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Development of a Model for the Prevention of Work-Related Musculoskeletal Disorders in the Upper Extremities

VIIVE PILLE

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TALLINN UNIVERSITY OF TECHNOLOGY
Faculty of Mechanical Engineering
Technomedicum
Institute of Cardiovascular Medicine

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Supervisors:

Prof. **Peeter Ross**, Institute of Cardiovascular Medicine,
Tallinn University of Technology

Prof. **Piia Tint**, Department of Business Administration,
Tallinn University of Technology

Prof. **Ruth Sepper**, Technomedicum,
Tallinn University of Technology

Opponents:
Prof. **Janis Ievinš,** Riga Technical University, Latvia
Assoc. Prof. **Eda Merisalu,** Estonian University of Life Sciences

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been presented for any academic degree.

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II. **Pille, V.,** Tuulik, V.-R., Saarik, S., Tint, P., Vare, T., Sepper, R.
Work-related musculoskeletal symptoms in industrial workers and the effect of balneotherapy. *Agronomy Research*, 2015, **13**(3), 820–828.

III. **Pille, V.,** Reinhold, K., Tint, P., Hartšenko, J.
Comparison of musculoskeletal disorders development in Estonian office and garment industry workers. *Agronomy Research*, 2016, **14**(4), in web: www.agronomy.emu.ee.

IV. **Pille, V.,** Reinhold, K., Tint, P**.,** Hartšenko, J.
Musculoskeletal disorders caused by the static posture of office and garment workers. *International Journal of Biology and Biomedical Engineering*, 2016, **10**, 191–201.

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Myotonometry as a tool for determination of fatigue in the upper extremities of garment industry workers. The Proceedings of the 11th International Conference *BIOMDLORE* 2016, October 20 –22, Druskininkai, Lithuania, 42-45.

VI. **Pille, V**., Oha, K., Lauri, M., Tint, P., Tuulik, V-R., Tuulik, V., Meigas, K.
The prevention of computer workers health disturbances caused by physical and physiological risks. *Proceedings of The Latvian Academy of Sciences, Section B.,* 2016, **70 (**5), 20–26.

Paper I.

Objective: A basic study to explain the incidence of musculoskeletal pain in various groups of workers, to measure hand muscle tone and stiffness, and to determine the effect of various rehabilitation methods for work-related musculoskeletal disorders.

Methodology: The Standardized Nordic Questionnaire for Analysis of Musculoskeletal Symptoms (Nordic musculoskeletal questionnaire), a baseline questionnaire (working time, hours/days worked per week); the Pain Visual Analogue Scale (VAS pain scale) and the Student T-test for statistical analyses were used. The Nordic questionnaire was filled out by the patients before and after the balneotherapy. The pain regions and the severity of pain were identified.

Results: A systematic approach to MSDs is the key to optimizing workplace ergonomics. The investigation of patients showed that myotonometry is both viable and applicable for different workers groups, office-workers, measurement of muscle tone and stiffness. The methodology can be used for office and garment workers and patients with occupational diseases. 66 office, 40 spa customer service and 18 industrial workers were investigated. The pain was long-lasting (Table 1, *Paper I*).

Paper II.

Objective: To identify the effect of balneotherapy on the prevention of MSDs and rehabilitation from MSDs.

Methodology: The Nordic musculoskeletal questionnaire and the VAS pain scale were used. Handgrip force was measured with a hand dynamometer. The number of patients investigated was 114 (in balneotherapy, N=19; warm mud (42 ^{0}C) was used).

Results: *M. abductor pollicis brevis* and *M. adductor pollicis* stiffness and muscle frequency were measured with Myoton-3 and the results are presented here. Pain severity after balneotherapy decreased from 2,37 to 1,13 in the neck and from 3,25 to 1,03 in wrists on the VAS pain scale. The treatment was more effective in workers whose muscular pain complaints had lasted for a shorter period of time and whose pain was less severe. It can be deduced that early treatment is more effective. There was a high incidence of musculoskeletal pain in 114 persons: 68,4 % in the neck; 63,2 % in the shoulders of all the patients investigated.

Paper III.

Objective: To examine the risk factors contained in the work environment and workers' complaints of MSDs resulting from continuous work in a forced position or in a static posture.

Methodology: The standard EVS-EN 15251:2007 for microclimate and lighting measurements in the work environment and the TESTO 435-2 and TESTO 545 measurement equipment were used. The other methods used: the ART tool, myotonometry, the VAS pain scale. Office (N=54) and garment workers (N=49) were investigated.

Results: A model of the influence of workplace ergonomics and working conditions on the developing of MSDs was created. In the garment workers' group, ergonomic risks were estimated to be higher; the group had a high incidence of pain complaints and multiple pain sites. As a rule, the pains lasted longer than in the office workers, which points at MSDs of chronic nature.

Paper IV.

Objective: To investigate the pain location and intensity in the three group of people (office and garment workers and patients with occupational diseases) and draw a conclusion regarding their relationship to the stages of MSDs. The investigated persons were: office workers (N=54); garment workers (N=49) and patients with occupational diseases (N=34).

Methodology: The Nordic questionnaire, the VAS pain scale and the myotonometric study of *M. adductor pollicis* and *M. trapezius med*. were used.

Results: A model of the dependences of pain duration in different locations and at different stages of MSDs (office and garment workers, patients with occupational diseases) was created. The pain complaints develop significantly sooner than muscle soreness or elevated muscle tone. The data on stiffness and frequency gathered from the patients in a sitting position, are higher than in a lying position.

Paper V.

Objective: To investigate the stiffness, frequency and decrement of several muscles at the beginning and at the end of the workweek.

Method: The myotonometric method was used. Garment workers' (N=32) *M. adductor pollicis*, *M. trapezius med* and *M. erector spinae* were investigated.

Results: The values of measured muscle stiffness were between 156 and 278 N/m, and the natural frequency of muscles was from 11,2 to 16,6 Hz. The stiffness of *M. trapezius* and *M. erector spinae* increased and the frequency of the measured muscles did not change significantly during the workweek.

Paper VI.

Objective: To clarify the relationships between the physiological and psychological factors in computer-equipped workplaces.

Methodology: A quantitative study was carried out. 192 computer workers were involved. The Work ability index (WAI) and Kiva questionnaire (KIVA) were used.

Results: Similar questions in different questionnaires (WAI and KIVA) used in the study were compared. In the office workers' group, the average WAI was estimated as 40 points. Correspondingly, the office workers' work ability is higher and can be assessed as good. It is possible to reduce physical and psychological risk at workplaces by communication, training and solving problems regarding the issues of their complaints. Several hazardous factors (indoor climate, psychosocial factors, static posture etc.) can affect the computer-worker. If the improvements in the working environment are implemented, the level of stress of workers can be decreased.

INTRODUCTION

The work-related musculoskeletal disorders (WRMSDs) caused by the repetitive movements and other hazards in the workplace, represent one of the biggest work-health connected problems in developed and developing countries (Nunes and McCauley Bush, 2012).

There are various WRMSDs and the variety of risk factors causing the changes in muscles is large (force, draught, cold etc.) (Tanaka and McGlothlin, 2001). To classify the forms of diseases of the soft textures, different disorders names as WRMSDs, repetitive strain or cumulative trauma disorders are used (McGauley Bush, 2011).

The current study is dedicated on the WRMSDs in the upper extremities of the body. There are some models of dependence between the WRMSDs (Karsh, 2006; Nunes and McGauley Bush, 2012) and the risk factors available in the scientific literature. Despite the willingness to control the WRMSDs, taking into account also the engineering design changes, training programs of workers in ergonomics, organizational changes in work time and breaks, the WRMSDs continuously constitute a big percentage of human stress, often leading to permanent, partial or total disability.

WRMSDs cause huge costs to the institutions, industrial premises and to the health care system. There are some additional costs in the form of loss of the productivity, training of substitute workers and compensation costs to the disabled persons.

The knowledge and the causes of WRMSDs are not new. MSDs were diagnosed already in the eighteenth century by the Italian physician Bernardino Ramazzini. He clarified the connections between the work conditions and certain disorders of the MSD system. These disorders happened due to the not-regular movement and forced postures (Putz-Anderson, 1988).

The work-related MSDs affecting the upper body and limbs are recognized as one of the leading causes of pain and disability in occupational health also in Estonia (Kahn *et al.*, 2007; Zheltoukhova and Bevan, 2011; National Labor Inspectorate, 2015).

Due to long-lasting arm, leg, back or neck problems, the work ability in Estonia was limited for 59 % of 15–64 years old workers in 2009. In Europe, 95,000 musculoskeletal ailments incidents were registered in 2010 among the working age population, which caused the direct costs almost for 400 million euros. Particularly common are these problems among women 40–65 years of age. The loss of life years per 1000 inhabitants caused by the temporary inability to work was the largest in Europe (Eurostat, 2009). In 2008, the compensation was paid for 6,4 million working days in Estonia; 16 % of that was the compensation for musculoskeletal disorders. According to the various estimates, the cost of sick leave constitute 6–15 % of GDP in Estonia (Statistics Estonia, 2010).

Musculoskeletal disorders (MSDs) are the main cause of the developing of occupational diseases in Europe and in the world (Riihimäki, 1999; Schneider *et al.*, 2010; Middlesworth, 2015). The development of MSDs in the garment industry and working with computers are the research objects in the current study and the prevalence is given to the upper limb and back pain (Barondes, 2001; Buckle and Devereux, 2002; Barr *et al*., 2004), which are the biggest cause of incapacity for work, with direct costs amounting to between 0,5 % and 2 % of gross domestic product in Europe (Uegaki *et al*., 2007; Bevan *et al*., 2009).

Work-related musculoskeletal disorders (WRMSDs) affecting the upper body and limbs are recognized as one of the leading causes of pain and disability in the occupational health (European Foundation, 2005; European Agency, 2007; Coggan *et al*., 2013). The Global Burden of Diseases 2010 Study (Hoy *et al.,* 2015) is the most comprehensive effort to date for estimating the global burden of musculoskeletal disorders. The prevalence of and burden from musculoskeletal disease development are high throughout the world. MSDs are the most common work-related diseases in the US and Australia (Zheltoukhova *et al.,* 2012; Summers *et al*., 2015). The changes in work character (work with computers in the large scale; static posture and monotonous work elsewhere) have resulted in pain and functional impairment and may affect the neck, shoulders, elbows, forearms, wrists and hands. For example, in the Netherlands and Belgium approximately 30 % and 40 % of workers respectively, reported neck or upper limb musculoskeletal disorders (Meerding *et al*., 1998; Buckle and Devereux, 2002; Picavet and Schouten, 2003). There are multiple personal factors (age, gender, pain intensity, impairment of the blood flow, years of professional upper extremities overuse etc.) that could predict the development of the overuse syndrome or disease and the effectiveness of the preventive treatment (Colombini *et al*., 2002; Burgel *et al*., 2004; Corlett, 2009). Musculoskeletal discomfort (especially pain symptoms) which has a risk of worsening with work activities, and that affects work ability or quality of life, needs to be identified. Unpleasant sensations from the musculoskeletal system are experienced by everyone and can be adaptive in circumstances when muscle soreness is experienced after physical training, for example. In prevention of work-related MSDs, it is necessary to assess musculoskeletal symptoms that have a potential of affecting workers' health in a negative way. Symptoms at risk of worsening (e.g. paraesthesia as the first phase before pain may be present in entrapment syndromes) which reduce work ability or impair quality of life should be targeted (Haber *et al.,* 2012).

Usually WRMSDs develop slowly, mostly over a number of years, their symptoms in the early stage of the disorder are nonspecific by nature (Hägg, 1991, 2000; Hartvigsen *et al.,* 2000; Feuerstein *et al.,* 2003). The main causes of repetitive strain injuries overload overuse syndrome and specific diseases are long-term work in a forced position, static tension of a single muscle groups, frequent repetitive stereotypic movements, manual displacement of weights.

The aim of this research is to elaborate the conceptual model for prevention of work-related musculoskeletal disorders which enable the possibility to the occupational health doctors to elaborate the basis for prevention and rehabilitation from badly organized workplace ergonomics.

In the view of the absence of research in MSDs development of office, industry workers and patients with occupational diseases, the **research questions** of the current thesis are:

Can the myotonometry and pain questionnaires give substantial information on the development of MSDs?

Are there connections between the age, work character, pain duration, pain regions and the stages (3) of the development of MSDs?

Thesis motivation: the research is based on the myotonometric and pain questionnaires data of 505 Estonian office and industry workers, to describe the employees most painful body regions as a result of non-ergonomic conditions at workplaces, the possibilities to improve the situation, and give the knowledge for prevention and rehabilitation from MSDs to the workers and the occupational health doctors.

The hypothesis:

H1 – there is a significant difference between the duration of pain between office, garment workers and the patients with occupational diseases;

H2 – there is a significant difference between the stages of ailment and the occurrence of pain in different regions of the body;

H3 – there is a correlation between the intensity of pain in the neck, wrist and back regions and the workers age;

H4 – there is a relationship between the occurrence of pain and on the age of workers in various occupations;

H5 – there is a relationship between of the occurrence of pain and the stages of illnesses (three stages) and age.

