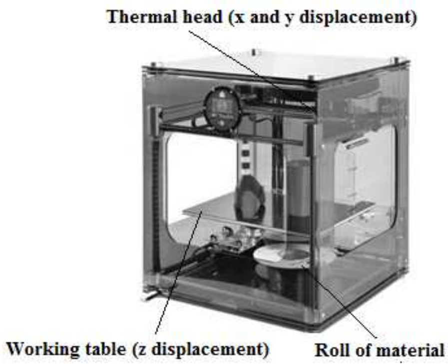

Figure 5. The BfB 3D Touch printer

In this approach, the printer used melting or softening material (acrylonitrile butadiene styrene or ABS) to produce the layers of the object. Figure 6 shows the 3D foot insole created by the 3D printer.

Figure 6. The 3D printed foot insole

New materials for 3D printers recently appeared with better mechanical characteristics and they will be used in a future approach.

3. DISCUSSION

Main ergonomic characteristics of proposed foot orthosis fabrication are:

- The use of modern technologies like 3D structured light scanners and 3D printers;
- The use of the one of the most cost effective scanning device (about 10,000-12,000 Euros)
- The use of noninvasive radiations during 3D scanning;
- Noncontact technique during scanning;
- Rapid scanning procedure (3-5 minutes);
- Relatively rapid 3D reconstruction (10-15 minutes);
- High precision in the 3D reconstruction of anatomic surfaces (about 1 mm errors);
- Very easy to modify 3D models;
- The use of the one of the most cost effective 3D printers (about 3,000 Euros);
- Work characteristics: speed and repeatability;
- Customized orthoses determine patient comfort and energy expenditure.

Proposed orthoses 3D modeling and fabrication have some disadvantages:

- Requires skills in the use of some 3D reconstruction and CAD or computer graphics software;
- Some materials used in the 3D printing are expensive.

4. CONCLUSION

The study showed the feasibility of the use of 3D scanners with structured light in the scanning of anatomic surfaces and of the 3D printers in the fabrication of foot orthosis. Proposed scanning and fabrication of foot orthoses use ergonomic and cost effective solutions for computer aided fabrication. These solutions may help the medical staff to fabricate customized orthosis or different pieces for orthosis and prosthesis with relatively cost effective equipment.
Most important advantages of the use of 3D scanning and Rapid Prototyping technologies are: the use of digital models, capture speed, repeatability and material uniformity.

Prices for optical scanners, CAD software, and 3D printers range widely and have gradually come down over time.
The design and fit of customized orthosis determine patient acceptance [6], comfort and energy expenditure.

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PSYCHO-ACOUSTICAL ERGONOMICS IN A LIGHT AIRCRAFT INTERIOR

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Abstract:

Noise levels in light aircraft interiors, particularly during take-off and climb phases of flight, often exceed acceptable values. Communication between a pilot, copilot and an Air Traffic Control (ATC) staff, as well as among passengers, is severe disrupted in such noisy environments. Based on noise measurements in a typical representative of a light aircraft, its spectral content and corresponding noise levels, parameters relevant to speech intelligibility are calculated. Speech Interference Level (SIL), Articulation Index (AI) and maximum communication distances are determined for various flight phases and vocal efforts.

1. INTRODUCTION

High levels of noise considerably downgrade the quality of speech communication, confirming this setback as a serious flight safety issue, [1]. Communication between pilot, copilot and ATC staff is often downgraded by the masking effects of background noise, [1, 2]. Beside communication difficulties, high noise levels increase stress and anxiety levels that influence psychomotor performance and can increase numerous errors in tasks that require vigilance, concentration, calculations and timing judgments, [3]. Interior noise level depends a lot on the aircraft and its powerplant, i.e. engine and propeller, but on average, the values are 80 dBA and above, up to 110 dBA in case of some piston aircraft (e.g. Cessna 210). Prolonged exposure to the noise exceeding 85 dBA is related to hearing damage risk, [2]. For certain phases of flight (e.g. takeoff) most general aviation aircraft do not provide adequate acoustical ergonomics.

2. THE SOURCES OF AIRCRAFT INTERIOR NOISE

Aircraft noise contains the following main components: engine noise (with engine compartment elements such as pumps and alternator, and an exhaust system), propeller noise, airframe noise and structure borne noise (as a particular kind of airframe noise),

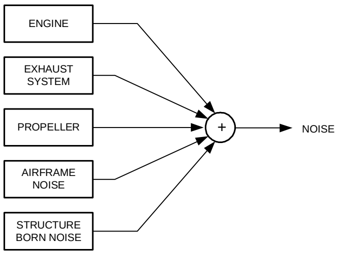

Figure 1: Aircraft noise sources

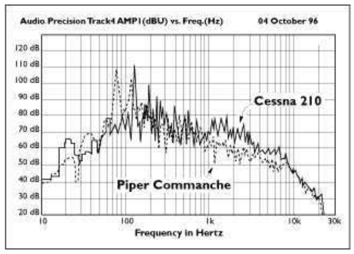

Figure 2: Noise spectrum (adopted from [6])

[4, 5]. Aircraft interior noise is combination of all mentioned components that, with various degrees, penetrate into the aircraft cabin as shown in Fig. 1. At low RPM interior noise is dominated by engine and exhaust noise. At higher RPM, due to propeller tip speed, the influence of propeller noise becomes considerable. In flight, aerodynamic noise becomes more significant as progressive speed rises. Noise spectrum of two common light aircraft is shown in Fig. 2, [6].

3. SPEECH COMMUNICATION UNDER NOISY CONDITIONS

Human speech has a fundamental frequency (pitch) in the range of 100-400 Hz (about 100 Hz for men and 200 Hz for women). Spectral peaks of the short term speech spectrum are called formants and are determined by the resonant characteristics of the vocal tract. Various vowel sounds and transitions among them are created by these formants. Normal conversation takes place in the frequency range from 500 to 3,000 Hz. Consonant sounds are impulsive and/or noisy, and occur in the frequency range of 2 kHz to about 9 kHz. Speech communication is often degraded by the masking effect of background noise and changes in vocal effort are necessary for various background noise levels. Auditory masking is intrusion of unwanted sounds that inevitably interfere with the speech signal. Masking effect is illustrated in spectral domain in Fig. 3-5. When the low-frequency noise is louder than the speech signal it effectively masks speech. At high sound pressure levels such noise effectively masks both vowels and consonants. High-frequency noise masks only the consonants, and its masking effectiveness decreases as the noise gets louder.
Noise exposure levels in a light aircraft afford less than desired intelligibility (<95%). The effects of cabin noise to speech communication could be compensated to some extent by various vocal efforts and by reducing the distance between the talker and listener. Long term spectrum of speech under various vocal efforts is shown in Fig. 6, [7] and corresponding sound levels in Table 1.

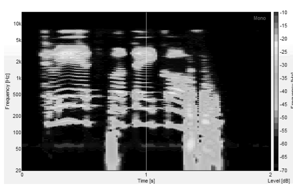

Figure 3: Clean speech

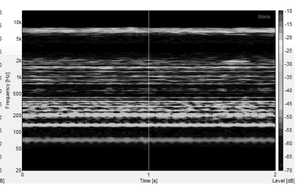

Figure 4: Cabin noise

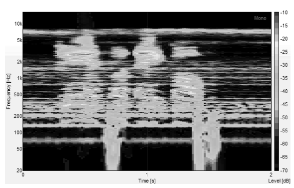

Figure 5: Speech + noise

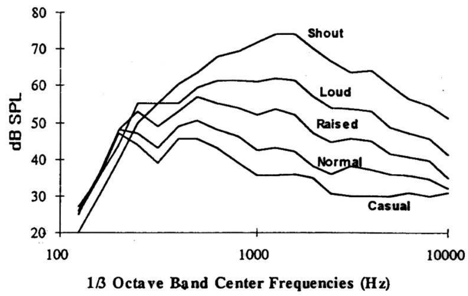

Figure 6: Long term spectra of voice under various vocal efforts (adopted from [7])

Table 1: Speech levels at various vocal efforts dBA

Voice	Average level dB/dBA
Casual	52.0/42.0
Normal	57.0/47.0 (private speech)
Raised	64.0/57.0
Loud	73.0/62.0
Shout	85.0/72.0

4. THE MEASURES OF SPEECH INTELIGIBILITY

Several noise metrics have evolved for assessing the influence of noise on speech, [2].

4.1 Speech Interference Level (SIL)

Speech Interference Level is defined as the arithmetic average of the sound pressure levels at 500, 1000, 2000 and 4000 Hz octave bands, [1, 2].

$$SIL = \frac{L_{p500} + L_{p1000} + L_{p2000} + L_{p4000}}{4} \quad \textbf{(1)}$$

A-weighted sound level L_{pa} correlate well with SIL for most sounds associated with aviation, [2]. Acceptable results of SIL values may be derived from A-weighted noise levels by using the following expression, [1]:

$$SIL = L_{pA} - 10 \quad \textbf{(2)}$$

4.3 Articulation Index (AI)

Articulation Index is the value, between zero and 1.0, which describes the masking of speech by background noise; this value is found by evaluating the signal to noise ratio in specific frequency bands, [2]. A quantitative measure of speech intelligibility is the percentage of speech items correctly perceived and recorded.

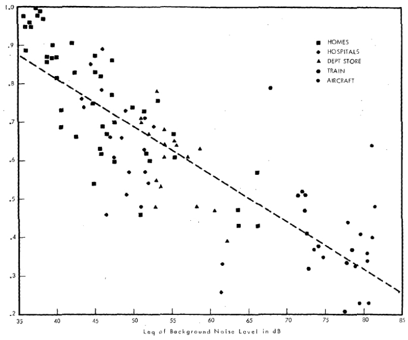

Figure 7: AI for conversations in various environments, adopted from [4]

An AI of 100% means that all speech can be understood, 0% means that no speech can be understood. An AI < 0,05 is representative of very poor speech intelligibility, and an AI > 0.80 represents good speech intelligibility. Articulation Index can be calculated from the 1/3 octave band levels between 200 Hz and 6300 Hz centre frequencies, [8]. It can also be approximately determined from graph shown in Fig. 7. Speech intelligibility should not be confused with speech quality, since speech intelligibility is related to the amount of speech items that are recognized correctly while speech quality is related to the quality of a reproduced speech signal with respect to the amount of audible distortions.

5. THE EXPERIMENT

Measurements were performed in Cessna 172N, a four-passenger, single piston-engine propeller driven aircraft. Noise signals were recorded with 40 kHz sampling frequency in 16-bit resolution, mono, using the ECM800 Behringer microphone, M-AUDIO Exterior Sound Card C400 and laptop computer. Noise levels were measured using Nor140 Norsonic Sound Analyzer. A-level weighting is used for measurements due to high correlation with people's subjective judgment of the loudness, [2]. Measurement position was between the front seats at the head level, according to ISO 5129:2001 standard.

