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ERGONOMICS AND DISABLED EMPLOYEES – A FORGOTTEN DIMENSION? HOW CAN WE FACE IT THROUGH COLLABORATION BETWEEN ACADEMIA AND BUSINESS

N. Rebernik[1], L. Moody[2], J. Saunders[2], S. Staskowiak[3], A. Kadyrbaeva[3]
[1]OZARA d.o.o., Maribor, SLOVENIA, natasa.rebernik@ozara.si
[2]Coventry University, Coventry, UNITED KINGDOM,
louise.moody@coventry.ac.uk, janet.saunders@coventry.ac.uk
[3]European Association of Service Providers for Persons with Disabilities (EASPD),
BELGIUM, sonia.staskowiak@easpd.eu, Kadyrbaeva@easpd.eu

Abstract

The right to work and to actively participate has become one of the basic rights in modern society. Furthermore the work, work place and work processes need to be designed in a way to ensure that they are safe, efficient and easy to use, and that they are not only accessible to employees without disabilities, but also that they meet needs of those employees that have some kind of impairment or disability and with that special needs at work.
Here Ergonomics, Universal design and Inclusive design step in, aiming at creation of an inclusive working environment for all. The article is presenting main results and a two year work of an EU funded project, conducted by a consortium of 10 partners from 6 EU countries, joined into a firm business-academia Knowledge Alliance. The ERGO WORK project brought to the involved stakeholders an important knowledge exchange and a deeper insight into methods, approaches and solutions for creating Ergonomic Work Places for All.

Keywords*: Ergonomics, Universal design, Inclusive design, Disabled people, Equal employment*

1. INTRODUCTION

In 2013 there were around 80 million people with disabilities in EU [1], and in 2012 around 42 million of them were aged 15–64 in the EU-27 if considering the EHSIS definition of disability [2]. In Europe there is clearly a growing population of people facing barriers in regard to physical and/or sensory impairment (be it light, moderate or severe), thus resulting in a great need to make the work places, services, spaces, information accessible, available and inclusive. Even more, a shift from the Medical to the Social model is still being very slow, meaning that disability is still too often recognised as a condition of the individual (medical model) instead of the inability of the society to adapt to the needs of all its citizens by facing the barriers and negative attitudes and including people regardless of their individual differences (social model). This sets the need to tackle the problem through a holistic approach, involving users and stakeholders throughout the whole research and design process by implementing User-cantered, Ergonomic, Universal, and Inclusive design to promote reasonable

accommodation at work and thus ensure equal employment opportunities also for persons with disabilities.

The concept of "reasonable accommodation" and the principle of adapting the workplace and/or job to the individual needs of (disabled) employees were introduced by EU Directives in 1989 and 2000. The inclusion of employees with disabilities in the mainstream workplace is a European priority. It is likely that both mainstream and sheltered workplaces will need far greater adaptation and accessibility to enable more disabled people to work and to meet the European Disability Strategy 2020 target of 75% mainstream employment for all citizens. Ergonomics, Universal, Inclusive Design expertise could have a key role to play. The European Disability Strategy (2010-2020) strives for a unified approach to inclusion, and to significantly increase the proportion of people with disabilities working in the open labor market [1, 3]. Significant variation exists across Europe in the 'equality gap' [4]. In developing countries, 80% to 90% of working age people with disabilities are unemployed; in industrialized countries the figure is between 50% and 70%[5].

The aim of the paper is, firstly to present main results of the ERGO WORK project [6], financed by European Union within the Lifelong Learning Programme, and secondly to emphasize the importance of Ergonomics, Universal and Inclusive Design in regard to equal opportunities for persons with disabilities in employment and at work.