The research tasks were:

- to determine the most important health risks for developing of MSDs of office and manufacturing workers and present the possibilities for rehabilitation (*Paper I*)
- to evaluate the available measurement methods of occupational fatigue and determine the most relevant method for effective rehabilitation (*Paper II*)
- to collect and analyse data on workplace ergonomics in offices and in the garment industry, to find the relationships between workplace ergonomics and the developing of pain in different muscles of the worker (*Paper II, III*)
- to work out a model for prevention of MSDs using the myotonometric and individual questionnaire data of different muscle pains in different workers' groups (including the patients with occupational diseases) (*Paper IV*)
- to examine the overuse (fatigue) of muscles with myotonometry in the beginning of the workweek and at the end of the workweek and to compare the results with the other researchers (*Paper V*)
- to show the psychosocial factors' influence to the development of MSDs (*Paper VI*).

The contribution: current research contributes to the elaboration of the conceptual model for prevention of MSDs in different groups of workers and the healthcare of patients with occupational diseases. The used research methods: ART-tool for clearing the ergonomic situation at the workplaces, Nordic musculoskeletal questionnaire and VAS pain scale for taking into consideration the pain sensations of workers, myotonometry for the experimental part of the work, the WAI and Kiva questionnaires for determination of psychosocial hazards influence on development of musculoskeletal disorders and the use of high-level statistics proved to be the tools for reaching the main aim of the study: the improvement of workers' health at workplace.

The novelty of the research lies in the determination of the importance of the most painful muscles in various body regions (in the neck, shoulders, elbows, wrists and back) dependences correlated to the pain duration (four stages), the pain severity, the age of workers and the three stages of MSDs in the preventive and rehabilitative medical activities. The novelty of the present study lies in the statement that the right hand of office workers is more painful than the left one (as proved by the questionnaires) due to a greater load affecting the right hand. Garment workers' both hands are painful to the same extent. The other authors' papers dedicated to garment workers' MSDs show the same tendency.

The study concentrates on the new myotonometrical method of investigation into muscle overuse which could help prevent MSDs development and loss of permanent work ability in the working age population.

The study was carried out during the years 2012-2015. The medical ethics committee of the National Institute for Health Development of Estonia approved the study, and the written informed consent was obtained from all the participants.

The structure of the PhD thesis includes the introduction, literature overview, research methodology, the main results of the study and the conclusions.

Abbreviations

General abbreviations and explanations:

ART-tool	–	assessment of repetitive tasks of the upper limbs
AT	–	after treatment
B	–	back
BMI	–	body mass index
BT	–	before treatment
E	–	elbow
EL	–	exposure level
EMG	–	electromyography
GW	–	garment workers
IMP	–	intramuscular pressure
IW	–	industrial workers
L	–	left (hand, shoulder, wrist)
MAS	–	musculo-articular stiffness
M. abd poll	–	*m. abductor pollicis brevis*
M. add poll	–	*m. adductor pollicis*
M. ext digit	–	*m. extensor digitorum*
M. er spin	–	*m. erector spinae*
M. flex car	–	*m. flexor carpi*
M. flex carpi	–	*m. flexor carpi radialis*
M. trapez	–	*m. trapezius medialis*
MTM	–	myotonometry
MS	–	musculoskeletal
MSDs	–	musculoskeletal disorders
N	–	number
Ne	–	neck
OD	–	occupational disease
ODP	–	patients with occupational disease
OHS	–	occupational health and safety
OW	–	office workers
R	–	right (hand, shoulder, wrist)
RL	–	risk level
S	–	shoulder
SD	–	standard deviation
Nordic musculoskeletal questionnaire	–	standardized Nordic questionnaire for analysis of musculoskeletal symptoms
W	–	wrist
WAI	–	Work ability index
TMG	–	tensiomyography
TS	–	task score
VAS pain scale	–	pain visual analogue scale (1 to 10)
WR	–	work-related

1. LITERATURE OVERVIEW

1.1 The prevalence of work-related musculoskeletal disorders

The most important problem to solve is the early detection and identification possible signs of work overload muscles overuse, which may lead to chronic diseases resulting in reduced work ability to the extent of disability. The symptoms occur with remissions and are dependent on physical workload; therefore, it is very difficult to objectively distinguish workers, who have permanent muscles overuse symptoms. One of the aims of the current study is to bring out possibilities of determination of the indications of a possible development of occupation disease and decrease of work ability.

Work, which does not allow physiological compensating changes in an organism by rest, will result in chronic damage and overload-based diseases not only in muscles, but also in tendons and joints as well as in the form of pinched nerves (carpal tunnel syndrome) and functional disorders (Dale *et al.,* 2013; Kapellusch *et al*., 2013; Harris-Adamson *et al*., 2014; Oha *et al.,* 2014). That is why it is essential to pay special attention to the development of muscle fatigue, availability of sufficient rest breaks, to primary complaints and individual assessment of physical workload (Sihawong *et al.,* 2010; Toomingas *et al.,* 2011; Taylor *et al.,* 2013; Coelho *et al.,* 2013).

For the rehabilitation from MSDs, different methods are used. One of them used in Estonia and elsewhere, is mud therapy (Schulz *et al.,* 2007; Chadzopulu *et al*., 2011; Pille *et al*., 2015). In the current work the accent is concentrated on the new health promotion and treatment methods that could help prevent MSDs development and loss of permanent work ability in the working age population (Garg and Kapellusch, 2009; Leah, 2011; Ditrolio *et al.,* 2011). Information about the circulatory system is very valuable because perfusion abnormalities are often an early stage in different malfunctions (e.g. overuse syndromes) (Barbe and Barr, 2006; Blagsted *et al.,* 2008; Anderson *et al*., 2010).

The methods for the determination of pain regions of the body, the Standardised Nordic questionnaire for the musculoskeletal (MS) symptoms (Kuorinka *et al*., 1987) and the pain Visual Analogue Scale have been used for decades to measure the individual level of MS pain of the upper extremities.

A complete understanding of this important occupational health problem requires further elucidation of the pathophysiological mechanism of tissue response, particularly at the early stage of these disorders. Work-related musculoskeletal disorders (WRMSDs) of neck and shoulder have been associated with several kinds of occupations and types of work, from those categorized as being physically demanding, such as farm work and patient care to those that are considered to be fairly static, such as dental work, work with video display terminals, sewing machine operators' work (Brisson *et al*., 1989; Chan *et al*., 2010; Chaiklieng *et al*., 2014) and office workers (Yu and Wong, 1996; Bernaards *et al.,* 2008; Gawke *et al.,* 2012). Repetitive tasks with hands can cause often the loss of work capacity in long term practice (Yassi, 1997; Shaw *et al.,* 2001).

Skeletal muscles are studied and assessed using myotonometry, a method devised in the years 1977 to 2011 at the University of Tartu by PhD Arved Vain. The Myoton-3 myotonometer enables to measure skeletal muscle tone as well as such biomechanical characteristics as stiffness and decrement. By using methods of mathematical physics, it is possible to analyse states of deformation and mechanical tension in materials. In the case of biological tissues, the standpoints of continuum biomechanics proceed from Athanasiou and Natoli (2008). Biomaterials have a discreet structure, so they cannot be considered a continuum. When solving many practical tasks it is possible to measure some behavioural parameters of biological materials directly, ignoring the strict conditions of the criteria of the continuous environment. When using continuum mechanics, the general principles, such as the constancy of mass, entropy, momentum and energy, will still apply.

A constant external contact, independent of the position of the device, the gravitation field or the user of the device, is created between the tested tissue and the testing end by means of a myotonometer with a force equal to the mass-creating gravity of the testing end mechanism. After that, a short-term external dynamic impact is exerted on the tissue by means of the actuator of the device, ending in quick release. The mechanical deformation of the tissue shape in real time as well as the response to that are registered in the form of a natural oscillation graph of the tissue by means of an acceleration transducer.

Prolonged work over load will cause hypoxia in muscles, most of the energy will be produced anaerobically, lactic acid and other metabolites will start accumulating in the muscles, causing muscle fatigue (Leclerc *et al.,* 2003; Jezelenberg *et al.,* 2004; Kennedy *et al.,* 2010). Increased oxygen consumption in case of physical labour is not the only cause of muscle hypoxia; it may also be caused by contraction of blood vessels due to increased muscle tone and in this way leads to a number of biochemical processes and produce pain (Vain, 2002a). Insufficient blood supply to muscles, as well as unfavourable metabolic processes play a primary role in the development of WRMSDs. Fatigue is a subjective manifestation of onerous physical work. Overloaded motor units, Cinderella units, develop in encumbered muscles and are replaced by other motor units; however, inflammatory changes will develop in muscles later on (Hägg, 2000; Kitahara *et al.,* 2000; Murthy *et al.*, 2001; McBeth and Jones, 2007).

According to the blood circulation physiology, the quantity of blood flowing through blood vessels depends mainly on the cross-section area of the blood vessels. Secondly, the blood flow rate is influenced by the pressure difference in any particular section of a blood vessel. In a working muscle, blood vessels are mechanically compressed during contractions. In the case of rhythmic muscular activity, blood flow decreases during contractions and increases during relaxation. Based on the differences, it is understandable why dynamic muscular activity does not cause as much muscle fatigue as static muscular activity. During heavy muscular activity, the oxygen consumption of an organism may increase by as much as 30 times, the cardiac output also increases (Athanasiou and Natoli, 2008).

The number of MSD investigations available in scientific literature is enormous. One group of the high incidence of WRMSDs are workers in the garment industry (Pun *et al.*, 2004). Many studies indicated that female sewing machine operators as well as several other groups of women who are performing monotonous, highly repetitive tasks and therefore have a high incidence of musculoskeletal complaints (Kaergaard and Anderson, 2000). The epidemiologic study divides the risk factors into two groups: (A) socio-demographic factors (used for collecting of detailed information on the history of disease), such as age, gender, ethnicity, level of education, type of job, and income; (B) information on upper limb disorders, which assessed the musculoskeletal problems in some body regions (neck, shoulders, elbows, hands/wrists). A number of epidemiological studies regarding work-related satisfaction, monotonous work with MSDs, role of job control, low social support, low job satisfaction, as well as monotonous work with MSDs, and the role of psycho-social factors and stress in these disorders have received increased attention (van den Heuvel *et al*., 2005; Park and Jang, 2010; Oha *et al*., 2010). The upper limb disorders are a subgroup of MSDs and are ailments which have an effect on the neck, shoulders, elbows, hands and arms (Leah, 2011). Wang *et al*. (2008, 2009a, b) have investigated different aspects of garment workers MSDs development, such as workplace and personal risk factors, self-reported pain and physical signs for MSDs, the influence of the chair improvement on the development of disorders (Fig.1.1).

Computer work cause health disorders already at an early age (Palm *et al*., 2007) in the form of headache, eyestrain and beginning of musculoskeletal disorder. The stiffness, frequency and decrement of muscles are possible to determine with myotonometry. The statistical values (validity, reliability of measurement) are also important in the choice of measurment methods (Pruyn *et al*., 2015). Computer work not only results in static muscle loading, but also in static spine loading. Although a relationship between sitting and low back pain could not be confirmed in a systematic review (Hartvigsen *et al*., 2000), prolonged sitting has been associated with development of disc degeneration (Videman and Battie, 1999). It has also been shown that static loading during sitting can affect lumbar spine stiffness (Maroudas *et al*., 1975; Beach *et al*., 2005). Furthermore, continuous compression on an intervertebral disc causes fluid outflow from the intervertebral disc (Kingma *et al.,* 2000) and may have a negative effect on tissue nutrition (Maroudas *et al*., 1975).

The current study is dedicated to the investigation of the development and prevention of office and garment workers' musculoskeletal disorders (Friedrich *et al*., 2000; Herbert *et al*., 2001; *Jahan et al.,* 2015). The literature in these fields is enormous: the computer workers health risks' investigations began with the creation of computers (Oha *et al*., 2010; Pereira *et al*., 2012, 2014; Mattoli *et al*., 2015) and now the influence of touch displays on upper-extremities are investigated (Camilleri *et al*., 2013).

Whereas heavy physical work is particularly associated with degenerative changes, static work is more often connected with tension neck syndrome (myofascial pain) or myalgia, local muscular pain, sore and movement resistance (Garg and Kapellusch, 2009). Static work concentrates on smaller muscle groups, which may be selectively overused through prolonged activation of some of the fibres in those muscles (Punnett *et al*., 1985). Exposure to static muscle activity is a well-established risk factor for musculoskeletal disorders, especially with regard to neck and shoulder pain (Barondes, 2001; Barbe and Barr, 2006; Zhang *et al*., 2011).