6. THE RESULTS

Noise measurements were performed on a one-hour route flight. Flight phases and their corresponding noise levels are shown in Table 2. Speech intelligibility measures are determined for each flight phase and presented in Table 3, with duplicated flight phases being omitted in the table. An articulation index of 0.3 was identified as adequate for acceptable communication, [5], which is, in this case, found equivalent to SIL 72, or 82 dBA.

Table 2: Flight phases and corresponding noise levels

Phase	Noise level dBA (+/- 0.5dBA)
taxiing	78.9
hold	80.2
taxiing	81.3
take off run	93.9
take off	91.1
climb	88.9
cruise	83.1
descend	74.0
landing	76.0
roll off	79.3
taxiing	78.7

Table 3: Speech intelligibility metrics

Flight phase	SIL	AI
taxiing	68.9	0.33
hold	70.2	0.32
take off run	83.9	0,15
take off	81.1	0.17
climb	78.9	0.17
cruise	73.1	0.28
descend	64.0	0.38
landing	66.0	0.36
roll off	68.7	0.34

The distance between the talker and listener (i.e. communication distance) is important when the conversation takes place. Speech levels are reduced typically by 6 dB for each distance doubling between the talker and listener, [7]. Distance for various values of SIL is shown in Fig. 8, and values for various flight phases (extracted from the graph) in Table 4.

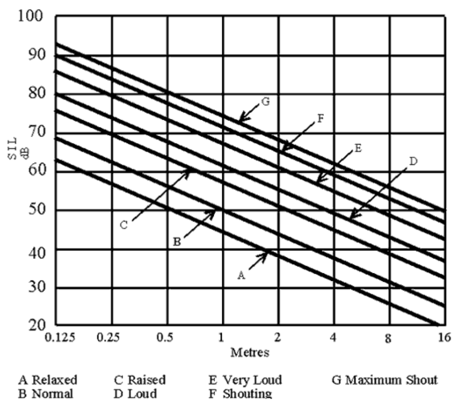

Figure 8: Communication distance for various values of SIL (adopted from [9])

Table 4: Communication distance for normal and loud voice

Flight phase	normal	loud
taxing	0.13	0,48
holding	-	0.42
take off run	-	-
take off	-	0.13
climb	-	0.17
cruise	-	0.33
descend	0.23	0.90
landing	0.19	0.70
roll off	0.12	0.47

7. CONCLUSION

Cabin noise in a light aircraft significantly interferes with speech intelligibility, particularly during high power settings, e.g. take-off and climb phase of a flight. At such noise levels, communication between pilot, copilot and ATC staff should be performed using communication headphones, preferably of noise canceling type. Despite the fact that an articulation index of 0.3 was identified as adequate for acceptable communication, the background noise level of less than 70 dBA should be a goal for speech communication in airplane (as in modern cars, for instance). Additional soundproofing may be required to achieve such sound levels, and may enable more comfortable travel, at least during cruise phase of a flight. It would also provide further noise reduction essential for hearing protection of pilots and passengers.

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A COMPARISON OF SPINAL ANGLES WHEN PERFORMING A TYPING TASK ON A LAPTOP AND DESKTOP IN HEALTHY SUBJECTS - A PRELIMINARY STUDY

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Abstract
Few reports have effectively evaluated different postural sitting positions at computer workstations and compared laptop and desktop computer usage, despite such research being relevant to rehabilitation; the provision of preventive guidelines, and postural re-education. Therefore, the purpose of this research was to discover whether there is a difference in four postural angles (neck angle, head tilt, lumbar angle and pelvic tilt) with regard to their effect on the cervical and lumbopelvic segments, whilst performing a typing task on a laptop and a desktop computer. Twenty healthy participants were asked to perform a five-minute typing task on each computer, while sitting at a standardized workstation. Neck angle, head tilt, lumbar angle and pelvic tilt were identified using reflective markers and coloured adhesive papers on bony landmarks, and the participants were photographed using a digital camera. The results were then analysed using MATLAB software. Paired t-tests were used to compare the differences within the angles' means. Statistically significant differences for all angles were found when comparing sitting at the desktop computer to sitting at the laptop. Neck angle ($p < 0.0005$); forward head tilt ($p < 0.0005$), and lumbar lordosis ($p = 0.018$) when using the laptop were significantly higher. The greatest posterior pelvic tilt was associated with the desktop ($p = 0.018$). Therefore, a desktop appears to be more appropriate for the cervical and lumbar regions; on the contrary, using a laptop may be more suitable for pelvic tilt.

Keywords: *laptop; desktop computer; spinal angles; neck flexion, head tilt, lumbar, pelvic tilt; posture; photogrammetry, typing task and office seating.*

1. INTRODUCTION

Computer usage at both home and work has now become a regular aspect of everyday life for people around the world. Not only is there an increase in use generally, but different designs have emerged in an attempt to increase portability. The popularity of laptops is because of the ease of setting up at any place, and their manageable weight and energy saving properties [1]. However, despite the vast developments that have taken place regarding desktop and laptop usage over the past few decades, there are still adverse effects which should not be ignored, including the possible impact on posture.

The rate of work-related musculoskeletal symptoms (MSS) and disorders (MSD) have accelerated to yet higher levels, particularly for the spine [2; 3; 4]. Since the 1980s, MSD/MSS related to computer use have been recognised as a common cause of sick leave; efficiency loss, and reported work related sickness in westernised societies [5; 6; 7; 8; 9; 10]. Over the next 20 years, MSDs are expected to be the most widespread of the major diseases among UK employees [11]. The risk of MSD/MSS to the users of different computers has often been reported as being associated with ergonomic and postural issues [12; 13].

The angle of a particular screen plays a role in determining ideal posture during laptop or desktop use [14]. Consequently, it is important to quantify the biomechanical principles involved [15; 16; 17]. Facing a visual display unit (VDU) involves three main features: looking down on a VDU, using it straight on or looking up. Looking down, as seen in laptops, might increase lower cervical flexion, causing increased demand on neck extensor muscles as they support the head [14; 18], thus causing neck problems [19; 20]. For an extended period, the computer user with a low monitor, tends to lean their head forward (turtle neck posture). Such posture may lead to chronic neck pain, influence thoracic vertebrae and the shoulder blades, and cause general imbalance in the musculoskeletal structure [21; 22; 23; 17; 1].

It has been reported that muscle fatigue is linked to the use of a higher VDU, particularly in both trapezius and cervical erector spinae [24; 25]; while placing the VDU at eye level or just below 5°, investigators found a reasonably consistent relationship between muscle activity and NA and HT [26]. Therefore, emphasis on the cervical region (upper and lower) should be taken into account, as this may influence the head position, such as forward head posture [27; 28; 29], thereby compromising the resting spinal column (double-S shape) [30; 31; 32] and the whole body [33]. The lumber and pelvic areas also appear to be key factors during sitting [30; 32]. There are various methods available for analysing posture, such as radiographs, sensors, subjective measures and digital photogrammetry [34; 35; 36; 37], although computerised photogrammetry analysis is considered one of the most widely used methods for body posture evaluation [38]. Two-dimensional digital image analysis using Matrix Laboratory (MATLAB) software has been used due to its longevity, the cost effectiveness, obtaining efficient results free from subjective bias as well as reliable [39]. Consequently, to examine the differences between users' posture during laptop and desktop use, it is imperative to evaluate posture in a valid and reliable way. Previous studies have overlooked some central aspects, such as examining the main segments simultaneously; starting with the head, through to the neck and lumbar and then the pelvis [40; 41; 42; 43], meaning that more research is required to evaluate them altogether during computer work.

The aim here is to contribute towards the existing body of evidence by considering two main criteria: firstly, ergonomic principles in order to customise workstations according to the user's anthropometry; secondly, the measuring of neck angle (NA), head tilt (HT), lumbar angle (LA) and pelvic tilt (PT) simultaneously, rather than assessing them separately. The discovery of statistically significant differences in the segment angles, during laptop and desktop usage, has implications for the use of such computers and will contribute towards reducing the risk of MSD/MSS.

Therefore, this preliminary study compares the sitting posture between a laptop and desktop during a typing task. The comparison is based on assessing the following segment angles: NA, HT, LA and PT. The results may inform a larger study which may be clinically useful for providing instructions and guiding postural re-education, as well as muscle strengthening programmes.

2. METHOD

A same subject crossover design in single session was been used with randomisation of the order of typing tasks on two computers. Healthy subjects with a normal spine were chosen to take part; therefore, congenital abnormalities such as scoliosis or incidences of MSDs, for instance low back pain or neck pain, were excluded [44; 45]. A convenience sample of twenty participants- healthy postgraduate university students- was recruited. The study was approved by the Ethics Committee of Cardiff University School of Healthcare Studies. Participants read the information sheets and gave informed consent.

Participants were photographed as they performed typing tasks using a single digital camera (Sony Cyber-shot DSC-P93, Japan) with a 5.1 Megapixel Super HAD CCD type, 14.0-Bit DXP digital photography processing, and 3x optical zoom lens along with a tripod with two in-built spirit levels so as to maintain the perpendicular position of the camera and eliminate error [46].

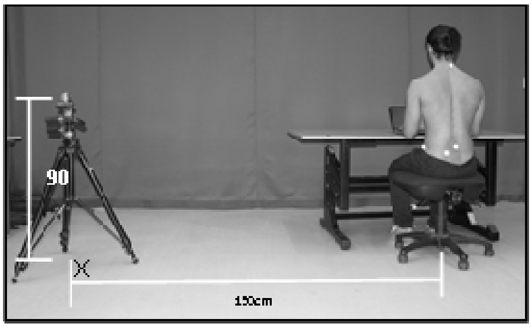

Figure 1: Work Station Set-Up and Position of the Camera

The computers were chosen for their popularity: a desktop (Sony ®, Model: PCV-7776) a laptop (HP Pavilion dv3). The tasks were performed on a standard adjustable hydraulic office table (Bambach, ergostyle ®), with back and arm rests removed to facilitate recognising the markers (Figure 1).

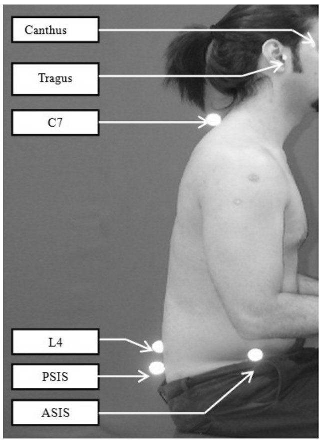

Figure 2: Identification of Reflective Markers over Anatomical Landmarks C7, L4, PSIS and ASIS and paper markers on Canthus and Tragus

An adjustable monitor stand for the desktop was used to match the participant's eye level.