2. ERGO WORK - Joining academia and business for new opportunities in creating ERGOnomic WORK places

Years ago an intensive discussion between representatives of OZARA Service and Disability Company Ltd. and the University of Maribor from Slovenia brought up several issues in regard to Ergonomics for disabled employees, among which there were mainly three deliberated. The first was a lack of specific ergonomic educational programmes involving ergonomics for disabled persons, the second was a lack of cooperation between higher education, research and real working environments, and the last was a lack of equal employment and working opportunities for disabled people. The idea about an international project arose, and a new project was born, namely "ERGO WORK - Joining academia and business for new opportunities in creating ERGOnomic WORK places" [6]. Finally, after being submitted by a consortium of 10 partners from Slovenia, Poland, United Kingdom, Italy, Spain and Belgium, the project was approved for EU funding, under Lifelong Learning Programme, Erasmus KA action (www.ergo-work.eu). Between 2013 and 2015, during the two active years of its implementation, outstanding results were achieved. The project focused on understanding barriers to the inclusion of disabled people in the workplace, and tackling these barriers through education and collaboration between academia and industry. It considered how to design work places and organize work and work processes, not only accessible to employees without disabilities, but also to meet the needs of those employees who have some kind of an impairment and special needs. Through the ERGO WORK Project the discipline of Ergonomics, accompanied with Universal and Inclusive design aspects, was applied. It's aim was to try to achieve a work-based inclusion through a.) intensive collaboration between academia and business, b.) upgrading the existing higher education curricula, c.) equipping students in disciplines, related to Ergonomics, with new knowledge and direct experience to become future experts, d.) and last but not least, to achieve awareness among employers and employees about the needs and abilities of disabled people at work.

The ERGO WORK project arose from the need for new knowledge, methods and approaches for equal opportunities of disabled people in labour market inclusion. The reasons for undertaking this project therefore were:

- Lack of HEI-B cooperation in Ergonomics in general and specifically for persons with disabilities;
- Lack of specific contents, modules and approaches in addressing equal opportunities work place design for persons with disabilities in most Curricula Ergonomics
- Lack of experts with specific knowledge in Ergonomics for persons with disabilities;
- Lack of equal opportunities for persons with disabilities due to a.) lack of ergonomic work places responding to PWD special needs, b.) lack of awareness amongst employers about the potential work efficiency of persons with disabilities with adapted ergonomic work places.

While looking for solutions experts discovered that the problem should be explored and addressed within a wider HEI-B alliance, not only within the employment area. The teaching of Ergonomics and approaches to the inclusion of persons with disabilities were recognized to lack strong cooperation and knowledge exchange between students, academia, schools, Vocational Educational Training systems and Business/Industry. Thus a long-term objective, aligned with the Article 27 of UN Convention on the Rights of PWD [7], was defined, aiming to set the foundation for a systematic sustainable cooperation between Academia and Business and all other relevant stakeholders in Ergonomics for persons with disabilities in order to foster Reasonable Accommodation at work.

Through a strong Business, Academic and Research alliance the project brought to the involved stakeholders a deeper insight into methods, approaches and solutions for creating Ergonomic work places for persons with physical disabilities, the blind and visually impaired, the deaf and hard of hearing as well as persons with mental health problems and/or intellectual disabilities.

During the two years of the project's implementation, the partnership carried out a.) an in depth analysis of the current situation in the European area (among relevant stakeholders and in the existing curricula), b.) updated the existing Ergonomics teaching contents at partner universities, and c.) finally tested and implemented the impact of the teaching contents within six pilot projects at involved Slovenian and Polish companies, carried out by four multidisciplinary working groups of students, professors, company staff and targeted Persons with Disabilities. Through an intensive promotion, dissemination and sustainability campaign we have been promoting sustainable cooperation between Academia and Business and all other relevant stakeholders in Ergonomics for Persons with Disabilities in order to foster Reasonable Accommodation at work. One of the important final steps has been addressing the System and Policy makers on regional, national and EU levels with two sets of recommendations: Recommendations for Multidisciplinary Curriculum Ergonomics [9] & Recommendations to the System and Policy makers [10].

2.1. In-depth Analysis of existing Curricula and Stakeholder needs

The study was carried out through an online survey in all 6 partner countries (Slovenia, Poland, UK, Italy, Spain, and Belgium) and an in-depth analysis of curricula containing Ergonomics content, focusing on curricula in the six partner countries [8].