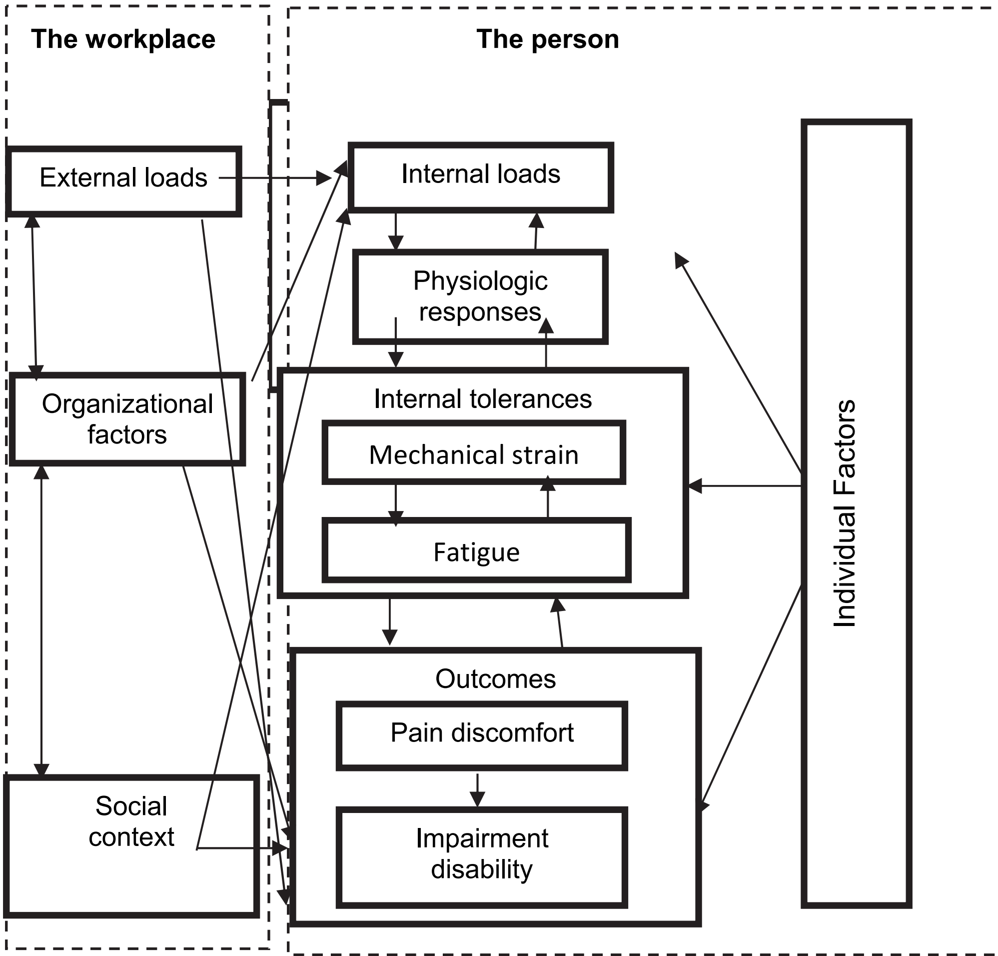

Figure 1.1 Risk factors development of musculoskeletal disorders (based on Lee, 2001).

Increased muscles tone and stiffness should be detected by the myotonometric method. It is possible to measure the trapezius muscle tone using Myoton-2 3 myometer (Vain, 2011). Both, work-related physical and psychosocial factors showed strong association with low-back pain and upper-extremity complaints. The work-related physical factors did not influence the absence of sickness, whereas the psychosocial factors showed some associations with sickness absence (Jezelenberg et al., 2004).

Garment and hospital (all female) workers were investigated. The prevalences of persistent shoulder, wrist, and hand pain were significantly greater among the garment workers. Workers engaged in hand sewing and trimming suffered especially high prevalences of persistent pain in all upper limb sites. GWs' assembly tasks appear to be associated with cumulative trauma of the hands and wrists; the biomechanical features of these jobs should be studied in greater detail. The findings demonstrate that an adjustable height task chair with a curved seat pan can reduce neck and shoulder pain severity in sewing machine operators (Rempel *et al*., 2007). An improved understanding of the mechanisms that characterize central sensitization and clinical pain will provide new approaches for the prevention and treatment of fibromyalgia and other chronic pain syndromes (Staud and Rodriquez, 2006).

The majority of occupational diseases in Estonia are musculoskeletal disorders (MSDs) (National, 2015). They are mainly caused by long-time monotonous work or work in awkward postures. Both office and industrial workers are complaining of musculoskeletal disorders. Work-related musculoskeletal disorders (WRMSDs) of office workers are of shorter duration, especially specific hand diseases like carpal tunnel syndrome and epicondylitis (Leah, 2011; Mattoli *et al.,* 2015). Manual workers, including garment workers, have a higher risk of developing an occupational disease. They are exposed to highly repetitive movements, awkward postures of hand, wrist, elbow, shoulder and neck. Usually, the work intensity is high (Wang *et al*., 2008; Hagberg *et al*., 2012).

In the previous study (Reinhold *et al*., 2008) of the Estonian garment workers MSDs, 230 persons (Group A, 16 men and 214 women) were involved. The main age of the investigated group was 36,2 years. Only 36 totally healthy persons (16 % of all examined) were identified in the sewers' group. The control-group (B) consisted of 33 persons (7 men, 26 women) of the management personnel (quality managers, sail agents, technologists, project managers, storekeepers etc.). In the control-group (B) 73 % of workers were healthy. The mean age of the control group workers was 36,8 years. The main complaints identified in the study in group A were: shoulder pain (27 %), lower back pain (46 %), neck pain (21 %), headache and fatigue of the head (15 %), carpal channel syndrome - moderate stadium (18 %), back pain in the pectoral region (8 %), fatigue of hands and disturbances in the sensitivities (16 %), pain in the hip (2 %), pain in the leg muscle (7 %), knee pains (6 %), pain in thigh muscle (2 %), back pain (8 %). Group B: upper limb pain (3 %), lower limb pains (12 %), pain in the neck (3 %), headache and fatigue of the head (12 %), knee pains (3 %), no carpal channel syndrome.

1.2 The concept of work-related musculoskeletal disorder (MSD)

Prolonged static muscle loading has been suggested to cause continuous activation of small motor units at a relatively high level of activation (Hägg, 1991). Subjects with relatively high levels of muscle activation and relatively few instants of relaxation during a low-intensity task have an increased risk of developing myalgia at the trapezius muscle (Veiersted *et al*., 1993). Computer work typically results in low-level static loading of back, shoulder and neck muscles, and could therefore increase the risk of developing muscular disorders like myalgia (Visser and van Dieen, 2006).

Stiffening of muscles is the forgoing stadium to the decrease of blood circulation in muscles. This stadium is the warning stadium for the development of MSDs. A great number of classification systems were found that described disorders of the muscle, tendon, or nerve that may be caused or aggravated by work (van Eerd *et al*., 2003). Duration of employment in piecework was associated with the prevalence of severe disability. A multivariate analysis found that the association was independent of age, smoking habits, education, type of task and total length of employment. The association was particularly strong for disabilities due to MSDs and in some cases (small numbers) due to cardiovascular disorders (Brisson *et al*., 1989). It has been shown that work-related shoulder pain is a major problem among garment workers (GW) in Thailand. The significant risk factors for shoulder pain included worked less than 10 years, no change of working posture each hour and inappropriate seat width. Work posture and workstation are contributing risk factors. In order to prevent shoulder pain in this occupational group, it is proposed that ergonomics education and redesign of seats at workstations should be routinely implemented (Steingrimsdottir *et al.,* 2004; Chaiklieng *et al.,* 2014).

There are different explanations of why prolonged, low-intensity work causes musculoskeletal diseases. A general model of how some of the most common pathological factors may act together in genesis disorders is presented in Fig.1.2.

Portable tensiomyography and myotonometry have been developed to measure mechanical and contractile properties of skeletal muscle. The ability of MTM more than TMG to detect an inherent change in stiffness can be conceivably exploited in a number of clinical/therapeutic applications that have to do with unnatural changes in passive muscle stiffness (Ditrolio *et al*., 2011).

Simultaneous intramuscular pressure IMP, electromyography EMG and myotonometric measurements were conducted during short-term and long-term isometric loading in subjects with pain in dorsal forearm. EMG and MTM parametres correlated positively and significantly with the IMP values and could explain 24 % to 73 % (r^2) of the variation found in IMP at the same time. Mechanical loading of the muscle increases IMP, which may subsequently decrease muscle perfusion. On a critical level of loading, the muscle membrane may not be able to stretch to allow the increase in the muscle volume, and as a result capillary flow can decrease significantly. At this moment, the muscle fatigue impairs the normal functioning of the tissue (Korhonen *et al*., 2005).

Psychological distress, aspects of illness behaviour, and somatic symptoms are important predictors of the onset of forearm pain in addition to work related psychosocial and mechanical factors. Misleading terms such as “cumulative trauma disorder” or “repetitive strain injury”, implying a single uniform ethology, should be avoided. (Macfarlane *et al*., 2000).

Workers are exposed to psychosocial, occupational, personal risk factors, which are connected with the development of MSDs. Bongers *et al.* (2012) divided the psychosocial factors into two groups: demand and control (monotonous work, time pressure, high concentration, high responsibilities, high work load, few opportunities to take breaks, lack of clarity, low control and little autonomy) and social support (poor social support from colleagues, poor social support from superiors).

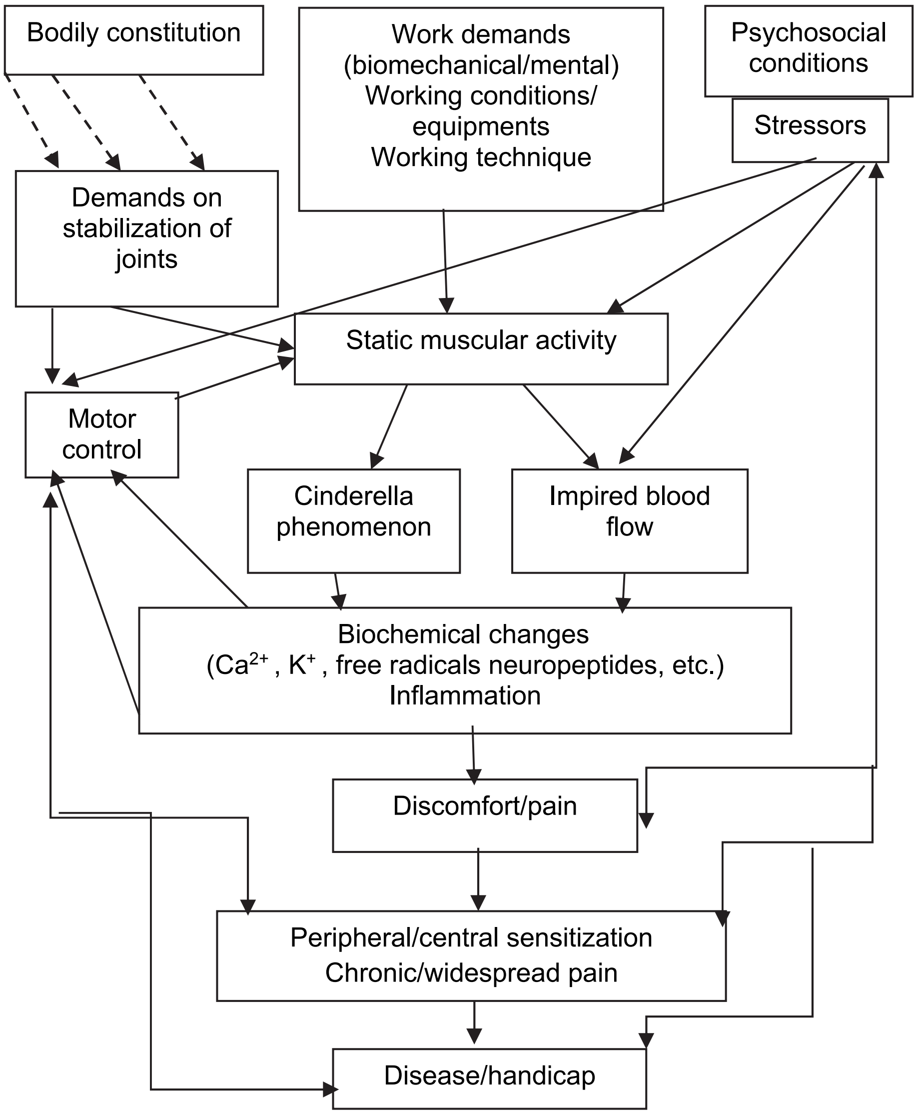

Figure 1.2 Model of factors involved in the emergence of disorders and ill health in the muscles with prolonged, low-intensity, static muscle activity (Toomingas *et al*., 2011*)*.

Skov *et al*. (1996) classified the psycho-social factors into four categories: demand (job demands, especially items like high demands for concentration and speed in the work; perception of competition), control (control over the content of the job, control over time aspects of the work, items like deciding working hours, holidays), support (social contact and support from colleagues, support from superiors, psychosocial work environment, (uncertainty of employment prospects (being concerned that one may become unemployed, transferred to another job, etc.), conflicts with colleagues, work role ambiguity, unclearly defined demands in the work, work role conflict, conflicting demands in the work, variation in the work).