Female participants wore tight fitting vests, while male participants were asked to take off their shirts. Reflective markers (2.5 cm diameter) were positioned using double sided adhesive tape on the skin of the following anatomical landmarks: the 7th cervical vertebra (C7); the 4th Lumbar vertebra (L4), and the lift Anterior Superior Iliac Spine (ASIS) and Posterior Superior Iliac Spine (PSIS) (Figure 2), whilst the participant was in a sitting position on the test chair. The lift tragus and canthus were covered by small sticky paper dots (8 mm diameter). To minimise error, the same researcher placed the markers, and they were not removed during the whole study to ensure further accuracy, and were checked in the second trial. The orders in which participants used the laptop and desktop were randomly chosen, and participants were blinded as to when both sittings were recorded [47].

The participants were given instructions to sit with their knees, hips and elbows at 90° (Figure 1) [48], using the goniometer, with the height of the chair and desk adjusted accordingly and feet placed shoulder width distance [49]. The top of the vertical desktop's VDU was at eye level [26], and viewing distance estimated according to an arm's length; the laptop's angle was between 119°-126° [50]. Subjects' forearms were supported by the table instead of the wrist [51]. There was a two minute rest between each session and participants walked around the laboratory.

To avoid changes in the movement of the neck and head, two windows of Microsoft Word 2010 were divided equally into vertical parallel pages on the VDU. The typing tasks included two different word documents to avoid the learning effect [52]. Photographic data on typing performance was analysed using a bespoke programme within MATLAB 2009b software by Dr Van Deursen of Cardiff University.

Normality and homogeneity were confirmed using histograms with an overlying normal distribution curve besides Q-Q. As the sample size was < 50, the Shapiro Wilk test was run for each set of angles to approve the normality and avoid misinterpretation. Dependent t-tests were used to compare differences within the angles' means. Significance level was set at a level of 0.05.

3. RESULTS

The recruited sample consisted of 15 males and 5 females. The demographic data presented in Table 1.

Table 1: Demographic characteristics of participants

	Male (n=15)			Female (n=5)			Overall (n=20)		
	Mean	SD*	Range	Mean	SD*	Range	Mean	SD*	Range
Age (years)	30.1	±2.5	25-34	28.4	±3.3	26-35	29.7	±2.8	25-35
Height (cm)	170.45	±7.72	151-182	166.9	±10.33	157-185	169.58	±8.59	185.51
Weight (Kg)	76.32	±11.28	60-95.4	62.1	±7.35	49.4- 72.1	72.76	±12.12	95.4-49.4
Forearm length (cm)	46.73	±2.32	42-49	45.4	±6.86	34-54	46.4	±4.2	54-34
BMI (Kg/m²)	26.31	±4.14	21.36-37.53	26.74	±2.55	22.25-29.55	24.95	±4.22	20.4-37.53

Key: n=sample size, SD= standard deviation, cm= centimetres, kg= kilograms, BMI= body mass index, m²= square meter.

Unlike the desktop, NA maximum positions were noted with the laptop workstation, causing the highest forward head position with 9.11^{o} difference (Table 2).

Table 2: The mean value and difference in all posture angles between Laptop and PC during typing work [mean (±SD)]

	Workstations		
Angle	**Laptop**	**Desktop**	**The difference between the two conditions**
NA	54.1 (5.8)	45.35 (7.37)	8.76
HT	144.27 (7.96)	149.81 (8.42)	5.54
LA	-11.84 (10.35)	-9.8 (8.98)	-2.04
PT	-2.85 (5.96)	-4.27 (4.76)	-1.42
Key: NA, HT, LA, and PT denote neck angle, head tilt, lumbar angle and pelvic tilt respectively. Negative values denote to either lordosis or posterior PT			

HT had a similar result, with approximately an 8^{o} difference. Both typing stations resulted in a negative value in both LA and PT for the majority of participants (Table 2). Forward lumbar kyphosis' revealed -2^{o} differences with the laptop compared to the desktop. In contrast, the greatest negative PT was found with the desktop - roughly 50% extra than the laptop. A single outlier is noticed at NA during laptop and HT on desktop for a female subject who was also the shortest participant (Figure 3).

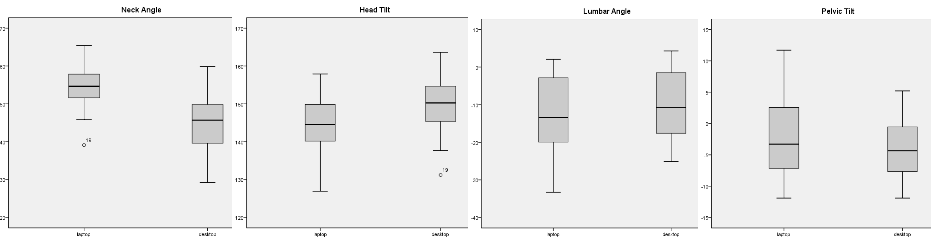

Figure 1: Box Plots Show the Medians, Interquartile Ranges and Extremes of the Range for NA, HT, LA and PT during Typing Tasks on laptop and PC.

The data shows a statistically significant difference ($t = 8.93$, $p < 0.0005$) in the mean angles of NAs. This reflects the angles during the laptop task being statistically significantly higher (mean= 54.1^{o}, SD= 5.8) than for the desktop (mean= 45.35^{o}, SD= 7.37). Similarly the mean angles on HTs are ($t= -6.33$, $p< 0.0005$), while the mean angles for the laptop task are statistically significantly lower (mean= 144.27^{o}, SD= 7.96) than for the desktop (mean= 149.81^{o}, SD= 8.42).

Both lumbar and pelvic segments show statistically significant differences ($t= -2.6$, $p\leq 0.018$) and ($t= 2.57$, $p\leq 0.019$), respectively. The mean angles of LAs in the laptop task are statistically significantly greater (mean= -11.84^{o}, SD= 10.35) than for the desktop (mean= -9.8^{o}, SD= 8.98); whereas mean angles on posterior PTs during the desktop task are statistically significantly higher (mean= -4.27^{o}, SD= 4.76) than for the laptop (mean= $-2.85.09^{o}$, SD= 5.96).

4. DISCUSSION

The results demonstrate that there were statistically significant differences in NA, HT, LA and PT between the two computers. The study outcomes reveal that neck flexion and tilting the head while working on a laptop is statistically significantly different compared with a desktop, for NA as well as HT angles (the p value for both is <0.0005). The current study's findings on NA and HT concur with a number of studies' reports and contrast with others. In terms of inferential analysis, the significant differences within NAs and HTs in the present findings are consistent with data presented by Straker et al. [42] and Saito et al. [40] who found compaoratively significant differences between laptop and desktop use during a typing task. However, the descriptive figures are not relative to some extent. For example, the variance in NAs and HTs were 6.6^o and 8.1^o respectively in the experiment by Straker et al. [42], while the current study reveals 9.11^o and 7.53^o. Nonetheless, NA was 3.8^o and HT -16.4^o in the study by Saito et al. [40]. The lower degree for NA by Straker et al. [42] could be explained by the calculation method being manual, with deviations from a vertical reference mark, which reduced the reliability level compared with a ground reference for body segments [53]. Meanwhile, the great difference that took place in the study by Saito et al. [40] cannot be clarified because of the uncertainty of the measurement tool, and also markers were used for the neck and head position. In contrast, Seghers et al. [41] have reported a non-significant difference in NAs and HTs during both typing tasks. However, the researchers may have dealt with the comparison of the laptop in a way that could have introduced another variable by providing a separate keyboard, which might have reduced the internal of validity of using the laptop's own keyboard. Hence, comparing laptop outcomes with a desktop in their study may be incomparable; regardless of that, the current study would be inappropriate.

These variances in the postural results may be related to the variation between the devices' designs. For example, the laptop screen is likely to cause pulling of the head and neck downwards and forward, and he upright posture in this study's procedures could be an additional factor that exaggerates the position in the laptop task due to the position of the screen. Thus, an increase in the upper cervical curvature (C1-C4) as well as a decrease in the lower cervical curvature (C5-T1) could be a problematic consequence [20]. Alternatively, the desktop seems to produce more upright posture for the cervical region.

Extreme NA combined with the head tilted forward plays a major role in the load on cervical segment tissue, perhaps resulting in the development of MSD/MSS [4]. Loads not only affect the neck segment but also other structures, such as 1st and 2nd rib elevation; upper thoracic kyphosis alteration and elevation; protraction, and downward rotation of the scapulae [12; 1]. Forward head tilt increases the pulling forces on the spine, exaggerating the posterior part of the thoracic region as it works as a stabiliser [29]. Cervicothoracic junction's mechanism therefore is affected, as extremely limited and great kinetic segments are linked (thoracic and cervical, respectively) [28]. Gill and Callaghan [27] also report that a secondary symptom may occur from abnormal proprioception in injured and irritated joints. Similar to the outcome of Annetts et al.[32], a positive pattern has been recognised between both segment angles, that is, as the NA increased, the HT posture increased as well, which may lead to increasing the upper cervical extension and the HT and vice versa. This pattern could work to balance the head posture alongside the gaze at the VDT by maintaining the direction of the eyes for reading the screen.

There are statistically significant differences between LAs and PTs for the laptop and desktop, with LA and PT angles of $p \leq 0.019$ and ≤ 0.018, respectively. Both angles were extracted in a negative magnitude as an indication of lordosis and posterior PT, except the single value in LA and two in PT. These were a male's LA, perhaps indicating a congenital deformity; the positive PT in a female subject may be a result of gender posture differences because of the different pelvis shape [54], which requires further research. To the researcher's knowledge, at the time of writing, no reported studies have examined the differences in LAs and/or PT between laptop and desktop use when sitting upright performing a typing task. Interestingly, the laptop task had more influence on extreme lordosis, which possibly results from the smaller posterior pelvic rotating, as stated by Straker et al. [43]. Unlike LA, PT is found to be high with the desktop trial, as the angle differences were -2^o for both lumbar and pelvis, probably due to biomechanical considerations, as a larger lordotic lumbar would supposedly be as a result of smaller posterior PT, as supported by Straker et al. [43] and Annetts et al. [32]. Although upright sitting is usually characterised by less posterior PT and more lordotic lumbar, the large negative PT values during the desktop task may have been due to be the modified chair and lack of backrest. Additionally, viewing the desktop's higher display may encourage erect head posture, perhaps combined with pushing the trunk backwards. An explanation for the laptop's influence on the lumbopelvic region may be its design, starting with a sharp viewing angle, along with the low height and close screen position. This probably results in pulling the lumbar forward in an attempt to sit upright, thereby causing shrinkage of the spinal vertebrae towards each other.

Slight posterior PT included in the laptop trial could be due to control by the Iliopsoas as a hip flexor and erector spinae muscles as back extensors [15]. O'Sullivan et al. [17] report that boosting the muscle activity of the paraspinal results from reducing the posterior PT and increasing lumbar lordosis, perhaps leading to spinal shrinkage; therefore, discomfort could result from the sustained compression on the discs [55].