2.1.1. Curricula analysis

An in-depth analysis was carried out, of curricula containing Ergonomics related content, focusing on curricula in the UK, Slovenian and Polish University partners, with additional input from the other partner countries and institutions. The study has drawn together a summary of Ergonomics teaching from 13 HEIs, 17 faculties and 6 countries. The content of the courses taught at these institutions was explored through face to face and telephone interviews. We wanted to understand what was needed to improve training for ergonomists in tackling the needs of disabled people in the workplace.

2.1.2. Stakeholder needs analysis

Stakeholder needs were gathered via an online survey, distributed throughout the networks of the 6 partner countries and completed by 480 participants across the 6 countries. The sample sizes completing the online survey differed between countries, Slovenia returning the largest number of survey completions. To prevent these differences skewing the data as a whole, the questions were analysed by country. The survey was completed by participants with, and without a disability, and there was also good representation from participants in positions of management responsibility, to provide the employer view.

2.1.3. In-depth Analysis Main findings

In whole, the study aimed to determine what a future curriculum should include in terms of the needs of disabled people in the workplace. There are a range of subject areas that might be relevant, and they may be drawn from both within, and outside of ergonomics as it is currently taught within the surveyed institutions. The data collected has shown a variable picture across the 6 European countries surveyed in terms of the adaptations made for disabled persons and the taught content available to ergonomics students. A need for better European collaboration and transfer of knowledge and practice in this area has been identified.
Our conclusion was that to improve training in Ergonomics for the needs of disabled employees, existing Ergonomics teaching would need greater tailoring to their specific needs. Our investigations proposed the following topics to be included in the teaching:

- inclusive design – ageing, different abilities, range of capabilities;
- empathic methods of design to raise awareness of students;
- some understanding of organisational behaviour;
- assistive technology knowledge;
- accessible environments knowledge;
- share knowledge about tools for inclusive design;
- include more knowledge about mental health needs – generally this area is neglected;
- focus on workplace interventions and PWD needs;

- incorporate knowledge from the 'Occupational Health' field and/or consider interdisciplinary cooperation. [9]

2.2. CURRICULUM ERGONOMICS – INCLUSIVE WORKPLACE DESIGN

In response to the survey results, the ERGO WORK project developed a new elective training module in inclusive workplace design for Ergonomics related courses in Slovenia and Poland. Five different modules were initially planned covering different types of disabilities and universal design. After advice from Coventry University, the five modules were merged to move away from a medical model of disability; and towards a broader understanding of Universal or Inclusive Design. The training module is specifically aimed at equipping students to improve jobs and workplaces for disabled people and consists of five teaching contents:

- Teaching content 1: Work Study and Ergonomics for PWD (Persons with Disabilities) – Understanding the workplace and job.
- Teaching content 2: Characteristics of PWD in Working Environment – Understanding individual employees and their needs.
- Teaching content 3: Ergonomics in Business – Understanding the job and business.
- Teaching content 4: Inclusive Design.
- Teaching content 5: Mobility of PWD (Persons with Disabilities).

Within each of the five teaching contents extended teaching materials, assignments and exercises were developed, tailored to local conditions in Slovenia and Poland, where they were also piloted through a serious of Pilot projects in cooperation with local companies.