1.3 Diagnostics criteria of work-related musculoskeletal disorders

Occupational illnesses develop by stages. At the first early stage, the rehabilitation is effective and the worker can return to work after a few weeks of treatment. At the next stage, treatment is possible, but it takes more time and sometimes the worker has to change the character of work in order not to be disabled in the future. In the case of occupational diseases, complaints and musculoskeletal changes are usually irreversible, but it is possible to use some rehabilitation methods to alleviate the sufferings of patients (Gawke *et al*., 2012; Pille *et al*., 2015). The MSDs are the common work-related diseases at the European level (Schneider *et al*., 2010). 25 % of the workers in 27 of EU member countries complained of upper back pain and 23 % of workers had neck, shoulder and hand complaints in 2007. Musculoskeletal disorders are the most common work-related diseases in the US and Australia, affecting millions of workers (Summers *et al*., 2015; Zheltoukhova *et al*., 2012). Middlesworth (2015) has estimated that MSDs are the single largest category of workplace injuries and are responsible for almost 30 % of all worker's compensation costs in the US. At the same time, the work intensity and the information amount is increasing and it is followed by psychological stress of workers. The project's "Fit for Work Europe" Estonian part was completed in 2011. The results showed that the health and ability to work of 50 % of the Estonian workers are affected by MSDs. In 2009, the ability to work was limited due to long-lasting hand, leg, back or neck troubles in 59 % of Estonian workers aged between 15 and 64 (Zheltoukhova *et al*., 2011).

Research conducted in different parts of the world, has reported a problem of upper limb disorders among various occupations (Yassi, 1997; Bernaards *et al*., 2008; Borle *et al*., 2012). There are numerous names for the term work-related upper limb disorders such as: work-related musculoskeletal disorders, repetitive strain injuries, cumulative trauma disorders and occupational overuse syndrome (Yassi, 1997).

The developing of MSDs is associated with complex of various hazards in the work environment, in the physiological (Widarenko *et al*., 2014), psychosocial (Park and Jang, 2010) and environmental (microclimate, lighting) field (van den Heuvel *et al*., 2005; Bongers *et al*., 2012; Tint *et al*., 2012; Coggon *et al.,* 2013).

Many WRMSDs development models have been worked out by different authors (Armstrong *et al*., 1993; Lee, 2001). In the Karsh's model (Karsh, 2006) the integrated model of the development of the MSDs considering different hazardous factors is presented. This model also contains physiological changes (muscle tension, muscle fatigue and tissue deformation). WRMSDs diagnostics criteria have been described by several authors. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders was published in 2001 (Sluiter *et al*., 2001). Exact diagnostic instructions can be found in "Notices on occupational diseases. A guide to diagnoses (European Agency, 2009).

Non-specific musculoskeletal pain syndrome is widely spread among personnel. Non-specific WRMSDs are musculoskeletal disorders that have ill-defined non-anatomical symptoms that spread over many areas: nerves, tendons and other anatomical structure (Nunes and McCauley Bush, 2012).

1.4 Preventive measures for work-related musculoskeletal disorder

The range of working conditions influencing the development of MSDs is wide: indoor climate (draught, badly organized ventilation, blowing on the worker), bad smells, noise from the street, high carbon dioxide concentration, too strong and not-convenient lighting and lighting sources; furniture (ergonomics): the workers have to work in a static posture by sewing machines or by computers. The patients with occupational diseases (OD), investigated in the current study, had different background for getting the OD: static posture or monotonous jobs supplementary with cold climate, noise or vibration. If various other risk factors are influencing on the person in the same time as working in static posture, then the probability of developing an occupational disease is increased (Tint *et al.,* 2012). The WRMSDs development has cultural differences (Madan *et al.,* 2008; Öztürk and Esin, 2011; Matsudaira *et al.,* 2011). Some of the authors have tried to model the dependences between the risk factors and the stages of MSDs (Lanfrachi and Duveau, 2008).

All these conditions have to be investigated for the prevention of MSDs and for hindering the development from the early stages of MSD to the occupational disability. In the early stages, workers often continue to work while sick (Aronson *et al.,* 2000; Campo and Darragh, 2012). There are several simple methods for checking the workplace ergonomic situation and pre-conditions for developing the MSDs (HSE, 2007; David *et al.,* 2008;), as well as medically controlled (electromyography, myotonometry etc.) (Hansson *et al.*, 2000; Viir *et al.,* 2006; Zinder and Padua, 2011). Myotonometry is often used for investigation for the possibilities of rehabilitation of sportsmen (Vain, 2002b; Korhonen *et al.*, 2005; Vain and Kums, 2012), as well as industrial and office workers.

At the present time 2-D and 3-D biomechanical models for controlling the MSDs have been worked out (Garg and Kapellusch, 2009). The application of the strain index, and threshold limit values have been first presented. The future developments of improved biomechanical applications are presented: improved estimates of tissue tolerance, estimating stress: complex jobs estimating stresses: job rotation, estimating stresses: use of multiple criteria to analyse jobs, improved instrumentation for data collection. Better instrumentation is needed for collecting and analysing data in industry, as well as better understanding of tissue tolerance under different loading conditions.

In today's economic context the input via productivity of highly skilled employees is a crucial asset in manufacturing. Employee performance and productivity are influenced by a number of factors including satisfaction, health, safety comfort and welfare (Kaare Kõrbe and Otto, 2014).

Costs associated with presenteeism due to WRMSDs may be substantial. WRMSDs reduced presenteeism in both physical therapists and occupational therapists (Chadzopolou *et al.*, 2011). WR upper-extremity disorders (WRUEDs) represent a disproportionate amount of indemnity and health care costs compared with many other occupational injuries and illnesses (Feuerstein *et al.,* 2003). Stimulation of leisure time physical activity may constitute one of the means of reducing musculoskeletal morbidity in the working population, in particular in sedentary workers (Hildebrandt *et al.,* 2011).

The physical activities and breaks in work are the possibilities to prevent the developing of MSDs (Hildebrandt *et al.*, 2000; Coelho *et al.,* 2013). In addition, the ergonomics of the workplaces could be changed (Kingma and van Dieen, 2009): for example using an exercise ball. It was hypothesized (Kingma and van Dieen, 2009) that sitting on an exercise ball would improve the spine motion relative to sitting on an office chair. However, the lumbar motion between the exercise ball and the office chair do not differ significantly.

Educating workers to use ergonomic work methdos is one of the possibilities to reduce the health disorders (Pun *et al.,* 2004; Rempel *et al.,* 2007; Reinhold *et al.,* 2008).

Adjustable chairs were introduced and workers were trained for their use. Symptom surveys were administered prior to and 6 months after introduction of adjustable chairs. Quantitative pre- and post-intervention measurement of joint position was performed utilizing videotapes among a subgroup of nineteen (Herbert *et al.,* 2001).

The chronic diseases causes and development until the disability (Palmer *et al*., 2005, 2008, 2011) are also investigated (Kaergaard and Anderson, 2000; Juul-Kristensen *et al.,* 2006; Howard *et al.,* 2012).

Functional restoration program has shown to be a viable treatment option for patients with chronic disabling occupational lumbar disorders is as effective in treating chronic disabling occupational upper extremity disorders. The meta-analysis identifies psychosocial factors as the predominant reason for the development of chronic disability in the case of any musculoskeletal injury irrespective of the site of involvement (Howard *et al.,* 2012). Good tools are needed to prevent and rehabilitate these conditions before the permanent loss of work capacity appears.

Heat and mud therapy as a part of balneotherapy are used as the rehabilitation means from MSDs. In the study of Tuulik *et al.,* (2015), the aim was to detect the effect of outpatient mud and spa therapies on the perfusion in the upper limbs in the case of the professional overuse. The soft tissue response to repeated heating is mainly due the capillary vascularisation and heat dissipation due to blood flow. The rise of microcirculation due the repeated heating was significant in the medium pain group (pain VAS 2–5). Medium pain group who had the hole body mud therapy the perfusion rose up to 19,1 % (p=0.039), rest flow up to 20,6 % (p=0,011) and peak flow up to 13,74 % (p=0,017) after nine sessions of therapy. The impairment of circulation could be one of the explanations for the work-related musculoskeletal overuse syndromes. There is a long tradition of use of spa treatment in the case of musculoskeletal problems.

2. MATERIAL AND METHODS

The office and garment workers and the patients with occupational diseases were investigated.

In *Paper I,* 18 industrial and 66 office workers were involved in myotonometric assesssment, pain location determination and use of balneotherapy for rehabilitation;

Paper II presents the myotonometric measurement of 114 industrial workers in different muscles, supplementary the pain locations investigation;

Paper III involves 54 office workers and 49 garment workers. The industrial workers were from one enterprise; investigated office workers were from three different workplaces (Table 2, *Paper III*). The study-groups were selected on the basis of the previous studies (Pille *et al*., 2014) which had concluded that the development of MSDs in office workers has a different character than in garment industry workers;

Paper IV is based on the study of 49 garment industry and 54 office workers, and 34 patients with occupational disease; a model of the connections between the pain characteristics and the three stages of MSDs was developed.

Paper V presents the data of myotonometry at the beginning and at the end of the workweek of 32 garment industry workers;

Paper VI presents the data of psychosocial investigations of 192 office workers.

Altogether 505 workers and patients were investigated.

2.1 Measurements of working environment hazards

The prevention of MSDs begins with an assessment of risks in the work environment as the basic data.

The indoor air measurements in office-rooms and in the garment industry are based on the following standards ISO 7726 “Thermal environments – Instruments and methods for measuring physical quantities”; EN 15251 “Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics”. The measuring equipment used for microclimate was TESTO 435.

The standard EVS-EN 15251:2007 gives the room temperature in three categories of the buildings: in office rooms the 1st category from 21–25,5 degrees; the 2nd category from 20 to 26,0 degrees and the third category from 18 to 27,0 degrees, in department scores 1st category from 17,5 to 24,0 degrees, the 2nd category from 16,0 to 25,0 degrees, and the third category from 15,0 to 25,0 degrees. The manufacturing space (e.g. garment industry) is not regulated with EVS-EN 15251.

2.2 Measurements of workplace ergonomics (the ART-tool)

The development of WRMSDs in both the investigated activities is very much dependent on the workplace ergonomics. In the current study, the risk level of office-workers and sewers was assessed using the ART tool (HSE, 2007). In 2007, the Health and Safety Executive (HSE) presented the prototype of a tool for risk assessment of repetitive tasks of the upper limbs. The technical content of the ART tool draws upon earlier work to develop the occupational repetitive actions methods (Colombini *et al.,* 2002) and the Quick Exposure Check (David *et al.,* 2008). As a result, the ART tool examines twelve risk factors that have been grouped into four stages: (1) frequency and repetition of movements; (2) force; (3) awkward postures (of the neck, back, shoulder/arm, wrist and hand); (4) additional factors (which include the aspect of task duration, recovery, perceived work pace and other object and work environment factors).

The result is the sum of the four stages: A, B, C and D (formula 2.1). These stages are divided into sub-stages: A1, A2, B, C1, C2, C3, C4, C5, D1, D2, D3. The body postures (in graphical mode) and conditions (by time) are given. The task score (*TS*) is calculated as follows:

$$TS = A1+A2+B+C1+C2+C3+C4+C5+D1+D2+D3 \qquad 2.1$$

where $A1$ – arm movements; $A2$ – repetition; B – force; $C1$ – head/neck posture; $C2$ – back posture; $C3$ – arm posture; $C4$ – wrist posture; $C5$ – hand/finger grip; $D1$ – breaks; $D2$ – work pace; $D3$ – other factors.

When assessing both arms, the scores for the left arm and right arm should be kept separate and not combined.

The calculation of the exposure score (*ES)* that is equal to risk level (*RL*) is achieved when the task score is multiplied by the duration multiplier (formula 2.2):

$$ES\ (RL) = \text{Task score} \times D4 \qquad 2.2$$

where $Task\ score$ – calculated by the formula 1; $D4$ – Duration multiplier depends on the duration of the activity.

The task and exposure scores help prioritise tasks that need the most urgent attention and help check the effectiveness of any improvements.

The system for interpreting the exposure score is proposed in Table 1 (*Paper III*).

2.3 Questionnaires for the pain location, strength and psychosocial risks

The workers' musculoskeletal complaints were assessed on the basis of the Nordic musculoskeletal questionnaire (Kuorinka *et al.,* 1987). The intensity of pain was assessed using the Visual Analogue Scale (VAS, a scale from one to ten). The workers filled out the questionnaire forms (*Paper I, II*, *III, IV*).