Hence, the laptop session is associated with more lordosis, which could possibly be a source of potential injury. O'Sullivan et al. [16] explain that in a slumped posture, reducing muscle efficiency owing to sit for long time could weaken the lumbopelvic segments, resulting in instability, and strain due to increasing the load on the Intervertebral Disc and ligaments [2; 3]. Thus, applying the correct working posture could be proposed to inform postural re-education during clinical visits and training programmes on computer work.

As the data are statistically significant, it is worth clarifying the overall pattern for NA, HT, LA and PT through the cervical and lumpopelvic segments. Black et al. [30] maintain that a converse trend is noted between cervical and lumbar segments during sitting, either in a slumped or upright position. Upright posture is characterised by cervical flexion, and the opposite is true for slumped posture; however, the investigators report this without alteration in the HT. Based on this, this study lends support to Black et al. [30], except for HT posture.

Annetts et al. [32] suggest that the ideal posture for both lumbopelvic and cervical segments does not usually match. However, the opposite may be true; in other words, awkward lumbopelvic posture could be the result of awkward cervical posture, in turn causing spinal misalignment, as supported by Gandavadi et al. [31]. Straker et al. [43] also assume a positive relationship between adolescents with neck pain who tend to demonstrate more lumbar lordosis.

The findings of the study have a number of implications for future practice, both ergonomically and clinically, for example the design of ergonomic rules for safe workspaces; as well as reducing biomechanic risks through supporting healthier body posture. Additionally, it could open help to control MSD/MSS linked to the design of the workstation.

The outcomes suggest that the user ought to follow an appropriate evaluation to organise the workstation effectively, including furniture as well as the actual computer. So far, there has been a lack of appropriate information on how various laptop workstations should be setup in relation to body posture and comfort, with this study providing preliminary data. It may be assumed that laptop users are highly subjected to harm due to their sitting posture, meaning that laptop use ought to be limited. A thorough awareness of the working postures that are preferable for enhancing users' health should be advocated through preventive programmes; otherwise, preventative intervention would be beneficial in the early stage of MSS.

The present outcomes perhaps advance a rehabilitative programme interconnected with the workers' occupational needs, such as functional strength exercises and stretching the main muscles used. The body needs to move instead of simply sitting still, so lifelong exercise and timed intervals would also be central elements.

Regardless the short period, this study has been carried out with healthy participants, age 25 to 35 years, recruited from a university, therefore it is likely that the findings do not relate to, for example, elderly or younger populations. Also, participants with a higher Body Mass Index formed one of the possible limitations, with difficulties in the accurate palpation of the relevant bony protrusions. Also, the clothes of the female participants created some obstacles to extracting the angles on MATLAB during the data collection process. Such software works by recognising the precise crossing rings that come across the skin's surface alongside the spine, consequently, it was problematic to click the mouse pointer over wrinkled tight fitting vests.

5. CONCLUSION

The findings reveal significant statistical differences in all angles, highlighting concerns over laptop use, especially regarding postural restrictions. It has demonstrated ideal posture with regard to neck flexion, head forward and lumbar lordosis accompanying the desktop trial, which favours the desktop for maintaining better posture, while the laptop is less ideal. In case of the mandatory use of a laptop, using it less than a desktop is recommended. In addition, these findings suggest converse trends associated between cervical and lumbar segments. Apart from several specific factors, this study supports segment association between cervical and lumbopelvic, either within upper and lower body segments or between them, which seems to be safer while working on a desktop. Importantly, laptop or desktop users should pay attention to this, as it seems to influence poor posture. Thus, a proper evaluation of the workstation, which depends on individual anthropometry, besides appropriate postural instructions, is necessary.

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CORRELATION BETWEEN QUALITY OF NEW MATERIALS, DESIGN AND CONSTRUCTIONS IN MATTRESSES

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Abstract
Human body is most sensitive about the part of bed with which it is in direct contact – mattress. The most important and the most burdened part of the mattress is definitely its core, regardless of whether it's from metal or from other materials. In order to provide proper support for our backs, the mattress has to have quality core. This research examines durability, elasticity and hardness of bonnell spring (BNL) and pocket spring (TFK) cores. By observing hardness value it can be concluded that the sample C2_TFK has the highest value of hardness value after the initial 100 and final 30000 cycles, while the sample C1_TFK has the lowest value. By observing firmness relations, sample C2_TFK is the firmest sample after the initial 100 cycles. At the same time, the softest is sample C1_TFK. The situation changed after the final 30000 cycles so the firmest became sample B1_BNL, and the softest remained the sample C1_TFK. About durability and height loss it can be concluded that the worst is sample B2_BNL because it has shown to be the weakest in most of the observed characteristics. Among bonnell spring core samples, B1_BNL has to be singled out as the sample with the lowest height loss from all the tested samples, hence the best. The samples of pocket spring core have justified their status as durable spring core system because at the end of the testing there was no serious damage. Regarding height loss, it is somewhat higher in the pocket spring core sample C2_TFK than in sample C1_TFK.

Keywords: *mattress, bonnell spring core, pocket spring core, elasticity, durability, hardness, HRN EN 1957.*

1. INTRODUCTION

Mattress is the most demanding product of the modern industry. The trend is to develop new technologies that allow construction of "healthy" mattresses that will be able to completely adjust to each body (Grbac, 2006). Mattress quality improvement is almost always based on quality improvement of supporting the body or increased comfort of mattress, both mattress core and topper above the core. One of those technologies is the principle of constructing multi-zone mattress cores born out of desire for the better body support while lying. Since they raise comfort to a higher level, such mattresses are nowadays considered to be of high-quality (Grbac, 2005).

This research examines durability, elasticity and hardness of bonnell and pocket spring cores (German: *Taschenfederkerne*, TFK), with the aim of determining correlation between quality of the product and characteristics of the materials (height, diameter and thickness of a core wire), as well as application of research results in practice. The research is based on the method of determining functional characteristics of mattresses according to HRN EN 1957: Domestic furniture – Beds and mattresses – Test methods for the determination of functional characteristics

2. MATTRESS SPRING CORES

A prerequisite for mattress comfort is the exactly determined elasticity and flexibility of the surface for lying. Mattress and elastic pad adjust to every movement and body shape in a way to try to evenly support it in every position. The choice of the most suitable mattress is the result of the fact that a man chooses what is the most comfortable for him (Savić et al., 2003). Manufactured industrially and with long durability and high quality, cores are nowadays almost the most important component of the mattress.
The most commonly used material in spring production is steel, along with some other materials such as brass, phosphor and silicon bronze, new silver, etc. Materials for the production of springs have to have high elasticity limit, high lasting dynamic hardness due to dynamic load and vibrations of own springs and to be tractable. While in use, steel springs, that are at the same time the basic spring core element, are subject to high static and dynamic loads of short-term or longer durability. Due to that, springs must have lasting elasticity, as well as enough plasticity to allow wire to be flexed and intertwined during core construction. Deformation of the core has to be mild and not too big.

3. MATERIALS AND METHODS

3.1. Samples

The research was conducted on six samples in total, from which four were bonnell spring cores and two were pocket spring cores. Their characteristics (and manufacturer) differentiated them. Codes were subscribed to samples. Letters in sample code (A, B and C) indicate differences in spring characteristics, and numbers (1 and 2) indicate different manufacturers (Fig.1-6)
Sample A1_BNL and A2_BNL also the samples B1_BNL and B2_BNL were bonnell spring core. Difference between the core A1_BNL and A2_BNL was in number of spring coils and manufacturer. Samples A1 and B1 differ from samples A2 and B2 (except in manufacturer) in number of spring coils (the former have five coils, and the latter six coils), while samples A (2.2 mm) differ from samples B (2.4 mm) in spring wire thickness.
Sample C1_TFK and C2_TFK were pocket spring core. These two samples differ in the core framework design and manufacturers.

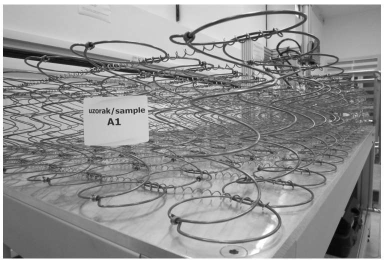

Figure 1: *Sample A1_BNL*

Figure2: *Sample A2_BNL*

Figure 3: *Sample B1_BNL*

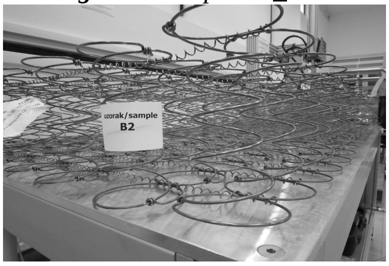

Figure 4: *Sample B2_BNL*

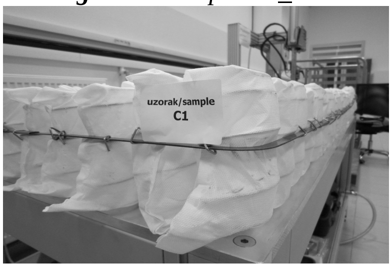

Figure 5: *Sample C1_TFK*

Figur6: *Sample C2_TFK*

3.2. Research method

The research is based on the test from the standard *HRN EN 1957: Domestic furniture – Beds and mattresses – Test methods for the determination of functional characteristics*. The standard describes methods for determining durability, elasticity and hardness of the mattress, and all types of beds equipped with mattresses, except for the water, air and children beds. Testing mechanical properties of the wires from which springs were built wasn't subject of this research. All tests were conducted in the Laboratory for furniture of the Faculty of Forestry with modern, computer-controlled devices (Fig. 7).

Figure 7: *Device for determining mattress durability and elasticity*

3. RESEARCH RESULTS

The results obtained in the research are summarized in Table 1. Since the paper is limited, results of inter-measurements are left out. However, it should be mentioned that, although not statistically processed, among them there were no significant changes. All the results can be found in the original paper (Varošanec, 2010).
Table 1 show measured core heights, all the parameters obtained by hardness measurement and, finally, firmness of each core before all the exposures to dynamic loads, after 100 and 30000 cycles.