2.3. PILOT PROJECTS IN SLOVENIA AND POLAND

2.3.1. Aim

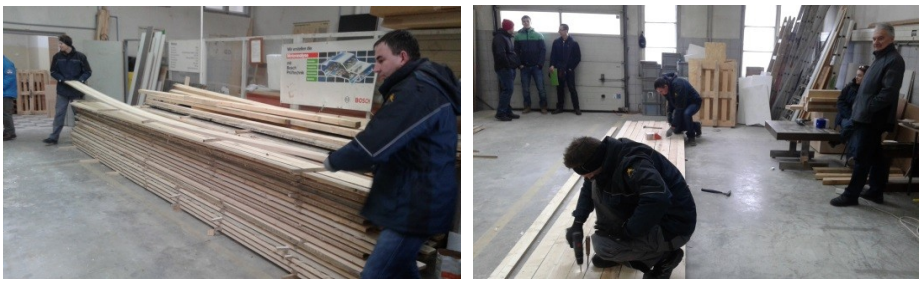
The aim of the Pilot projects was to test the teaching contents in a real business environment facing real business needs and challenges in creating human, disabled employees adapted work places.
The pilot projects were planned to be (and were) implemented in 2 'testing countries', Slovenia and Poland, where the partnership has established firm national alliances of Universities, partner companies and associated companies.

2.3.2. Implementation

The Slovenian and Polish partners carried out several meetings and creative workshops with the potential companies for collaboration to identify suitable workplaces in which the curriculum knowledge could be tested and applied. As a result 4 multidisciplinary groups were formed of 6 students alongside 3-4 experts coming from academia and business (2 groups in Slovenia, 2 groups in Poland). 6 pilot projects were implemented (Table 1). Pilot project 1 is briefly presented through Figure 1, showing working process at OZARA d.o.o., and Figure 2, showing OWAS analysis chart with body stress details, and a sketch of a rotatable loading table, ergonomic chair and other suggested improvements.

Table 1: Pilot projects implementation

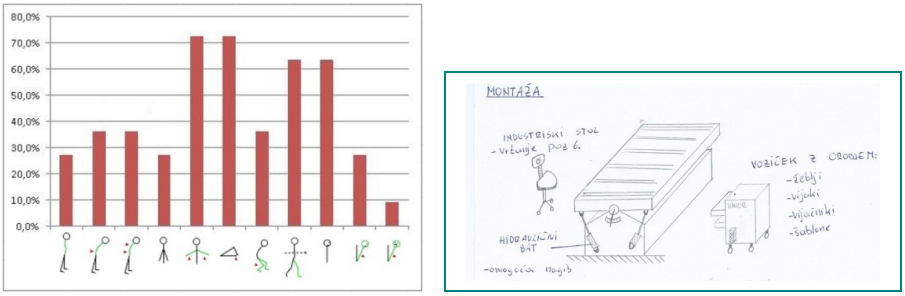
Pilot project no. - Country	Company	Work place/process
PP1 - Slovenia	OZARA d.o.o. Disability company with min.40% disabled employees. & Kovinarstvo BUČAR s.p. Metal company, a client of the disability company OZARA d.o.o.	a.) Ergonomic analysis with proposed improvements for work places and a work process in a production of a 6-m long wooden pallet (Figures 1 and 2) b.) Accessibility analysis of premises from a perspective of physically and sensory disabled employees c.) Adaptation of an office work station of a non-disabled employee at risk of back injures (a sitting-standing work station employed).
PP2 - Slovenia	Bodočnost Maribor d.o.o. Disability company with min.40% disabled employees.	a.) Ergonomic analysis with proposed improvements for the work places and work processes at an assembly-production line of cosmetic products b.) Accessibility analysis of company premises a perspective of physically and sensory disabled employees
PP3 - Poland	Łuksja Sp. z o.o. 70% of the workforce have a disability.	Review of the activity of using the multi-ply spreading and cutting machine and proposal of improvements for ease of use.
PP4 - Poland	Medical & Diagnostic Center Ltd. Medical centre	Work place was analysed and re-organised to better fit the needs of a call centre operator with a disability.
PP5 - Poland	Asaj Network of electrical installation and lighting stores	Analysed the workplace with proposed solutions for a sales manager with disability.
PP6 - Poland	UDT Office of technical inspection	Analysed the workplace with proposed solutions for an employee of the Administration Department



a. b.

Figure 1: 6-meter long wooden pallet production process, Pilot project 1 (Slovenia); a.) Carrying wooden planks, b.) Drilling on the floor.