Description of t*he VAS pain scale:* it is an instrument for measuring the characteristics or attitudes that are believed to range across a continuum of values and cannot easily be measured directly, e.g. the amount of pain. The pain a patient feels ranges across a continuum from none to an extreme amount of pain (Wewers and Lowe, 1990). The VAS pain scale consists of a 10 cm horizontal line with written descriptions at either end (not at all; very much); the subjects were asked to mark on the line the point that they felt represented their perception of their current state of pain in the respective body region. The patients were asked about the pain duration, letting them fill out the Nordic musculoskeletal questionnaire's four duration groups**:** pain lasting for 1−7 days, 8−30 days, more than 30 days or pain felt every day.

The *WAI questionnaire* is used (*Paper VI*) to determine the connections between the workers' demands of the job and the fulfilment of them during the work (Tuomi *et al.,* 1998). The interview is carried out by an occupational health professional who rates the responses according to the instructions.

The KIVA questionnaire (Näsman, 2011) is composed of seven questions (*Paper VI*): 1) Have you enjoyed coming to work in the last weeks? 2) I regard my job meaningful; 3) I feel in control of my work; 4) I get on with my fellow-workers; 5) My immediate superior performs as a superior; 6) How certain are you that you will keep the job with this employer? 7) How much can you influence factors concerning your job?

2.4 Myotonometry (MTM)

The results of the study suggest that a handheld myometer may be an effective clinical measure of active muscle stiffness. The valid, reliable and precise measurements it collects is combined with the ease of use and ability to measure (Zinder and Padua, 2011).

The myotonometric method gives a possibility of evaluating muscle conditions. Myotonometric method is based on creating the mechanical impulses in the examined muscle and determining muscle stiffness and flexibility according to the muscles mechanical response.

Muscle stiffness (N/m) reflects the ability of a muscle to resist external force, natural frequency (Hz) shows the tone and the logarithmic decrement expresses the character of the damping of its oscillation related to muscle elasticity**.**

The parameters may be compared to the standard value of a corresponding individual muscle, and statistically determined population standards may be used to evaluate the health disturbances potentially caused by work.

The device "MYOTON-3" enables easy repetition of measurement, processes the data at the same time and gives statistical ratings in real time.

The following muscles: *M. add pollicis* left and right hand; *M. abd pollicis brevis* left and right hand; *M. flexor capri* right and left; *M. extensor digit*, right and left; *M. trapezius med,* both sides of the spine were measured in sitting and lying position.

M. adductor pollicis; action: adducts the carpometacarpal joint, and both adducts and assists in flexion of metacarpophalangeal joint, so that thumb moves toward the plane of the palm; aids in opposition of the thumb toward the little finger.

M. abductor pollicis brevis: the muscle abducts the carpometacarpal and metacarpophalangeal joints of the thumb in a ventral direction perpendicular to the plane of the palm. By virtue of its attachment into the dorsal extensor expansion, extends the interphalangeal joint of the thumb, assists in opposition, and may assist in flexion and medial rotation, of the metacarpophalangeal joint.

M. extensor digitorum: extends the metacarpophalangeal joints and in conjunction with lumbricales and interossei, extends the interphalangeal joints of the second through fifth digits; assists in the abduction of the index, ring and little fingers and in the extension and the abduction of the wrist.

M. flexor carpi radialis: flexes and abducts the wrist, and may assist in pronation of the forearm and in the flexion of the elbow.

M. trapezius med action: with the origin fixed, adduction of scapula, performed chiefly by the middle fibers, with stabilization by upper lower fibers. Rotation of scapula so that the glenoid cavity faces cranially, performed chiefly by the upper and lower fibers, with stabilization by the middle fibers. In addition, the upper fibers elevate, and lower fibers depress, the scapula. With the insertion fixed and acting unilaterally, upper fibers extend, laterally flex, and rotate the head and joints of the cervical vertebrae so that the face turns toward the opposite side. With insertion fixed and acting bilaterally, the upper trapezius extends the neck (Kendall et al., 2005).

2.5 Statistical analysis

The mean and standard deviation (SD) were calculated in the course of the measurements. The Student's *t test* was used. The statistical significance of the *t test* was $p=0,05$ (*Paper I, II*).

Univariate analysis, correlation analysis, parametric and nonparametric tests were applied in SPSS (*Paper III, IV*). The Shapiro-Wilk test (more appropriate for small samples) was used for the numerical means of assessing normality. The latter is the prerequisite for many other statistical tests. If the Shapiro-Wilk test *p-value* is greater than 0,05 it is possible to reject the alternative hypothesis and conclude that the data come from a normal distribution. To compare the significant mean difference between two groups, the Student's *t-test* was used; to compare the significant mean difference between three groups, the ANOVA test was used. If the Shapiro-Wilk test *p-value* was below 0,05, the data significantly deviate of from a normal distribution. For checking the hypothesis, Pearson's Chi-Square test, Likelihood Ratio, Fisher's Exact test, and the Linear-by-Linear association test (Field, 2013) were used. *P-value* $<0,05$ ($p<0,1$ in some dependences) was taken to be significant (*Paper VI*).

3. PREVENTION OF AND REHABILITATION FROM WRMSDs

3.1 The influence of environment and ergonomics on development of MSDs

An office workplace where there is no direct contact with natural light or outdoor air is presented in Fig. 2 (*Paper III)*. These conditions are not allowed by the standard EVS-EN 15251. Fig. 3 (*Paper III*) depicts a workplace in an atrium-type building, where there is a shortage of natural light. The windows can be opened, the room is opposite to the atrium, so in very hot summer days the conditions are good. In winter, it is not possible to use natural light as the opposite workrooms inside the atrium are very close and this disturbs the scientific work in the room shown in Fig. 3.

The workplaces depicted in Fig. 4 (*Paper III*) (gore machine) and Fig. 5 (*Paper III*) (universal sewing machine) are from the garment industry. Working with the core machine, the right hand of the worker is moving up and down hundreds of times during the workday. The right hand is under big stress. Working by the universal sewing machine, the worker is working in the forced position for 8 hours a day (excluding the rest periods, 10 minutes per hour, and the lunch break). The static posture over a long period of time is a clear risk factor for developing MSDs in the neck, upper or lower back.

The results of the assessment of the risk level by the ART-tool (Table 4, *Paper III*) show that office workers' RL is medium (14–19,2); while the garment workers' ergonomic risk is on a high level (24–41). There is a difference in the risk level of the left and right hand for the office-workers. There is no difference in the RL of a garment worker, who works with two hands at the same physical level (universal sewing machine). The highest risk for developing the MSDs was stated for the worker's (gore machine) right hand, i.e. 41 points (Table 4, *Paper III*).

In the schematic drawing (Fig. 3.1), the development of MSDs is presented. The presented factors could be taken as a basis for elaborating a prevention and rehabilitations model and for performance of work ability and quality of life of people. At the first stage of health disorders (1^{st} stage of MSDs), the subjective data on fatigue and pain in overloaded muscles was noticed by the workers; at the 2^{nd} stage of MSDs, the pain was over 5 points by the VAS scale and muscle fatigue was more intense. The objective symptoms are more pronounced and can be diagnosed for clinical syndromes. The ability to work has decreased. At the chronic stage of disease, if the rehabilitation has not begun in time, the illness might continue developing until the patient is disabled.

The model (Fig.3.1) for the prevention and rehabilitation of MSDs has to include:

(1) Risk analysis data (the level and effectiveness of lighting, indoor climate, ergonomics etc.) in a workplace;
(2) Health status data of workers using the questionnaires (work ability index –WAI; the Nordic questionnaire for MSD s, psychological tests).
(3) The results of the muscle strain measurements (myotonometry).

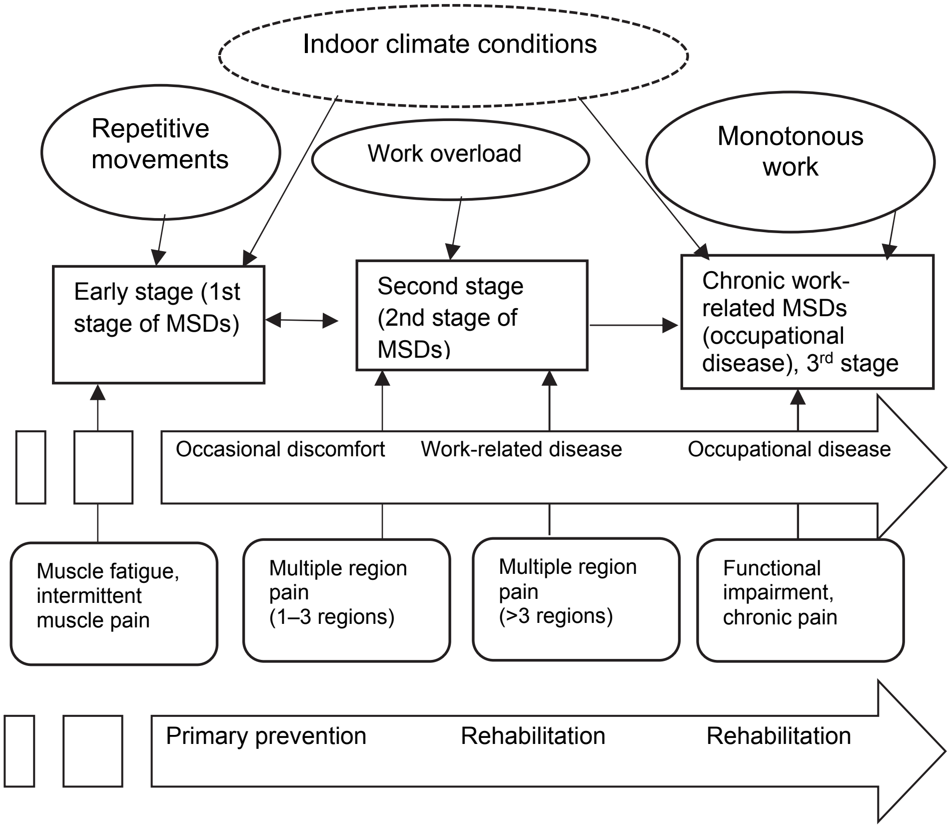

Figure 3.1 The factors influencing the development of MSDs as an occupational disease.

There is a good correlation between the ergonomic risk level (determined by the ART-tool) and the pain regions (R=0,893), but the correlation between the temperature in the workroom and the pain groups of workers was not high (R=0,396). The microclimate conditions in garment industry are usually normal, therefore we cannot consider the room temperature a risk factor in the garment industry, however, it can be a risk factor during outdoor activities, like driving an agriculture machine or in construction areas etc.

In *Paper VI,* 192 office workers were investigated using WAI and Kiva questionnaires. The results were: the work is monotonous, only 60 % of the workers are able to recover from a day's workload after workday or work shift; the workers were slightly more satisfied with their job than with their current life etc. There was a correlation between the monotonous work (data from ART-tool) and MSDs development (R=0,682).

These data could be the basis for the developing of the model and a subsequent IT program for designing computer-equipped and industrial workplaces for different age groups in order to prevent decreased work ability and the development of an occupational disease. These recommendations could be followed by the occupational health and family doctors in their therapeutic treatment work.

3.2 The change in status during work in a static posture

Normal parameter values of the myotonometric test are: frequency characterizing muscle tension: 11 Hz–16 Hz; decrement, characterizing of muscle flexibility: 1,0–1,2; stiffness, characterizing muscle's property: 150 N/m–300 N/m.

Paper I: 18 industrial workers (IW) were subjected to myotonometric test (Table 1). In the workers with the diagnosis of *M. abd poll brev* decrement (working hand muscle disturbance), there was no significance between the hands. The stiffness deviated significantly from the norm (>300 N/m).

66 office-workers (OW) were subjected to the myotonometric test. The average values of frequency were nearly the same for both hands; the stiffness of the hand muscles was lower than that in IW. The shoulder muscle stiffness was much lower than for the hands.

Paper II: 114 industrial workers with professional overuse of upper extremities were investigated. 19 workers of the group who reported pain in the two or more regions of the upper extremities due to the work overload, received balneotherapy. They were divided into two groups (6 – wrist region tenosynovitis, 13 with no chronic diseases). The effect of balneotherapy is visible for the group with no chronic disease (Table 2, *Paper II*).

Paper IV: 54 office workers, 49 garment industry workers, 34 patients with occupational disease *M. add. poll brev* and *M. trapezius med* were measured. There is a great difference in stiffness is for all the groups, measured in sitting position. The stiffness of muscles of patients with OD is lower than that of office workers or garment workers (Table 3, *Paper IV*). Thumb muscle parameters are the opposite (Fig. 3.3). In addition, the right and left hand were differently loaded for garment workers (the same data) and office workers (left hand less loaded).

Paper V: 32 garment workers' muscles were investigated myotonometrically in the beginning of the work-week and at the end of the work-week. In Table 1. measured muscle's determinants are presented. The stiffness is rather high compared with *M. trapezius med* (Table 1, *Paper V*). Muscle tiredness increases during the workweek (*Paper V*), the left hand is less loaded than the right hand, therefore the stiffness values are more constant.

In the conclusion, different muscles stiffness, decrement and frequency are measured in the current study. The stiffness of muscles is increasing during the static posture; the frequency of *M. trapezius med* is lower (11,0–-12,0) measured in the lying position (sitting: 15,0–17,0); the decrement of hand muscles and *M.* e*rector spinae* is near 2.0, but in *M. trapezius med* it is much lower (1,3–-1,5).