Table 1: Aggregated data of the samples A, B and C before testing and after 100 and 30000 cycles

Sample	Measured core height	C1	C2	C3	**H [N/mm]**	A [mm²]	K	**Hs**
A1_BNL-0	158	7,35	6,40	7,56	**7,10**	13138,56	1849,53	**5,1**
A2_BNL-0	155	6,42	6,89	7,40	**6,91**	14820,74	2146,20	**5,7**
B1_BNL-0	151	10,12	10,67	10,94	**10,58**	9728,01	919,56	**2,5**
B2_BNL-0	159	7,86	8,59	8,89	**8,45**	12345,86	1461,65	**4,1**
C1_TFK-0	130	5,14	4,88	5,67	**5,23**	18348,93	3509,34	**8**
C2_TFK-0	141	15,42	12,12	8,58	**12,04**	10819,70	898,65	**2,4**
A1_BNL-100	156	7,62	8,10	8,14	**7,95**	13137,21	1651,97	**4,6**
A2_BNL-100	153	6,73	7,12	7,22	**7,03**	14805,25	2107,63	**5,7**
B1_BNL-100	148	8,58	9,24	10,21	**9,34**	11318,90	1211,42	**3,4**
B2_BNL-100	158	7,20	7,73	8,16	**7,70**	13396,96	1740,50	**4,8**
C1_TFK-100	122	5,09	4,98	4,93	**5,00**	18834,78	3767,60	**8,2**
C2_TFK-100	138	11,97	9,89	7,75	**9,87**	11101,76	1124,80	**3,1**
A1_BNL-30000	152	7,17	8,16	8,32	**7,88**	13155,08	1668,62	**4,6**
A2_BNL-30000	151	6,77	6,66	7,52	**6,98**	14324,03	2051,32	**5,5**
B1_BNL-30000	147	10,18	10,66	11,20	**10,68**	9684,03	906,93	**2,5**
B2_BNL-30000	156	8,30	9,03	9,68	**9,00**	11867,56	1318,23	**3,7**
C1_TFK-30000	124	4,29	4,97	4,29	**4,51**	20033,75	4438,71	**8,8**
C2_TFK-30000	135	14,17	11,17	7,24	**10,86**	12082,87	1112,36	**3,1**

Note: C1 - slope at 210 N load; K - coef. calculated from load/deflection curve
C2 - slope at 275 N load; H - hardness value
C3 - slope at 340 N load; Hs - firmness rating
A - area under load/deflection curve (under the load curve from 0 to 450 N)

Figures 12 to 14 show load/deflection curves of all the cores before testing and after 100 and 30000 cycles. It is interesting to note that TFK cores (C-samples) keep their interrelation from beginning until end while elasticity curves of bonnell cores (A- and B-samples) change their position with regard to the other.

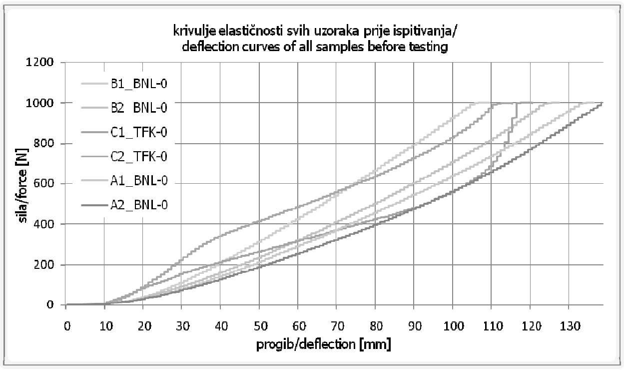

Figure 8: Load/deflection curves of all samples before rolling test

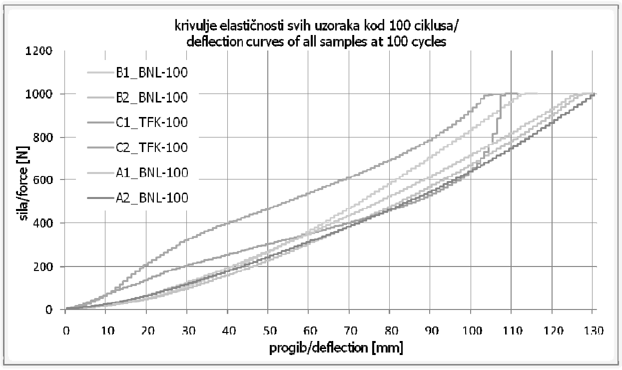

Figure 9: Load/deflection curves of all samples after 100 rolling cycles

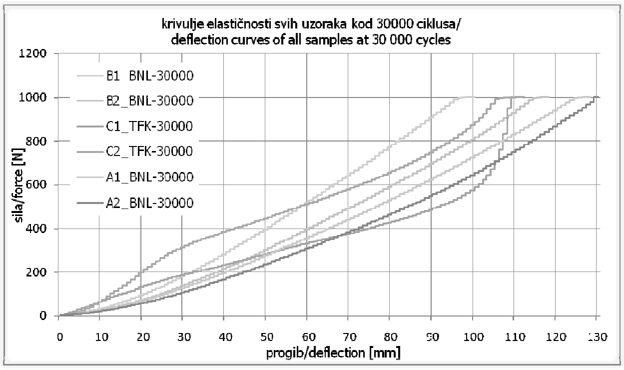

Figure 10: Load/deflection curves of all samples after 30000 rolling cycles

5. CONCLUSION

The aim of the research was to explore characteristics of cores for mattresses construction and to determine which core system is more durable with regard to different characteristics, which is their height loss value, firmness and hardness in comparison within type and comparison with the examined types.

Based on the conducted researches and measurements of bonnell cores and pocket spring cores characteristics, the following conclusions can be made:

- **Hardness value:** By observing hardness value relations of all bonnell and pocket spring cores samples, it can be concluded that the sample with pocket spring core with wire thickness of 1.8 mm and steel framework on the bottom/end of springs (C2_TFK) has the highest value of hardness value after the initial 100 and final 30000 cycles, while the sample with pocket spring core with wire thickness of 1.8 mm and steel framework in the middle of the spring height (C1_TFK) has the lowest value.
- **Firmness rating:** By observing firmness relations of all the tested samples, sample C2_TFK is *the firmest* sample after the initial 100 cycles. At the same time, *the softest* is sample C1_TFK (with steel framework in the middle of springs height).The situation changed after the final 30000 cycles so *the firmest* became sample B1_BNL (with wire thickness of 2.4 mm and 5 coils), and *the softest* remained the sample C1_TFK. Firmness of other samples is approximately around middle value for firmness rating.
- **Durability and height loss:** Generally speaking, if from all the examined samples one should be pointed out as the worst, it would be sample with bonnell spring core with wire thickness of 2.4 mm and 6 coils (B2_BNL) because it has shown to be the weakest in most of the observed characteristics. Height loss of the sample in question after testing was also among the highest, hence the worst. Among bonnell spring core samples, B1_BNL has to be singled out as the sample with the lowest height loss from all the tested samples, hence the best. The samples of pocket spring core have justified their status as durable spring core system because at the end of the testing there was no serious damage. Regarding height loss, it is somewhat higher in the pocket spring core sample C2_TFK than in sample C1_TFK.

Due to a small number of samples, conclusions based on the results can only be general and can confirm the expected interrelations of the samples. In addition to the higher number of samples, it would most certainly be interesting to conduct same researches with complete mattresses and identical cores and compare them with these results

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ANALYSES OF WORK STUDY IN DRAWING-IN IN WARP PREPARATION OF WEAVING PROCESS

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Abstract
Drawing-in of warp threads through heddles on different shafts or jacquard and the reed is one of the phases in making fabrics which is still mostly performed by hand. When the warp is multicolored consisting of a larger number of threads, drawing-in through several shafts with complicated drawing-in is more time-consuming than the weaving process itself due to a great portion of handwork, especially if it is woven on a faster and modern loom. During drawing-in certain problems arise which make the work difficult. Incorrect body posture of the worker in sitting position additionally loads the spine. According to the analysis of workplace drawing-in through shafts and reed some improvements are possible in order to facilitate and maximize productivity. Ergonomic chair design with the ability to adjust the height of the body and the ability to customize the position of shafts enables the improvement of working conditions.

Keywords: work study, drawing-in, shafts, heddles, jacquard, reed

1. INTRODUCTION

Warp wound on the warp beam is prepared for weaving. Before weaving it is necessary to draw warp threads into the elements of the weaving machine. Heald shafts, reed and drop wires are parts of the weaving machine for shed formation (heddles with shafts), beat-up, maintenance of width and warp density (reed) and they stop the machine in case of a warp thread breakage (drop wires) [1].

Drawing-in warp threads through shafts or heddles, reed and drop wires (Fig. 1) require high precision, skill and concentration of workers. This phase of the work in making the fabric is still handmade. The time required to manually draw in warp threads through shafts, reed and drop wires is often longer than weaving itself. Due to manual drawing-in warp threads the process of warp preparation is time consuming, and there is also a great probability of error in drawing-in through the elements of the weaving machine. Any error results re-drawing-in warp threads or a fault in the fabric. A production quota is often set for these jobs which leads to psychological burden of a worker asking himself whether the production quota will be performed and the warp correctly drawn in [2-5].

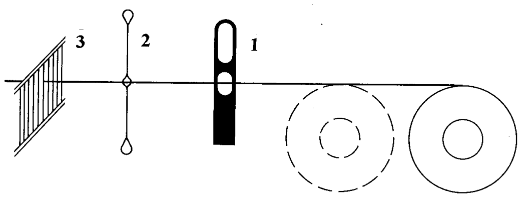

Figure 1: Process of drawing-in threads through the elements of the weaving machine
1 - drop wire, 2 - heddle, 3 - reed

Each warp thread should be drawn in according to specific rules. Drawing-in warp threads can be carried out by machine, but this kind of machines is not frequent in the industry. Their high precision in preparation of warp threads, shafts, reed and drop wires requires a longer and more precise preparation. These machines for warp preparation reduce the total time of drawing-in as well as the frequency of errors and simple machine operation by computer control.

2. DRAWING-IN WARP THREADS

2.1 Drawing-in warp threads through shafts

Drawing-in warp threads through shafts means drawing warp threads into heddles mounted in heddle frames or hung on cords of the harness on the jacquard weaving machines. This process is still carried out manually with two operators. One of them selects thread by thread according to the arrangement of drop wires and the other arranges heddles according to drawing-in through shafts and draws in threads [1].
There is a drawing-in method in which a certain tension is applied when only one operator is necessary. However, this kind of drawing-in significantly burdens the worker, especially in case of complex types of drawing-in and a great number of shafts. Worker productivity may be significantly increased using an auxiliary device which feeds the threads according to their warping (Fig. 2) [6-10].