Through the pilot projects a number of recommendations for improvements in workplace design and layout were suggested. After completion and evaluation of the pilot projects, the curriculum and the contents were finalised and mechanisms to ensure their sustainability in the Polish and Slovenian partner universities continue to be explored. The ergonomics based content may be a useful addition to programs in engineering, design, occupational health or business.



a. b.

Figure 2: 6-meter long wooden pallet production process, Pilot project 1 (Slovenia); a.) OWAS analysis, b.) Sketch of proposed improvements.

2.3.3. Main results and benefits of the Pilot projects

The projects led to a number of benefits for those involved. The students involved gained experience in collaboration with business, gaining new knowledge about ergonomics, inclusion and business demands. They gained empathy with the employees they were working with. Employees with disabilities were involved in co-designing solutions for their working environment, as well as gaining an understanding of ergonomic principles. The academics involved benefitted from the knowledge exchange with business as well as the development of core teaching content. The business partners benefitted from improvements to their working environments and new knowledge about ergonomics and inclusive design.

2.4. RECOMMENDATIONS TO THE SYSTEM AND POLICY MAKERS

Employment-related policies are under the competences of Member States in the European Union. Therefore, it is important to provide recommendations to the system and policy makers on both European and national levels.
Inclusion of disabled persons in the open labour market is a high-priority objective for Europe. Addressing the special needs of disabled employees through tailored ergonomic solutions and workplace adjustments is one of the ways in which this objective can be achieved. Therefore, the European Commission (EC) and the European Parliament need to take the lead in stimulating fully inclusive employment conditions by Member States.
Within the ERGO WORK project, with reference to the EASPD Thessaloniki Declaration (2009), a set of recommendations has been developed, emphasizing the importance and benefits of social inclusion and active involvement of disabled persons in the labour market. A brief summary is presented in Table 2, whereas the complete set of recommendations is available at the project's website as an official sustainability result, namely "Recommendations to System and Policy makers" [10].

Table 2: Recommendations for System and Policy makers on EU and National levels (brief summary)

EU level	National levels
To promote the development of employment opportunities for Persons With Disabilities (PWD) in the framework of the European Employment Directive and the European social dialogue	Member States should ensure legal framework guaranteeing adapted and fully accessible workplaces of high quality, and further on include in their Action Plans measures to combat discrimination and social exclusion, and define clear targets to be achieved on reduction of unemployment rates and increase of employment of PWD.
To extend the spectrum of employment opportunities for PWD in terms of Public Procurement, under European Social Fund etc.	To raise awareness among employers, able-bodied employees and the public in general about the specific needs of PWD. Improvements need to be made in terms of information and the overall culture at workplaces.
To encourage better European collaboration and transfer of knowledge and practices in the field of ergonomics and workplace adjustment for PWD.	To foster the enhancement of information for disabled employees. They need to be conscious of their rights, of EU provisions for meeting their needs, and of what adaptations are possible to facilitate them.
To foster the development of professionals specialized in ergonomic solutions for PWD, and to promote multidisciplinary ergonomics curricula in universities, with the focus on inclusive, accessible and universal design.	To support more research in assistive technology and accessible environment solutions, as well as in the specific needs of disabled people, particularly in areas often neglected in workplace design (e.g. mental health needs and intellectual disability), and to improve knowledge about adaptations that goes beyond purely physical adaptations to buildings.
The Erasmus+ programme should tackle the promotion and the development of training opportunities for ergonomics specialists focused on the needs of PWD	To develop policies based on ‘career thinking’ as a precondition for sustainable employment, taking also into consideration Life-long Learning strategy.
To promote tailor-made job opportunities addressing the needs and abilities of PWD while providing them with the necessary security, including flexible social protection schemes	To raise awareness among companies about the benefits of employing PWD, and to support with subsidies, know-how and other contributions for employing PWD, for designing tailor made work places for PWD, employing experts in Ergonomics for PWD etc. To strengthen incentives for employers to hire disabled people, and to cover the costs linked to adjusting the work place
To develop instruments to collect accurate and comparable data on employment and on the situation of PWD in employment, thus promoting collaboration with Eurostat and academic world.	To support the establishment of (supported employment) agencies that assist employers in adapting the work place, coaching, job design, job creation and all other services required to support PWD in employment
To have a clear overview of the needs of PWD in terms of employment, it is crucial to involve representatives of the disability sector and the academic world in political consultations on relevant topics.	The public sector needs to set an example by providing adapted and accessible work places for PWD.