A summary of the myotonometric measurements is given in Table 3.1 and the in Fig. 3.2–-3.5 (the notations on the Figures are: OW- office workers, GW garment workers, ODP - patients with occupational diseases, L - left, R – right).

The decrement and stiffness of *M. adductor pollicis* have the highest levels in patients with occupational disease (Fig. 3.2 and 3.3). The correlation between the incidence of pain and muscles tone and stiffness is presented in Table 3.2.

Table 3.1. The results of myotonometry

The Paper	The workers groups	Muscle stiffness, N/m	Frequency, Hz	Decrement
Paper I	18 industrial workers (IW) 66 office workers (OW)	311,4 (R hand); 348,8 (L hand), 244,5 (R hand); 247,1 (L hand). Shoulder muscles: 191,2 (R)–190,7 (L),	-	2,0 (R hand); 1,6 (L hand), 2,0 (L hand); 1.9 (R hand),
Paper II	6 IW with wrist region tenosynovitis 13 IW with no chronic diseases in wrist region	*Abd poll brev* (L): 295,2 (BT)–309,0 (AT); 313,9 (BT)–254,5 (AT);	18,6 (BT)–19,4 (AT) 19,7 (BT)–16,7 (AT)	-
Paper IV	54 OW, 49 GW, 34 ODP	Lying position *M. trapezius med* (L): 193,0 (OW)–175,0 (GW)–213,2 (ODP); *M. trapezius med* (R): 192,4 (OW)–187,2 (GW) –207,0 (ODP) Sitting position *M. trapezius med* (L): 337,0 (OW)–342 (GW)– 283,1 (ODP) *M. trapezius med* (R): 323,2(OW)– 318,2(GW)– 280,1(ODP)	11,4(OW)– 12,4(GW)– 11,2(ODP) 11,0(OW)– 11,7(GW)– 11,8(ODP) 17,4(OW)– 17,3(GW)– 15,2(ODP) 16,8(OW)– 16,4(GW)– 15,0(ODP)	1,4(OW)– 1,3(GW)– 1,5(ODP) 1,3(OW)– 1,5(GW)– 1,5(ODP) 1,3(OW)– 1,4(GW)– 1,5(ODP) 1,3(OW)– 1,5(GW)– 1,5(ODP)
Paper V	32 garment workers	BEGIN *M. er spinae* (L): 265,0; (R):272,2 END *M. er spinae* (L): 272,2; (R):260,2	15,0(L)– 15,0(R) 14,9(L)– 15,4(R)	2,0(L)–1,9(R) 2,0(L)–2,1(R)

BT- before treatment; AT- after treatment;
OW-office workers, GW-garment workers, ODP- patients with occupational disease
BEGIN- the beginning of the workweek; END- the end of the workweek

Table 3.2. Health complaints according to the Nordic musculoskeletal questionnaire

Anatomical region	**Office workers**	**Garment workers**	**Patients with occupational diseases**	**p-value**
Pain occurrence during the past 12 months (%)				
Neck	30 (55.6) SD 0.5	35 (71.4) SD 0.4	29 (74.0) SD 0.3	0.06
Shoulder right	20 (37.0) SD 0.5	30 (61.2) SD 0.5	26 (66.0) SD 0.5	0.00*
Shoulder left	16 (29.6) SD 0.5	24 (48.9) SD 0.5	19 (48.1) SD 0.4	0.03*
Elbow right	4 (7.4) SD 0.3	11 (22.4) SD 0.4	25 (64.2) SD 0.5	0.03*
Elbow left	2 (3.7) SD 0.2	14 (28.6) SD 0.5	19 (48.7) SD 0.2	0.00*
Wrist right	11 (20.4) SD 0.4	25 (51.0) SD 0.5	30 (76.9) SD 0.5	0.00*
Wrist left	2 (3.7) SD 0.2	24 (48.9) SD 0.5	25 (64.0) SD 0.3	0.00*

The office workers (OW) have a high frequency of neck pain but there is no significant difference compared to the other investigated groups (GW, ODP). The hand pain significantly differs between the office and garment workers and patients with occupational disease (OW, GW, ODP). Pain severity is higher in the patients' group as compared with the garment workers (GW) and particularly with the office workers group. This also applies to the thumb and trapezius muscle tone changes between the groups (OW, GW, ODP).

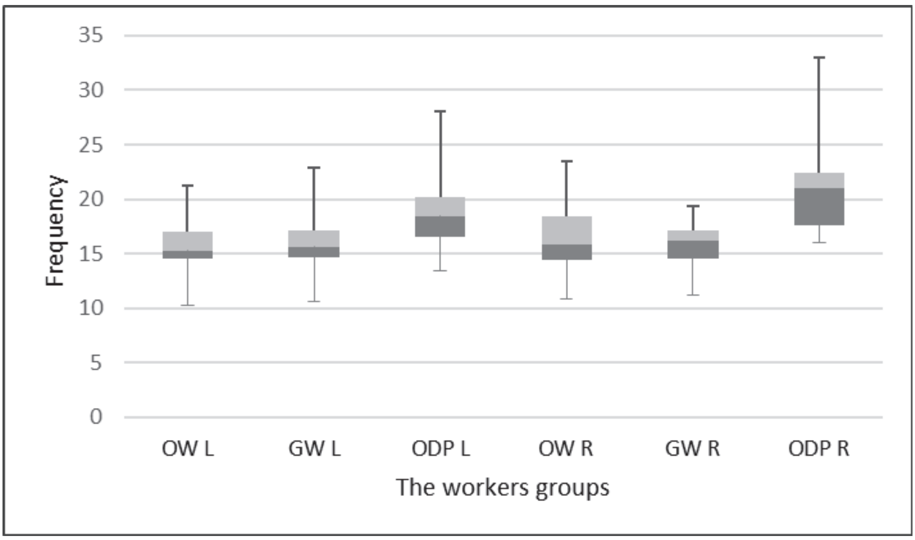

Figure 3.2 The differences between the tone of M. adductor pollicis left and right hand
OW- office workers, GW garment workers, ODP - patients with occupational disease,
L - left, R - right

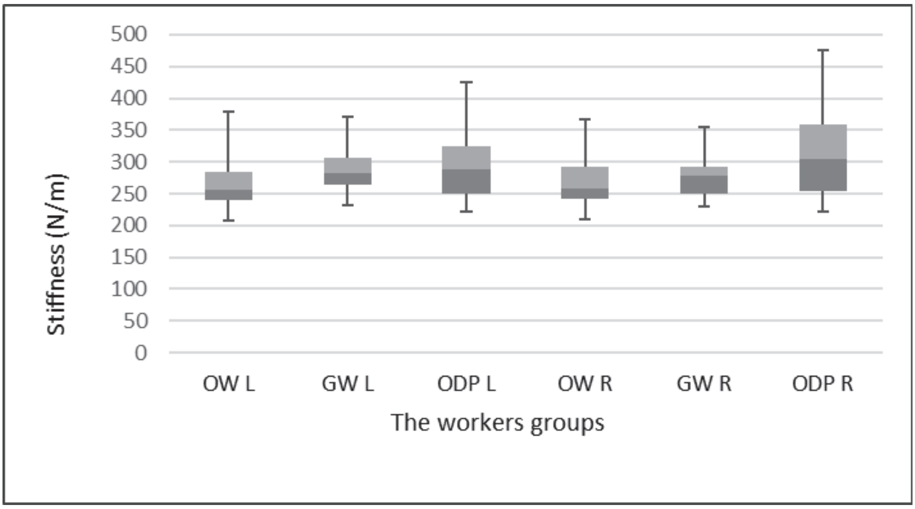

Figure 3.3 The differences between the stiffness of M. adductor pollicis left and right hand

The decrement and stiffness of *m. trapezius* have the highest levels in patients of office and garment workers (Fig. 3.4 and 3.5).

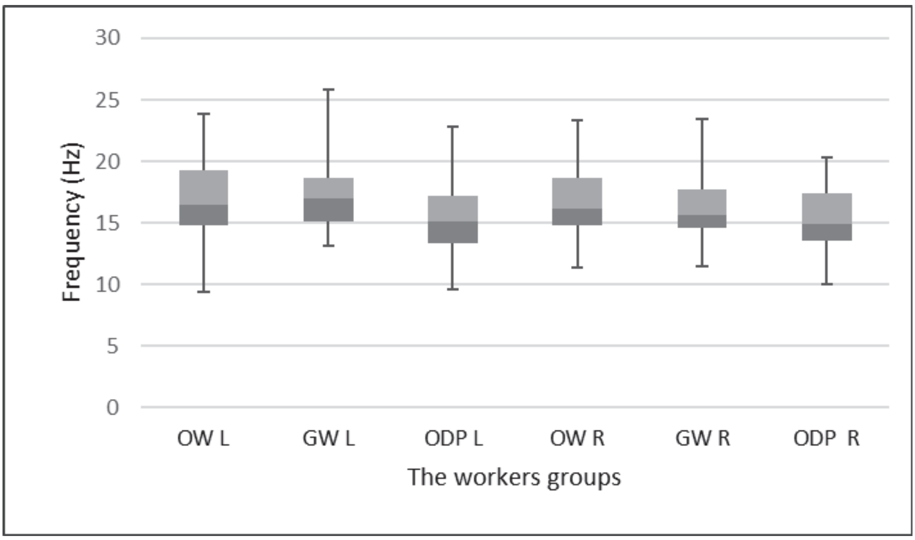

Figure 3.4 The differences between the tone of M. trapezius (left and right) among the workers groups

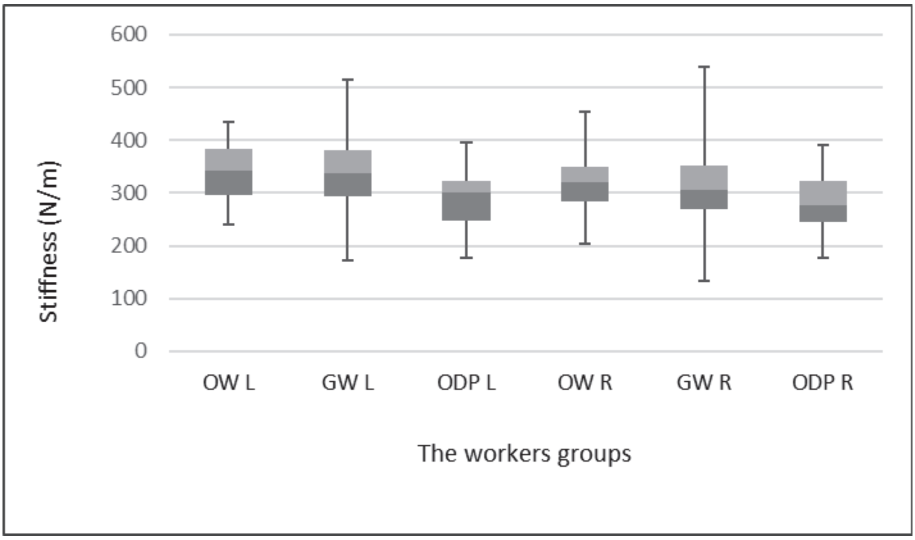

Figure 3.5 The differences between the stiffness of M. trapezius (left and right) among the workers groups

The results of the measurements of *M. adductor pollicis* show that the frequency and the stiffness of the muscles are increasing from office workers in the direction of the patients with occupational diseases; it means that the muscles lose their elasticity as a result of a great overuse and working in the static posture (GW, ODP). In the case of *M. trapezius med* measurements, the stiffness and frequency have higher values for OW as compared with GW, this means that GW work puts more load on the hands, but the *M. trapezius med* is exposed to a greater load during the computer work. The myotonometric study revealed differences in the tone and muscle stiffness between the three groups: office workers (OW), garment workers (GW) and persons with occupational diseases (ODP).

3.3 The model for the prevention of and rehabilitation from MSDs

When compiling of the model for prevention of occupational diseases (Fig.11), the pain strength in different anatomical regions, pain duration, the occupation and the workers' age were taken into account.

The pain strength presented in Table 5 (*Paper III)*, shows that the right hand thumb muscles are more painful of garment workers and patients with occupational diseases. Only two of the office workers (OW=54) had pain in the left wrist (VAS pain scale=3‒4 (10 max)). The other 11 office workers had pain in the right wrist (VAS pain scale, mean=3,9). The pain occurrence in the garment workers (GW)' both hands was similar and the pain intensity was 5,7 on the 10-point scale.

The pain durations in different regions of the body (OW, GW, ODP) are presented in Fig. 3.6 to 3.8.