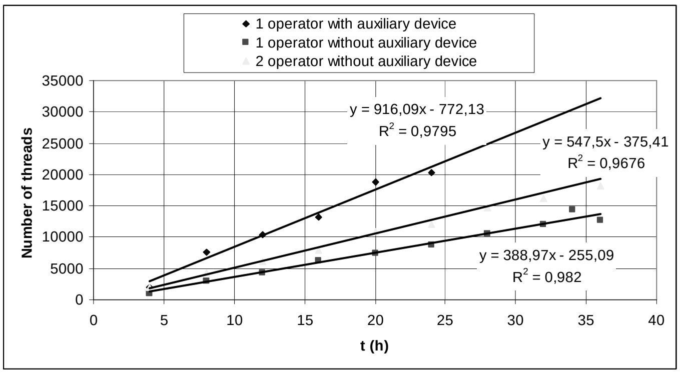

Figure 2: Comparison of time for manual drawing-in with one or two operators and using a semiautomatic machine

2.2 Drawing-in warp threads through the reed

Warp can be drawn-in through the reed on the machine itself (e.g. on the jacquard loom) or outside the machine.
The graph in Fig. 3 shows the productivity of manual and machine drawing-in through the reed. Drawing-in through the reed depends on the skill of the operator and on reed size and yarn count. Besides manual drawing-in, it is also possible to use an auxiliary device with the following characteristics [1]:

- reed size: 20 to 500 wires/10 cm
- reed height: greater than 52 mm
- reed width: unlimited

Special drawing-in needles, being are slightly shorter, but wider than the needles for drawing-in through heddle shafts, are used.

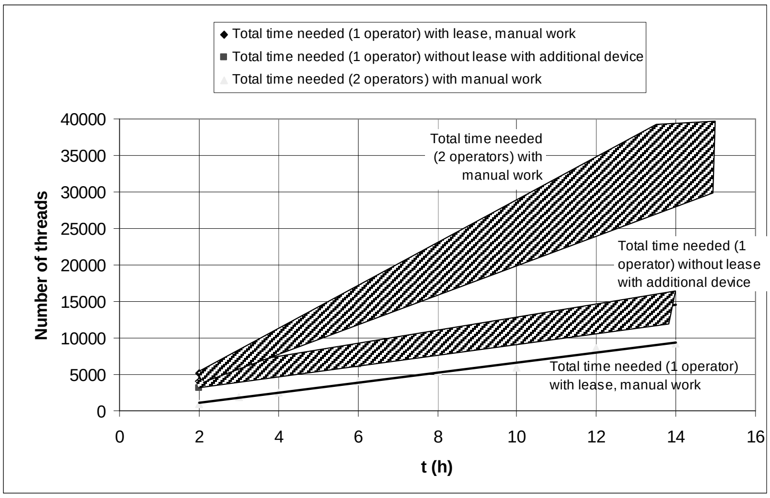

Figure 3: Comparison of time for drawing-in through the reed manually or manually with an additional device

2.3 Mounting drop wires

The loom has two or more rows of drop wires, and each warp thread should have its stop motion or drop wire. Drop wires are mounted on the loom. It is relatively simple to mount them using a lease. Bodily posture is standing bent posture with arms stretched. Due to the improper body posture of the worker during mounting drop wires and difficult working conditions drop wire mounting conditions are applied more and more. Drawing-in by machine enhances labor productivity to a great extent (Fig. 4) [1].

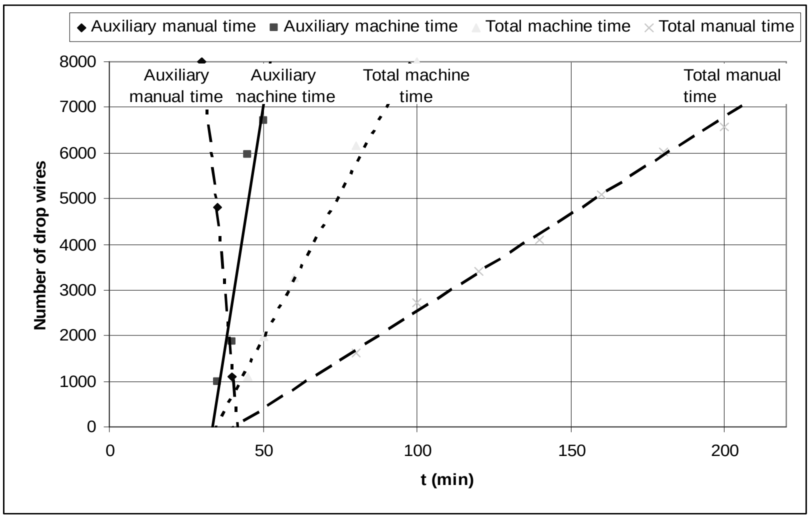

Figure 4: Comparison of the time for manual mounting drop wires and by machine in wool production

3. ERGONOMIC SOLUTION OF DRAWING WARP THREADS INTO SHAFTS

Manual drawing into shafts and reed is carried out outside the weaving machine, while drop wire mounting is performed on the machine. The body posture of the worker while drawing-in warp threads is incorrect and affects spine load significantly. Sitting posture of the worker on the chair which has not been designed ergonomically for this workplace additionally loads the spine. The body is rotated, the spine is flexed in an incorrect position for the entire time of drawing-in why the worker begins to feel pain. The legs are also in an incorrect position, which slows circulation and thus such a posture adversely affects the cardiovascular system (Fig. 5.). Besides irregular postures that burden the spine, eyestrain also occurs because of intense use.

Figure 5: Improper body posture of the worker drawing-in warp threads

Ergonomic body posture can be achieved using a suitable chair for seating that would allow the height regulation of the seat, backrests and rotation. The chair that would be best suited for this workplace is a saddle chair. A person who sits on the classic chair keeps the body in the position at an angle of 90 °. Sitting this way slows the circulation in the lower extremities while the upper body is bent and the spine takes the form of letter C, which is irregular and causes pain. A proposal for improving the saddle chair that is different because the person sits at an angle of 135 ° with the reduced pressure on the lower extremities, which means that circulation does not slow down. The spine is corrected and takes its natural position in the form of letter S. (Fig. 6).

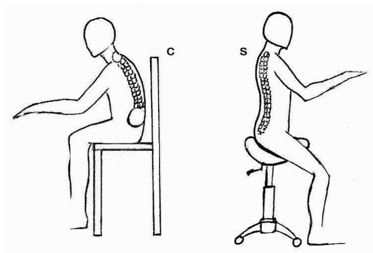

Figure 6: Classic chair and saddle chair differences in body posture

Due to the different position of the lower extremities it is possible to do work in the position to desktop without rotation of the spine, because this way allows the worker to sit closer to the working surface. Saddle chair should be designed in such a way that an individual worker can adjust the chair according to height and type of the work performed. Since the arms and shoulders move horizontally from left to right at drawing-in, the regulation of the seat should also allow the backrest and armrest to rotate according to the body rotation. Besides that, the chair should allow tilting forward and backward, which means that it can fully monitor the movement of the body with the purpose of supporting. (Fig. 7.).

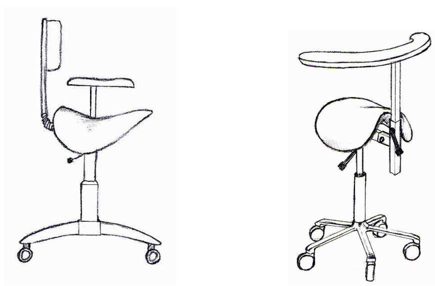

Figure 7: Suggestions of two types saddle chair

4. CONCLUSION

Drawing-in warp threads through shafts, reed and drop wires is one of the major phases in making fabric. Since drawing-in is mostly done by hand, the working conditions are of utmost importance. Drawing-in warp threads is a seemingly simple and comfortable job in comparison to weaving; there is no noise and dust, it is a sitting position workplace, and the work is only possible in the first or probably in the second shift etc. However, drawing-in warp threads is one of the most difficult jobs in which physical effort and eyestrain are very significant. In particular, spine load due to long sitting in an incorrect position, and adverse effects on the circulatory system (the appearance of the leg veins, etc.) can be emphasized. The purpose of this study is to indicate how hard the process of drawing-in warp threads by hand is and to find a solution using an appropriate ergonomic chair. According to the analysis of work it is possible to improve and humanize this workplace by using a special saddle chair as a replacement for usual chairs most frequently used in the industry.

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ESTIMATION OF LUMBAR SPINE LOAD DURING LIFTING TASK EXECUTION

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Abstract
In lifting task execution, lumbar spine load is affected by numerous variables, where some of them can be identified as most significant. In order to keep lifting task execution most effective while avoiding lumbar spine injury caused by spine instability, risk factors should be minimized. Biomechanical analysis protocol is created for the purpose of lifting task analysis, which reveals real-time variations of biomechanical variables, essential for estimation of lumbar spine stability. Performed analysis conclusions emphasize that although proper lifting technique is well-known theoretically, lifting object geometry, center of mass, subject anthropometry and lifting capabilities, should be sufficiently determined before the task execution is demanded.

Keywords: *lifting task, lumbar spine load, spine instability, biomechanical analysis*

1. INTRODUCTION

Lumbar spine health preservation is primary objective of many scientific and professional researches, in order to reach final consensus on acceptable spinal loads magnitude, regardless of load type applied upon the spine, in symmetric or asymmetric interactions [1-7]. Besides, studies have been focusing on specific objective to explain and understood spinal mechanisms and response to different cases that have been studied [3, 4, 6], as well as spinal stability [8-12]. Recommendations from such extensive exploration of spine and its mechanisms are foundation for ergonomic purposes, where emerged new methods and technologies can improve knowledge and understanding of impact on spine caused by external conditions [9, 10, 12-16].
Extensive and thorough research were conducted, but despite of that, there is no consensus on safe and reliable material handling techniques, regardless of whether it is lifting, moving, pushing or pulling task demanded. Possible explanation may be reached through understanding that spine is a complex system, almost never activated in isolated, experimentally controlled conditions. Furthermore, movements in material handling tasks are not proper neither symmetrical and injury prevention mechanisms always try to dissipate load and reactive activity among muscles and structures, acting coordinated and precise. Therefore, main objective should be addressed to conditions

and circumstances that lead to nerves irritation, spinal segments and ligament or muscle tissue damage. Such objective may provide understanding of risky inter spinal movements and deformations, as a consequence of external load reduced on spinal segments and structures. Instead of extensive literature overview on spine performance and injury etiology, our objective is to explore relationship between the worker and the cargo that should be handled, in order to reach a conclusion how dimensions and properties of cargo can affect the spine load, estimated through changes in spine geometry.

Focus of this paper is addressed at estimation on lumbar spine instability caused by irregularities in lifting task conditions and circumstances, which occur when lifting task is not anthropometrically appropriate for the person for whom the task is assigned. Lifting objects, or generally objects for manual handling, often embrace the dimensions that can be classified as bulky, can cause deviation from the correct position for lifting, resulting in material handling posture change, that can be considered as risk factor.

2. METHODS

2.1. Experimental design overview

The in vivo experiments will be described briefly for lifting task execution. Subjects have to spontaneously lift the empty box (50cm high, 40cm wide and 50cm long) without any kind of handles, from the floor back to starting position, defined as standing upright. Box is left empty with intent to explore lifting interaction consequences for anthropometrically different persons in identical lifting task, but the box size is selected so it can become an obstacle to the proper lifting execution. It should be mentioned that experimental data acquisition restrictions influenced the choice of smaller box size than intended to be used, since there is known problem with markers disappearance in most MOCAP acquisitions. Prior to lifting task execution, subjects were instructed on lifting objective in order to enable collecting of comparable results, while lifting task was designed uniformly, regardless of differences in subjects capabilities or any other personal data.