3. CONCLUSION

The present article presents the findings collected through implementation of the ERGO WORK project and clearly arguments the need for further systematic approach to be undertaken at all operational levels, firstly promoting academia and business cooperation and secondly involving all relevant stakeholders, especially employers and (disabled) employees. Having made a step forward in academia-business cooperation, and the improvement of higher educational teaching contents through ERGO WORK project, the partnership recognized there was still not enough involvement of employers, companies and company staff identified, resulting in active participation in creating equal employment opportunities and reasonably accommodated workplaces for ALL.

In spite of strong efforts by all relevant stakeholders in the last decades, the EU and national strategic and legislative frameworks do not bring desired results. An employment rate among disabled people is in general still as low as 5%, which puts a group of disabled people under high risk of being or becoming socially excluded. Also those being employed, face great challenges in getting appropriate reasonable accommodation, respect, equal treatment and equal payment for their work.

On the other hand, employers face challenges, such as fear, ignorance, prejudice, high efficiency market demands, which prevents them to fully understand benefits of employing disabled persons or to understand how to accommodate a disabled person at work, not necessarily needing to invest in expensive accessibility solutions. Many times companies do not have the knowledge or resources to make changes. Moreover, there are cultural barriers to employment of people with disabilities, with employers in fear of making mistakes, and the costs associated with adaptations. This requires practical guidance on cultural and organizational change, emphasizing countless benefits of inclusive, ergonomically designed work places. Less absenteeism, increased satisfaction, motivation and efficiency at work, where employers care about their employees' accommodation and address their needs at work, are only a few of the benefits that should be promoted.

From the mentioned findings, a continuation of the ERGO WORK project has been considered a must. Thus a follow-on project, namely ERGO@work, has been developed and applied for funding under the Erasmus+ KA2 Strategic Partnerships. It's aim is to develop competences of employers and employees directly working with disabled people to gain more specific, tailor made knowledge on how to serve disabled employees in a most effective and user friendly way. When approved, the project will bring an added value to extending employers' and employees' competences by implementing a set of concrete activities and delivering a set of beneficial results: practical towards employers oriented training course, international event for mentors working with disabled employees, national training events for companies, a self-assessment tool for employers and employees on how accessible their companies actually are, a knowledge sharing platform (as an upgrade of existing ERGO WORK e-pltaform), and a set of practice-based recommendations to decision makers.

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A NOVEL MEASUREMENT SYSTEM FOR TESTING TRUNK NEUROMUSCULAR FUNCTIONS RELEVANT IN BACK PAIN

N. Sarabon[1,2], A. Panjan[2], M. Voglar[1]
[1] University of Primorska, Andrej Marusic Institute, Department of Health Study, Koper, SLOVENIA, nejc.sarabon@iam.upr.si and matej.voglar@iam.upr.si
[2] S2P Ltd., Laboratory for Motor Control and Motor Behavior, Ljubljana, SLOVENIA, info@s2p.si

Abstract

Low back pain (LBP) remains the most common musculo-skeletal health problem of the working population. In the individuals with LBP, several alterations in trunk neuromuscular (TNC) functions (mobility, kinesthesia, strength, postural stability functions, etc.) can be observed. These alterations differ among individuals with different occupations i.e. biomechanical work requirements. We need to know individual`s specific neuromuscular deficits in order to address them with prevention measures such as active rests, adaptation of work tasks and/or environment, etc. Objective assessment of work related changes of TNC functions has been limited to research laboratory environment. The aim of this presentation is to explain the purpose and technical/functional characteristics of the integrated measurement system for valid and objective assessment of the TNC functions. It has been developed as a part of the research project carried out between the university and the industry. This diagnostic system has opened a new avenue in prevention- and rehabilitation-related studies run by our research group.