The difference between the office and garment workers' painful regions also lies in the neck area. The neck pain complaints are high in both groups: garment industry workers (71,3 %) and in the computer workers (55,6 %). The low back pain data have the same trend. Pain duration is the longest in the neck region (Table 6, *Paper III*), both in the office and the garment industry workers. Different hazardous factors (indoor climate, psychosocial factors, static posture etc.) are influencing the computer worker (Fig.1, *Paper IV*). If improvement methods in the working environment are implemented, the workers' stress level could be decreased. Tables 5 and 6 (*Paper III*) show that garment workers have more pains (Fig. 2, *Paper IV*). Office workers have less long-term pains that last over 30 days and they do not have daily pains. A remarkable group of workers are people who have severe pain, which means 5 points on the VAS scale and pain duration is over 30 days or the pain is continuous. Workers with severe pain complaints should be treated, because it may lead to an occupational disease and cause permanent incapacity. It is necessary to check the job management.

The workers feeling pain in several regions of the body were directed to therapy. In both investigated groups (the office and garment workers), the therapy helped the workers and most of the workers were rehabilitated in a week's time.

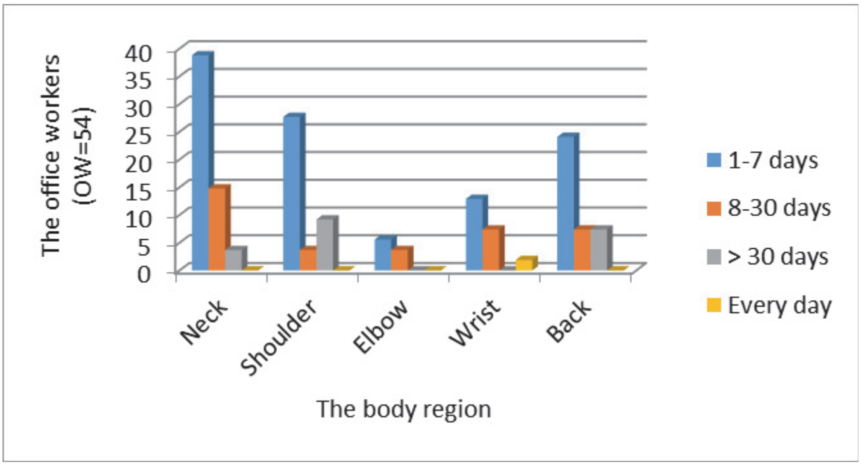

Figure 3.6 Pain location and duration in office workers (OW).

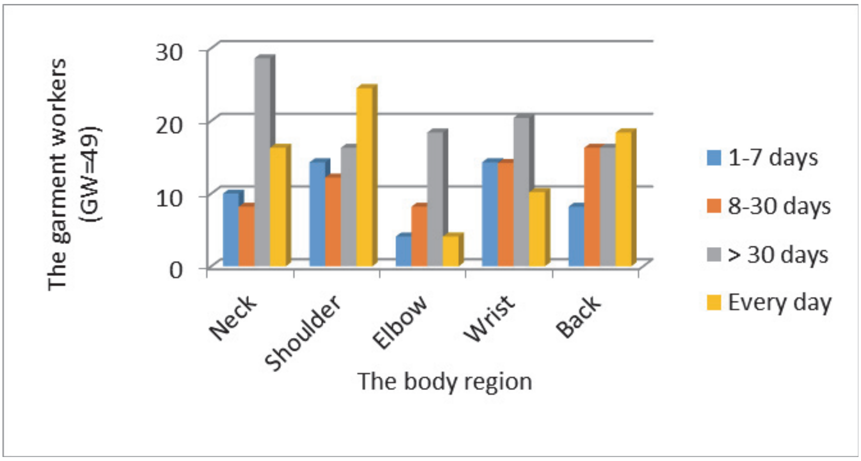

Figure 3.7 Pain location and duration in garment industry workers (GW).

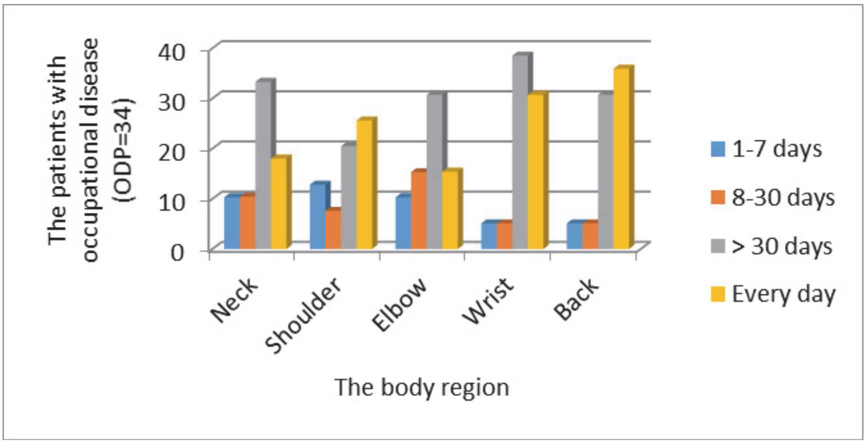

Figure 3.8 Pain location and duration in patients with occupational diseases (ODP).

The pain intensity in different workers' groups (Fig. 3.9) shows that the sensation of pain is the strongest in the garment workers (GW) and in the group of patients with occupational diseases (ODP). The office workers (OW) feel the greatest pain in the neck and in the back. The prevalence of pain sites in different workers group (Fig. 3.10) shows that the office workers (OW) feel mostly the pain in one region of the body, while the garment workers and the patients with occupational diseases feel it in many regions (26 % of ODP feel pain in eight regions of the body). It has to be taken into consideration that occupational disease patients on the average have 3–5 diagnosed specific diagnoses (carpal tunnel syndrome, epicondylitis, rotator cuff syndromes, different tenosynovitis in the hand regions). They are also affected by psychosocial aspects like chronic diseases and loss of work. Workers, who have muscle pains, need more attention, work environment adjustments, treatments and encouragement to be more active in the treatment process.

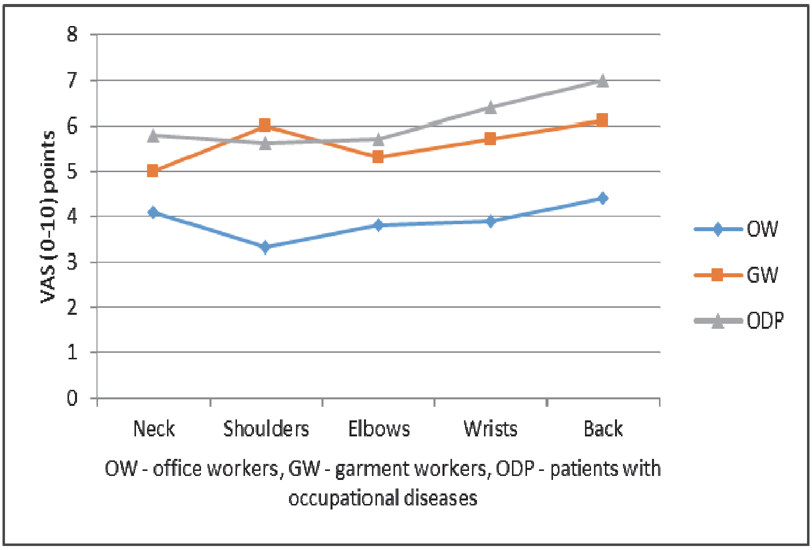

Fig. 3.9 Pain intensity by VAS (0-10) in different workers groups.

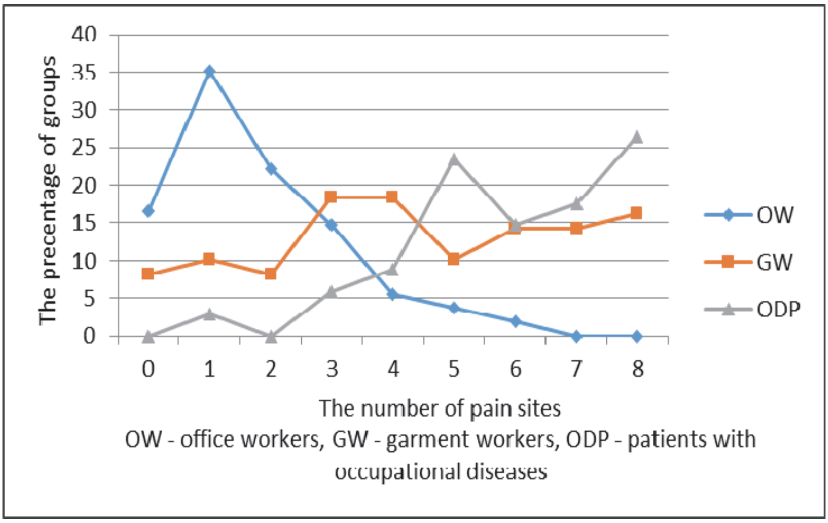

Fig.3.10 Prevalence of pain sites in different workers groups.

Table 3.2. *Statistical analysis of the hypotheses (Fig. 3.11).*

Hypotheses		**Test** Neck, shoulder, elbow, wrist. back	**P-value**
H1: The pain duration in different anatomical regions of the body is dependent upon the occupation (GW, OW, patients with OD).	GW, OW, patients with OD	Square test (*Paper IV*): 11,1–32,8	From 0,000 (N, W, B) to 0,086 (E)
H2: The duration of pain is dependent on the MSD stage (early stage, stage 2, chronic WRMSDs (stage 3)	GW, OW, patients with OD	Square test (*Paper IV*): 12,5–33,3	From 0,000 ((N, S, B) to 0,053 (E)
H3: The occurrence of pain is dependent on workers' age (the workers were divided into four groups: ≤25, 26–40, 41–55 and ≥55 years of age).	GW, OW, patients with OD	Square test (*Paper IV*): 6,9–26,6	From 0,000 (N) to 0,648 (E)
H4: Duration of pain is dependent on the age of workers in different occupations.	GW, OW, patients with OD	Square test: Likelihood ratio (*Paper IV*): 0,153–16,5	From 0,011 (N, GW) to 0,985 (B, ODP)
H5: Duration of pain is dependent on the stages of illness in different occupations.	GW, OW, patients with OD	Square test: Likelihood ratio (*Paper IV*): 0,641–24,0	From 0,001 (S, GW) to 0,726 (B, OW)

**N–neck; S–shoulders; E–elbows; W–wrists; B–back*

H1- the statistical analysis (Table 3.2, column 4; Fig. 3.11) confirm that there is a significant difference between the duration of pain between OW; GW and ODP, except the elbow pain had not correlation.
H2- the statistical analysis confirms that there is a significant difference between the stages of ailment and the occurrence of pain in different regions of the body, not proved in the case of elbow pain.
H3- the statistical analysis showed that there was a correlation between the intensity of pain in the neck, wrist and back regions and the workers age. There was no correlation of pain in the shoulder and elbow regions.
H4- the relationship between the body regions and the occupation was confirmed as follows: in the neck region of GW and more severely in the neck region of GW. For ODP and in all other body regions, pain occurrence is not dependent on the age of the worker. Therefore, we can conclude that the pain occurrence caused by a static posture and monotonous work, is not dependent on the age of the person. The MSDs may develop in younger workers.
H5- the statistics on the relationship of the occurrence of pain and the stages of illnesses (three stages) was confirmed only regarding shoulder pain in garment workers. It confirms that garment workers' shoulders are a weak body region and suffer from the overload. Pain occurrence and duration are not dependent on the age. MSDs may occur in workers of any age.

On the basis of the results of the current study it can be stated that the right hand of office workers is more painful than the left one (as proved by the questionnaires) due to a greater load affecting the right hand. Garment workers' both hands are painful to the same extent. The other authors' papers dedicated to garment workers' MSDs show the same tendency.

There is a large number of other factors influencing the development of MSDs (based on the literature review), like psychosocial factors *(Paper VI,* only office workers involved). The results of *Paper VI* show the differences and similarities of the WAI and KIVA questionnaire and can be used in the future research and elaboration of the model.

In the office workers' group (presented in *Paper VI*), the average work ability index was estimated to be 40 points; in the garment workers' group, the average work ability index was lower, approximately 37,3 and the result fluctuation was greater, the minimum and maximum work ability indexes were 23,5 and 49 respectively. Correspondingly, the office workers' work ability is higher and can be assessed as good. The garment workers' work ability can be placed on the boundary of being good, since good is assessed between 37 and 43 points. It must also to be noted that work ability was estimated as moderate or bad in 16 workers. This has to be taken into consideration and employees should be given more freedom to change the work environment or be provided rehabilitation, so that their work ability would not decrease even more. Among the office workers, there were no results that would have indicated low work ability. In patients group were the average work ability index was very low 19 points (min 10, max 32).

Suggestions (*Paper VI*) were made for ergonomic improvements at workplaces (new ergonomic chairs, the possibility to changing the height of the worktable; change of the position of a monitor etc.). Complaints about the air of the work environment and lighting deficiency were forwarded to the employer. The rehabilitation of MSDs is possible using balneotherapy.