2.2. Evaluation criteria

As literature overview indicates, several possible criteria can be selected in order to estimate spinal injury risks, but as most comprehensive can be identified spinal stability. Although the consensus on lumbar spine stability definition is not present [8], authors consider it as fine-tuned neuromuscular system coordination of the lumbar spine mechanism, provoked by posture and load parameters, in order to ensure controlled spinal segments motion. Lack of adequate lumbar spine stability mechanism response represented as involved muscles co-activation will cause variation of lumbar spine torque, which along with changes in shear and compressive axial forces can indicate that stability of lumbar spine is compromised, revealing potential to injury. Of course, magnitude of applied load is considered to be inside recommended margins, thus this notion does not certify that injury risks are not present.

Biomechanical analysis protocol allows that 3D moments and forces can be estimated, but available data acquisition procedure lacks in tracking of detailed and fine geometry changes for closely positioned markers, needed to determine exact change for each of lumbar spine segments, as important factor [17, 18]. Protocol offers data of forces components that coincide with fixed coordinate system, but their conversion into axial and shear forces is dependent on each spinal segment spatial position determination. Since analysis focus is on estimation of human factors that are possibly affected by lifting subject-object interactions in symmetric lifting tasks, most important results can be expected in sagittal plane. Thus, shear and axial load could not be considered as reliable variables, so as one of most appropriate variables for purpose of this paper is nominated lumbar spine moment in L5/S1 joint, for flexion and extension in sagittal plane.

2.3. Data acquisition

Data acquisition was made by an 8 IR camera BTS Elite system (Italy) at 100 Hz, with passive reflective markers used and placed on subject body as shown on Fig.1, which represents simplified wireframe model of passive reflective markers layout positioned on specific anatomical places, with an explanation of abbreviations on the right side.

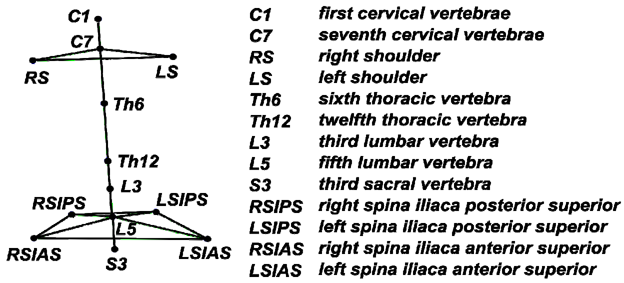

Figure 1: Wireframe model of passive reflective markers layout

After the lifting attempts were performed and relevant data acquired, protocol for biomechanical analysis was designed in BTS Smart Analyzer software, in order to enable appropriate biomechanical analysis. Designed protocol consists of vectors of 3D forces and torques for each marker position.

3. RESULTS

Data acquisition has been successfully completed for two healthy, asymptomatic males (22 yr., 1.92 m, and 102 kg, BMI=28), and (23 yr., 1.7 m, and 75 kg, BMI=26), as Subject 1 and Subject 2 respectively. As described earlier, after the data acquisition, data processing through analysis protocol in BTS Smart Analyzer enabled changes overview of lumbar spine moment at L5/S1, which is shown in Fig.2 and Fig.3 for Subject 1 and Subject 2, respectively.
Results of lumbar spine moment's changes presented in Fig.2 and Fig.3 are time dependent, which enables opportunity to directly track and compare changes according to lifting task phase. It is shown that the execution time was very similar, but the line chart indicates important differences in task execution parameters. Moment curve slope and moment values for specific time points will be used as lumbar spine moment curves comparison variables. Positive moment values are related with extension activity of spine while negative corresponds to flexion, where zero value is identified as neutral position of spine segments during upright standing.

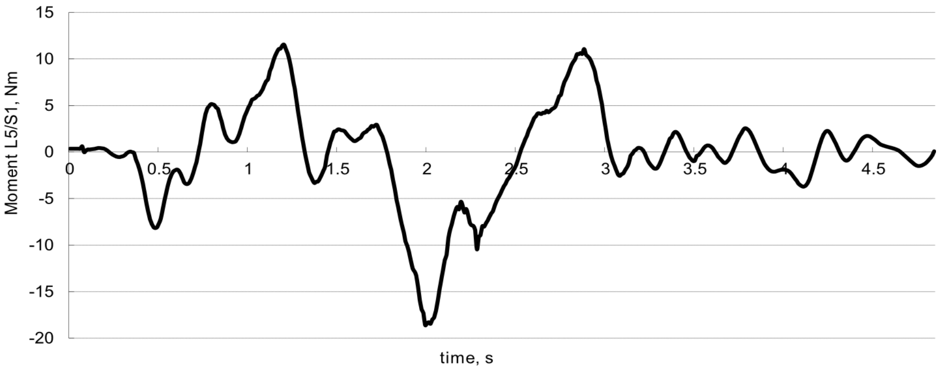

Figure 2: Time dependent lumbar spine moment at L5/S1 graph for Subject 1

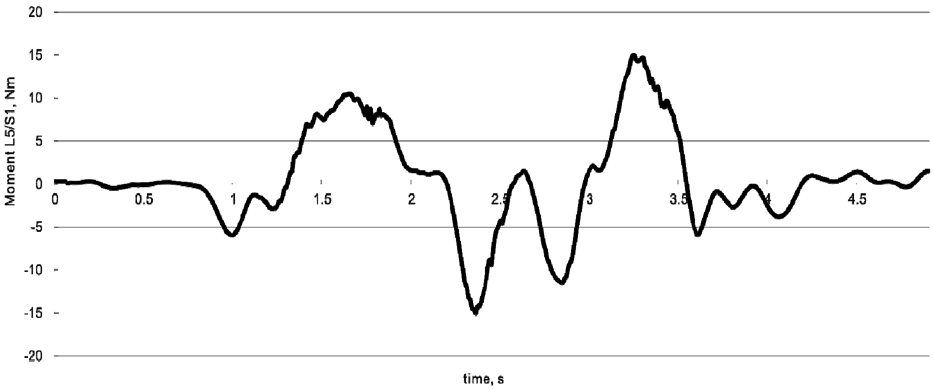

Figure 3: Time dependent lumbar spine moment at L5/S1 graph for Subject 2

For both graphs it is obvious that prior to task execution subjects have prepared starting posture with back extension contraction, but the curves do not match, although the magnitudes were similar. In this phase, Fig.2 shows spinal instability more obvious than Fig.3, but the final slope was more consistent. Both peaks were at around 12 Nm, which indicates that Subject 2 has induced higher level of spinal stability activities, relative to his anthropometrical data. In flexion both subjects have shown strong oscillations, which is the first indicator that their lifting techniques were not completely appropriate. Most important findings are expected in later phases, grasp and lift, which can be considered as risk phases, according to Fig.2 and Fig.3. As expected, Subject 2 has to significantly adjust his grasp to the box, while the lifting was also influenced by lifting technique adaptations to the box size and position. This resulted with significant transitions of extension and flexion of the spine, much more than for the Subject 1. Such transitions that occur while handling loads are obvious sign that lumbar spine stability can be compromised, especially if lifting technique is not correct. Also, in lifting phase Subject 2 performed faster lifting which is obvious from steeper moment curve, as another indicator for injury risks [3, 4, 6]. Although the box was empty, Subject 2 reached around 30% higher final extension moment, in standing upright position, which is another indicator that lifting implementation is really affected by subject anthropometry. Furthermore, both subjects have shown weaknesses in their lifting capabilities and techniques, which can be identified through implementation of designed protocol. Although the understanding of lumbar spine stability concept is present, experimental data presented and discussed did not explain the cause of observed sudden lumbar spine moment transitions from flexion to extension and vice versa in lifting phases. Possible rationale is that lifting object dimensions truly affects lifting technique and execution, with consequence of narrowing down the selection of persons for whom the task may be permitted.

4. CONCLUSION

Lifting and handling tasks may have serious consequences if implemented technique and subject capabilities are not adequate, especially if fatigue occurs in repetitive tasks [6, 11]. Spine stability is considered as one of most comprehensive criteria for evaluating lumbar spine risks, monitored through lumbar spine moment change, since MOCAP acquisition and analysis used is primarily based on inverse dynamics, and may not represent true spinal load. This paper emphasizes that although proper lifting technique is theoretically known, its implementation in real circumstances can be uncertain, and what is even more important, human error in lifting skills is underestimated. Simple lifting task with bulky, empty box caused significant variations in lifting attempts, regardless who handled it, showing that many individual traits are disregarded. This conclusion is important in human factors since it has consequence in determining to whom the task should be assigned to, despite the fact that individual may have adequate capabilities. Authors also recognize that asymmetric and rapid lifting exertions may have even more impact on spinal stability and consequently, on injury risks, especially for repetitive tasks. This conclusion implies that lifting technique should be properly evaluated (and even improved), but also that there are preferred persons for specific lifting and handling task.

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ERGONOMIC ANALYSIS OF OPHTHALMIC NURSE WORKPLACE

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Abstract
The paper presents a research on the workplace ophthalmic nurse regarding strain and stress. In the workplace the Intravenous Fluorescein angiography or fluorescent angiography is made which is a technique for examining the circulation of the retina and choroids using a fluorescent dye and specialized camera. The working procedure is complex and since nurses must assist in several forced position for longer time ergonomic analyses were made aimed to determine strain and stress at workplace. For assessment of body postures OWAS analysis was used.
The results obtained with the analysis were compared to standard values respectively and recommendation for improvements was made.

Keywords: ergonomic analysis, OWAS, body postures, nursing

1. INTRODUCTION

Nurses have been the subject of many studies to examine how physical stress and other work related factors may affect their health and well-being. Many of these studies focused in the first instance on high back pain. Resent investigations tends to confirm that the physical work load of those working in nursing homes is relatively high. Also most research has been carried out in general hospitals, but there is no available data about physical work load of ophthalmic nurse in functional diagnostics. Since diagnostics and treatment procedures of macula diseases become more complex and advanced also related nurse assistance become more complicated and stressful. Nurses must assist in several forced positions for longer time therefore ergonomic analyses were made aimed to determine possible health problems.

For the purpose of our research we used one of the widely used methods of observation in working posture studies, the Ovako Working Posture Analysis System (OWAS). Generally OWAS method is used to identify and evaluate harmful working postures and is widely spread in all professions. The purpose of OWAS is to provide a system for analyzing and classifying working postures with the aim of developing working methods consistent with the promotion of occupational health.