Keywords: *Trunk flexion, spine stability, low back pain, postural reflexes, trunk mobility.*

1. INTRODUCTION

Nowadays, lower back pain (LBP) is the most common musculo-skeletal problem in working population. Based on epidemiological studies, 70 % to 85 % of people experience LBP once in a lifetime. In 60% to 70% of these the problem re-occurs several times and often leads to chronic pain [1]. Chronic LBP affects an individual`s life in general and decreases his/her quality of life. LBP limits movement and activities of daily living. As such, it is the second most common reason for absenteeism among all reasons (Drobnič-Kovač, 2002). To summarize, LBP represents a huge socio-economical problem in majority of developed countries, resulting in cumulative annual costs of several billions in EU [2].

In most cases, LBP has a multi-factorial background, the most important being biomechanical factors influenced by neuro-muscular, anatomical, morphological and functional characteristics of an individual. In people suffering from LBP, several modifications of trunk neuro-muscular functions can be observed: (a) delayed activation, increased activation level, pronounced direction dependence of activation, more phasic activation, and loss of selective activation have been shown for *m. transversus abdominis* [3], (2) decreased maximal strength, local muscular endurance, strength ratios between

muscle groups [4], (3) impaired kinesthetic sensory functions of the trunk, (4) increased postural sway during upright stance and impaired automatic postural responses to (un)expected mechanical perturbations [5]. In short, an optimal function of the trunk (being safe and efficient at the same time) should be grounded on a well-balanced relationship between stability and mobility influenced by the interplay of three components: passive tissue, muscles and neural control. When this ground stones are disrupted, a cascade of injurious biomechanical changes start to take place, resulting in tissue trauma and irritation.

Objective evaluation of trunk related neuro-muscular functions and musculo-skeletal characteristics help identify the exact changes which can be either a result of or a cause for LBP. In spite of the obvious scientific proofs, such evaluation procedures have been limited to research labs and have not been introduced to daily work of specialists in preventive care or rehabilitation. In the framework of our recent research-and-development project, we successfully bridged the above mentioned gap, having built the trunk neuromuscular control (TNC) diagnostic system aimed for use in daily practice of professionals from different fields – dealing with prevention and rehabilitation of LBP. The aim of this paper is to give an insight into the general concept of the TNC system and to present specific testing procedures encompassed in it.

2. TECHNICAL CHARACTERISTICS OF THE SYSTEM

The TNC measurement system was developed as a research prototype to study trunk neuro-muscular control in the context of chronic LBP prevention (ergonomics) and treatment (optimization of physiotherapy). Technical characteristics of the system had to meet the needs for objective evaluations which are described into more details below. An additional requirement was that the measurement system had to be portable, thus enabling for on-field measurements. The system has been modified and optimized, based on our own user experience, leading to the current third version.

The TNC measurement system consists of a vertical tower. Sensory components are attached on two sides of the tower. There is also a small computer table on the side, underneath which all the electronics are embedded. The system encompasses the following measurement components: (1) bilateral force plate with eight force sensors used to measure centre-of-pressure trajectory during postural tasks, (2) wireless inertial measurement units (IMUs) used to measure orientation of body segments on which they are attached, (3) surface electromyography (EMG) synchronized with the perturbation module, (4) strain gauge based force sensor for measurement of voluntary muscle force, (5) electro-magnetic perturbation module used for applying load over the subject`s hands, and (6) high resolution camera for body posture analysis. A custom developed software (ARS trunk, S2P, Science to Practice, Ltd., Ljubljana, Slovenia) unify all the measurement components around the central acquisition/computer unit. The software is aimed for carrying out signals acquisition, storage, post-processing, quantification and building reports on results. Let us give a concise overview of the measurements we perform using our TNC system for studying LBP underlying mechanisms.

2.1 Mobility/flexibility

Regarding mobility of the trunk the following four movements are being tested using IMUs: (1) flexion, (2) extension, (3) left lateral flexion, and (4) right lateral flexion maximal range-of-motion. For all the four movement directions maximal range of motion is measured separately for angular change at sacrum, lumbar spine and thoracic spine. The subject performs the trunk movements from an upright stance position. Additionally, mobility of hips is tested in directions of: (1) flexion, (2) extension, (3) internal rotation, and (4) external rotation. Generally speaking, a balanced mobility relationship between hips (high/good mobility) and lumbar spine (moderate mobility and good stability) is one of the ground-stones of healthy back.

2.2 Strength

Muscular strength of the trunk is tested using maximal voluntary contraction force under isometric conditions (Figure 1). Three muscle groups are tested (trunk flexors, extensors and lateral flexors). The isometric dynamometer consists of a pelvic fixator (padded horizontal plate with a rigid strap) and a sensorized shoulder-girdle support. The latter detects the developed voluntary force. Besides the maximal voluntary force, local muscular endurance of trunk extensors is also tested (time to fatigue defined as the time until failing to sustain the 60% maximal voluntary force.

Figure 1: Testing maximal voluntary contraction force/torque for trunk extensors under isometric conditions (left) and the corresponding signals (right).

2.3 Position Sense

During the measurements of trunk position sense, IMUs are placed over the spine in the same way as for the mobility/flexibility tests. During this test the subject wears a non-transparent mask in order to exclude visual information and to facilitate use of kinaesthetic senses in the repositioning task. The task of the subject is to bent forward (trunk flexion), hold the position of ~50% range-of-motion for 3 seconds (guided by the measurer), return to an upright position and repeat the task again with the aim to match the pre-gained positions as precisely as possible (self-performed). The outcome measure of this test is called active re-positioning error, being defined as the absolute angular difference between the guided (reference position) repetition and the self-performed (match) repetition.

2.4 Weight-bearing Symmetry

The ground reaction force contra-lateral (a)symmetries are tested using two different tasks: (1) weight bearing (a)symmetry during different parallel stance positions – upright, semi-squat, and deep squat; and (2) left-to-right (a)symmetry in static balance measured with centre-of-pressure parameters related to single-leg quiet stance task. During both the tasks, the subjects sustains akimbo (hands on hips) position of his/her hands. Quiet stance stability is measured using centre-of-pressure parameters (mean velocity, amplitude and frequency) and contra-lateral difference is calculated.

Figure 2: Measurement of postural reflex responses to sudden mechanical perturbation (left) and the corresponding array of signals for a selected muscle (right).

2.5 Automatic activation patterns of trunk muscles

Two types of automatic postural muscle actions are being tested: (1) anticipatory postural adaptations which proceed quick voluntary arms flexion to 90° and (2) postural reflex responses evoked by sudden mechanical loading (6-8% body mass) applied over the arms (Figure 2). In both tests the subject is equipped with EMG sensors (i.e. electrodes) placed over the selected trunk muscles – bilaterally m. multifidus, m. erector spinae, m. obliques abdominis internus, m. obliques abdominis externus, and unilaterally m. rectus abdominis and m. deltoideus. Time delays (i.e. latencies) and amplitudes of the pre-processed EMG signals are being quantified and averaged across 20 repetitions to ensure appropriate reliability. The referent time event for latencies calculation is the onset of m. deltoideus activation for APAs and the instant of load release for PRRs.

3. CONCLUSION

This paper delivers a report on technical characteristics of the custom developed TNC measurement system focusing on objective evaluation of movement functions related to LBP. Inspite of the initial aim of the TNC system being fundamental and applied research, the system has found its way to daily clinical practice. Namely, some of the consortium partners (Port of Koper, Science to Practice Ltd., Motus Melior Ltd.) adopted it as a part of their ongoing testing and decision making routine. We strongly believe that our mobile TNC system will enable us to run new applied research in the area of musculo-skeletal health of working population and gain objective data that will help better understand sources of LBP pathologies and thus optimize related preventive measures.

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