2. RESEARCH PROBLEM

While working, the workers are exposed to various strains and stressors that contribute to stress. Strains and stresses belong to an important group of factors that reduce human efficiency at work due to disturbed hemostasis, resulting in fatigue [2, 3, 4] To reduce the effects of this phenomenon, working hours should be interrupted by several rest periods and breaks. Beside that workplace should be designed considering human dimensions using anthropometric measures. From the ergonomic point of view the most important factors that influence stress at work can be divided into:

1. working environment with working conditions such as noise, heat, humidity, illumination, air velocity and
2. body postures; especially awkward postures that can cause health problems.

There are of course another influence factors such as psychophysical, dependent from human characteristics and personality but these factors were not subject of our research.

Since there were some complains evidenced about back pains in Fluorescein angiography ambulance we decided to observe all nursing activities during nurse's workday. Intravenous Fluorescein angiography or fluorescent angiography is a technique for examining the circulation of the retina and choroid using a fluorescent dye and specialized camera. It involves injection of sodium fluorescein into the systemic circulation, and then an angiogram is obtained by photographing the dynamic fine structure of retinal blood vessels and vascular hemodynamics and vascular physiology, pathology, diagnosis and treatment of ocular fundus. Nursing approach to management involves:

- patient consent,
- ophthalmic preparation (visual acuity, drops are then instilled into both eyes to dilate the pupils, measuring OCT, inserting IV cannulla,
- the procedure,
- after the procedure.

3. METHODOLOGY

For the presented problem consideration the following steps were taken:

- workplace analysis and evaluation; analysis of the existent workstation dimensions with respect to working postures and workers' perceptions; Fluorescein angiography ambulance is working once a week but for clinical patients the procedure can be done every day. For our research we followed up patients in the ambulance, three sequence ambulances. The observation was conducted all day, three times per hour on 27 (3x9) patients.
- workplace analysis considering working environment; accurate measures of noise, illumination, heat, humidity and air velocity were taken,
- The extended OWAS method was used to evaluate the strain caused by different operators' postures at nursing workstations.

3.1. Workplace Fluorescein angiography

The following figures demonstrate the different operators' postures at observed workstation. Operator seat near the table and make visual acuity. When putting lances to the glasses the operator has to twist thoraxlumbal spine, upper limb is raised above the head and hands are loaded to, because a lot of precise grasps is needed.

Figure 1: Operators make vision acuity and instill drops into both eyes

Operator is banding to the patient and pouring a drop into patients' eyes. Thoraxlumbal spine is bending in lumbar and cervical area, upper limb is raised above and hands are loaded to, because a lot of precise grasps is needed, too.

Figure 2: Operator assist in the procedure

During the procedure (Figure 2) operator is banding near the patient. Thoraxlumbal spine is bending and twist in lumbar and cervical area, upper limb is raised above the head and hands are loaded to, because a nurse must hold an eyelid apart to enable photograph eye fundus.

3.2. OWAS method

OWAS, the Ovako Working Posture Analysis System, was developed in Finland for examining workers postures in steel industry in 1973 [1, 2]. The method was successful and therefore further developed and modified. It is considered a practical method for identifying and evaluating working postures. The OWAS procedure consists of two parts: an observational technique to classify body postures, and a set of criteria for the redesign of working methods and workplaces. Body postures are classified into 28 positions including the positions of back (four positions), upper limbs (four), hands (three), lower limbs (nine), head and neck (five), as well as load or force handled (three). Each body area consists of ranked postures that describe the risk or severity of that body area's posture.

Since OWAS is a time-sampling method it requires the time sampling of tasks at intervals ranging from 15 seconds to 1 minute. The system was originally developed for use in manufacturing industries, where workstations are static and job tasks repetitive and predictable in nature, but later other methods were developed, too, such as RULA and REBA. RULA (Rapid Upper Limb Assessment) is used for assessing the risk of work-related upper limb disorders and is mostly used for seated work. REBA (Rapid Entire Body Assessment) is used for assessing the risk of work related entire body disorders and therefore more appropriate for standing work. Since our Laboratory for Operations and Production Management has many years' of experiences with OWAS method we decided to use OWAS for working postures assessment.

As explained before by OWAS body postures are classified into 28 positions. Each of these positions has pre-defined high risk and low risk postures, which are coded by the observer. After calculating the amount of time the worker is in these postures, the final step is to assign a four-level action code for task improvement. The four action codes are defined as follows: changes are not needed, changes needed in near future, changes needed immediately, needed intensive observation.

4. WORKPLACE ANALYSIS AND RESULTS

For workplace analysis considering working environment accurate measures of noise, illumination, heat and air velocity were taken (Table 1). Measured values of temperature and air velocity are suitable for work they are doing. Also noise level is within recommended values since conversation between patients and medical personnel is needed (doctor is giving instructions to the patient and patient can also ask questions). Space illumination is extremely low and this is a problem because the working procedure requires darkness.

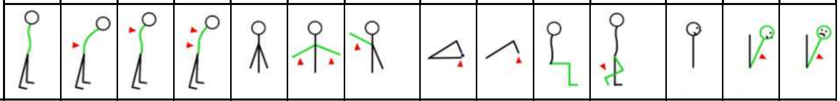
Table 1: Noise level, illumination, temperature and air velocity

	Measured values			
	Noise [dB]	Illumination [lx]	Temp. [ºC]	Air velocity [ms^{-1}]
	50	20	24,7	0,07
	45	10	24,6	0,14
	45	10	24,8	0,09
Average value	46,6	13,3	24,7	0,10

Results of OWAS method (conducted 3 days, 3 times per hour, 27 people) used to evaluate the strain caused by different operators' postures at observed workstations are presented in Table 2 and in Figure 3. Percentage of each body posture was calculated using equation (1) and also time portion for that body posture was calculated (2).

$$p = \frac{\sum F_p}{\sum F_s}[\%] \qquad t_p = \frac{450 \cdot p}{100}[\min] \qquad (1) \text{ and } (2)$$

Table 2: OWAS – calculated results with recommended measures

Body parts	Thoraxlumbal spine				Upper limb			Hands		Lower limb		Head		
	1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.3**	**5.1**	**5.2**	**5.3**
														
Nr. of measures	24	6	12	39	21	6	54	54	15	30	51	21	33	27
p_i [%]	29,6	7,4	14,8	48,1	25,9	7,4	66,7	78,3	21,7	37	62,9	25,9	40,7	33,3
t_{pi} [min]	53,3	13,3	26,6	86,6	46,6	13,3	120,1	140,9	39,1	66,6	113,2	46,6	73,3	59,9
Measure	☐	☐	☐	☐	☐	☐	●	★	☐	☐	●	☐	●	●

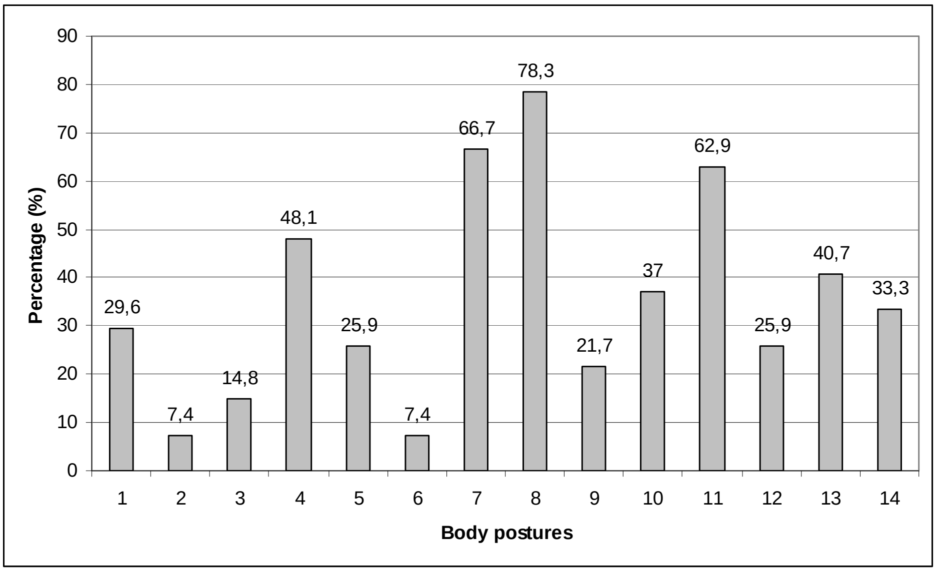
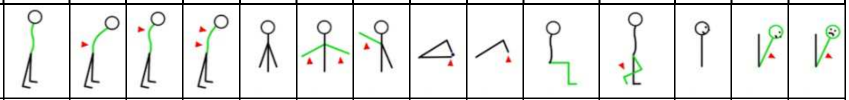


Figure 3: The histogram of the OWAS results applied at the inspected workplace

Obtained results were compared with recommended measures (Table 3) and results are presented with signs. Results confirmed previous prepositions showing that body postures 2.3 - one arm above shoulders, 3.1 – fine grasp and 4.3 – standing on one leg have high percentage and therefore changes are needed immediately or in near future. Also for head postures 5.2 – bent forward head and neck and 5.3 – bent to side head and neck changes are needed in near future. For another postures changes are not needed unless it makes discomfort.

Table 3: OWAS – review table of recommended measures

Part	Thoraxlumbal spine				Upper limb			Hands		Lower limb		Head		
	1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.3**	**5.1**	**5.2**	**5.3**
OWAS / %														
10	□	□	□	●	□	□	□	□	□	□	□	□	□	□
20	□	□	□	●	□	□	□	□	□	□	□	□	□	□
30	□	□	●	●	□	□	□	□	□	□	□	□	●	●
40	□	●	●	▲	□	●	●	□	□	□	●	□	●	●
50	□	●	●	▲	□	●	●	□	□	□	●	□	●	●
60	□	●	▲	▲	□	●	●	□	□	□	●	□	▲	▲
70	□	●	▲	▲	□	●	●	□	□	□	●	□	▲	▲
80	□	▲	▲	▲	□	▲	▲	★	★	□	▲	□	▲	▲
90	□	▲	▲	▲	□	▲	▲	★	★	●	▲	□	▲	▲
100	□	▲	▲	▲	□	▲	▲	★	★	●	▲	□	▲	▲

Legend for Table 3:

□ - changes are not needed
● - changes needed in near future
▲- changes needed immediately
★ - needed intensive observation

5. CONCLUSIONS

The results of the presented research using OWAS method confirmed the nursing complaints about high back pains and high load on hands. Likewise attention to eyestrain of operators that perform photography on specialized camera should be drawn. The problem is operators' presbiopia and lens accommodation that lead to fatigue. Another problem is lighting that appear at every flash. For solving this problem an assistant should wear protective glasses.

The presented problem is complex and further investigation should be taken. Since OWAS has some limitations body postures could be checked using other methods such as RULA or REBA before taking restrictive changes.

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