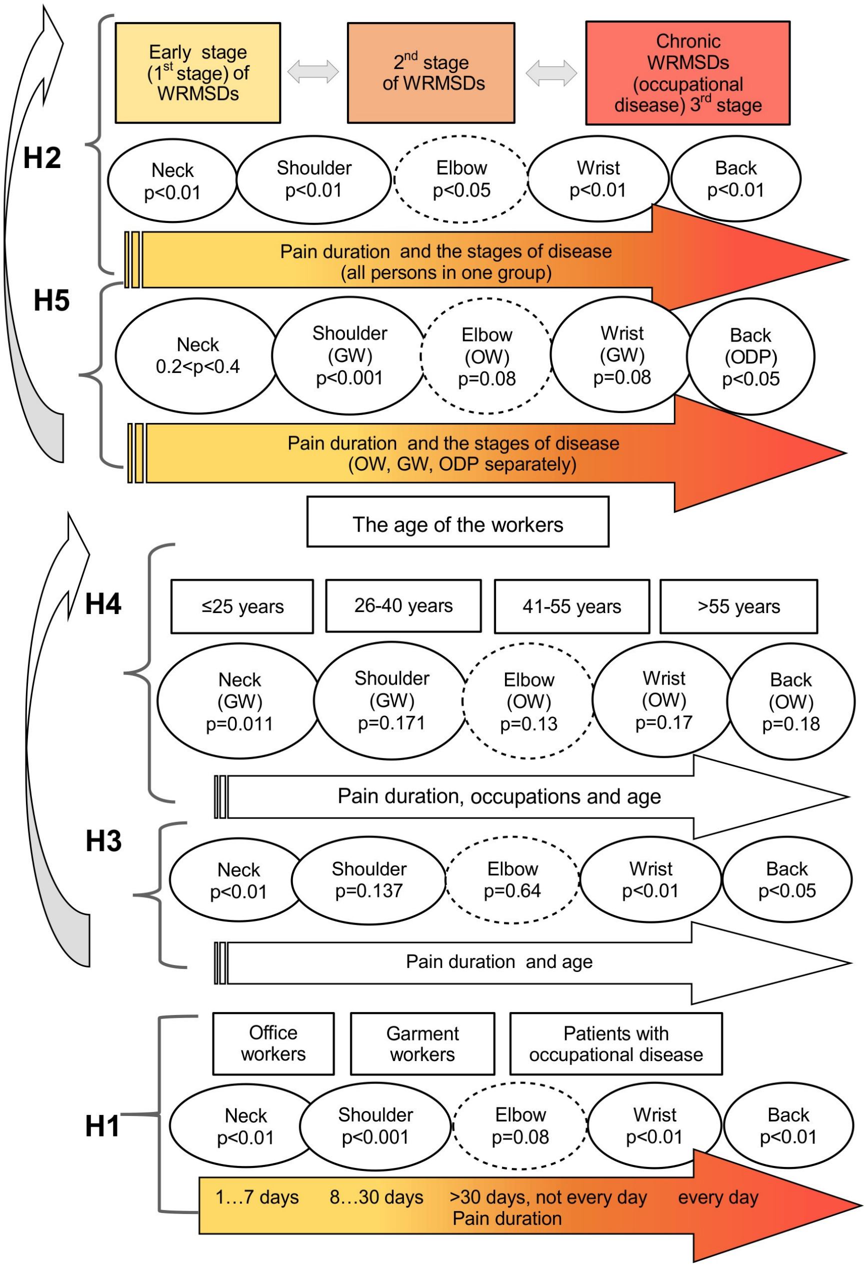

Figure 3.11 The dependences of the pain duration in different locations and at different stages of MSDs (office workers, garment industry workers, patients with occupational diseases).

3.4. Discussion

The neck pain is mentioned as the most prevalent musculoskeletal complaint of office workers (Blagsted *et al*., 2008), but the pain symptoms in other body regions are reported as well (Juul-Kristensen *et al*., 2008). The number of workers studied by Andresen *et al.* (2010) was 544. The areas of pain were as follows: neck 53 % of the people studied, lower back 43 %, R shoulder 36 %, upper back 33 %, knees 20 %, R hand 22 %, L shoulder 24 %, feet 18 %, R elbow 16 %, hips 15 %, L hand 10 % and L elbow 10 %. Pain intensity was rather unvaried: from 4,18 to 4,93 on the scale of 0 to 9.

Neck pain is very common among office workers (Sihawong *et al.,* 2010). Approximately 43 % to 69 % of the office workers experienced neck pain in the preceding 12 months. A survey of MSDs among visual display unit (VDU) users in a bank showed the prevalence of complaints in various body parts as follows: neck 31,4 %, shoulder 16,5 %, hand and wrist 14,9 % and arm 6,6 %. Frequent users of VDU had significantly more musculoskeletal problems in the neck and shoulder regions than infrequent users (Yu and Wong, 1996). Modification of the workstation design and improvement of work organization should be able to reduce the prevalence of these disorders.

The corresponding results (OW) obtained by the authors of this paper were: 55,6 % in the neck, 42,6 % in the shoulders, 38,9 % in the back, 5,96 % in the elbows and 22,2 % in the wrist (the percentage of people suffering from pain of all the people studied). Pain intensity was from 3,3 to 4,4 in the present study (Table 5, *Paper III*).

The results of the assessment (Table 3, *Paper III*) show that office workers' risk level is medium (14–19,2); while garment workers' ergonomic risk is on a high level (24–41).

It can be concluded that the results derived from this study are similar to or higher when compared to those of the other authors. New data are derived from a comprehensive study of wrist pains.

In the garment workers' group (230 people, Reinhold *et al*., 2008) the incidence of pain in different areas of the body was rather variable: the pain in the shoulders was felt by 27 % of the workers studied, lower back pain by 46 %, pain in the neck area by 21 %, headache and brain fatigue by 15 %, carpal channel syndrome - moderate stadium by 18%, back pain in the pectoral region by 8 %, fatigue of hands and disturbances in the sensitiveness by 16 %, pain in hip by 2 %, pain in the leg muscles by 7 %, knee pains by 6 %, pain in thigh muscles by 2 % and back pain by 8 % of the workers.

The pain in the neck/shoulder region (12,9 % of garment workers), in hands/wrists (6,9 %) and in arms/forearms (3,7 %) was reported by Wang *et al.* (2009). The most frequent physical signs observed in the neck/shoulder region were rotator cuff tendonitis (7,3 %), somatic pain syndrome (6,9 %), radicular pain syndrome (6,0 %) and thoracic outlet syndrome (4,6 %).

According to Herbert *et al.* (2001), the areas and frequency of pain among garment workers were observed as follows: in neck 47 % of the people studied, R shoulder 66 %, L shoulder 36 %, L elbow 26 %, R elbow 29 %, R forearm 29 %, L forearm 24 %, R wrist 25 %, L wrist 19 %, R hand 42 % and L hand 36 %.

Thus, the data are variable, but the problem is actual and several researchers are looking for ways of decreasing the risk factors in the garment workers' work environment and also for the best means of rehabilitation.

The results of the present study of garment workers correspond to the previous data regarding back pain (59,1 %). The frequency of pain occurrence in the neck area (71,4 % of all GW), in the shoulders (67,3 % of all GW), wrist/hand region (53,1 % of all GW) is higher when compared to the study of Reinhold et al. (2008).

In the study of Friedrich *et al.* (2000), the proportion of sewing industry workers suffering from neck, upper back and lower back pain was much higher: 52,4 %, 54,8 % and 72,8 % respectively of all the workers studied, which is in better conformity with the results of the present study.

The work is repetitive both for workers (in the garment industry and in offices), but the movements, made by the right hand, are different. The probability of developing the carpal-syndrome disease is higher for office workers who use the mouse. As the number of musculo-skeletal disorders has arisen caused by the work with computers therefore the rehabilitation methods are very important. The authors of the present study suggest the following: the complex treatments of these syndromes include active and passive methods of physiotherapy. The active part is organized by a physiotherapist. Systematic application of physical education, exercise therapy improves the functional capacity of the organism to resist physical stress. The role of the physical therapist in the occupational health team is to ensure that an optimum work environment exists for the prevention of injury and for the rehabilitation of work-related impairment, activity limitation, and participation restrictions. There are also physical therapies, which influence the tissues metabolic activity and have positive influence on the recovery process. These are massage, physical agents' therapies and water immersion therapy. The most important is the workplace ergonomic design to prevent the health damages. The microclimate measurements are in the accordance with our previous measurements (Reinhold et al., 2008; Tint et al., 2012). Thus, the intensity of pain and the frequency of its occurrence in certain areas of the body are closely linked to the risk factors in the work environment. They have to be determined on the individual level.

The number of years, worked as a spooler was significantly associated with the presence of pain in the right elbow and right forearm and left forearm. The significant relationship was found between the years worked and the pain in three locations of the eleven investigated. Quantitative ergonomic analysis revealed a significant decrease in exposure to awkward posture in two anatomic sites (the right elbow and right wrist) after introduction and training in use of the adjustable chair (Herbert *et al.,* 2001).

A further study of larger groups of workers by means of the myotonometric method would also be expedient. The models for determination of the relationship between the musculoskeletal pain and age or occupation are not readily available in the scientific literature, seeing that the development of the disease is very much dependent on a person and the persons' general health status. The models mostly deal with the problem of how to return to work after developing musculoskeletal disorders (Schulz *et al*., 2007). However, it is concluded that the future development of models that are truly transdisciplinary and address the temporal and multidimensional aspects of occupational disability remains a goal (Marcus et al., 2002). In literature, the following models are also available: connecting the biomechanical factors and MSDs (Chao, 2003), psychosocial factors, stress and MSDs, work demands and MSDs (Lanfranchi and Duveau, 2008), chronic musculoskeletal pain and motor function. The epidemiology of chronic musculoskeletal pain is investigated by several authors (Gran, 2003; McBeth and Jones, 2007; Cimmino *et al.,* 2011).

The group and individual risk factors for musculoskeletal pain in adult population are well documented; however, the mechanisms which underlie these associations are inadequately understood and require further research. Individual and workplace psychosocial factors are strongly associated with musculoskeletal pain, interventions targeting these factors should form part of an effective treatment programme. Physical and psychosocial risk factors are at work in the development of chronic widespread pain and in the determination of its outcome. The risk factors for developing pain in muscles associated with work are gender and age, familial aggregation and genetic susceptibility; stressful life events, pain-prone lifestyle, physical trauma and recurrent pain episodes (Gran, 2003; Holmström and Engholm, 2003; Winkel, 2008; Mourao *et al.,* 2010).

The current study did not show the MSDs development dependence with the age. According to results of this investigation, the incidence of WRMSDs is correlated with exposure to physical load in a person's professional work and length of service. To prevent WRMSDs it is important to use the individual approach.

CONCLUSIONS

Based on the current investigation, it can be concluded that scientific WRMSDs studies and their development are relevant. The most important problem to solve, is to early detect and identification of possible signs of work overload, which may lead to chronic diseases that are connected to overload or reduce workers ability to work to the extent of disability. The symptoms occur with remissions and are dependent on the physical workload; therefore it is very difficult to objectively distinguish workers, who have permanent muscles overload symptoms. The aim of this study is to bring out the possibilities, of determining the early symptoms of overload that would indicate possible development of chronic disease and a decrease in work ability. The effectiveness of rehabilitation has also been evaluated during different stages of WRMSDs.

The novelty of the investigation lies in the following:

- A systematic approach to MSDs is the key to optimizing the workplace ergonomics. The patients' muscles state investigations showed that myotonometry is viable and applicable for the measurements of muscle fatigue. The methodology can be used for office-workers, garment workers and patients with occupational disease. 66 office workers and 18 industrial workers were investigated and their pain was long-lasting (*Paper I*).
- The pain in muscles after balneotherapy decreased from 2,37 to 1,13 in the neck and from 3,25 to 1,03 in wrists respectively on the VAS pain scale. The stiffness of extensors (*M. abductor pollicis*) was higher than in the flexors (*M. adductor pollicis*) already before the treatment. There was a high incidence of musculoskeletal pain in 114 investigated persons: 68,4 % in the neck; 63,2 % in shoulders (*Paper II*).
- A model taking into account the ergonomics of the workplace and working conditions' influence on the developing of MSDs was created. Systematic application of physical education, exercise therapy improves the functional capacity of the organism to physical stress *Paper III*).
- A model of the dependences of pain duration in different locations and at different stages of MSDs (office workers, garment workers, patients with occupational diseases). Pain complaints develop significantly sooner than muscle soreness or elevated muscle tone. The tone and stiffness of *M. trapezius med* is higher of office and garment workers than in patients with occupational diseases (*Paper IV*).
- The values of the measured stiffness of the muscles were between 156–278 N/m and for the own frequency of muscles 11,2–16,6 Hz. The increased decrement results indicate a slight muscle overload rather than a persistent condition. The stiffness of the investigated muscles increased and the frequency decreased during the workweek (*Paper V*).
- The psychological complaints of workers (*Paper VI*) showed that only 60 % of computer workers were able to recover from a day's workload or work shift; the workers were slightly more satisfied with their

job than with their current life. There was the correlation between the monotonous work (data from the ART-tool, *Paper III*) and MSDs development (R=0,682).

Future research: preventive programs/models will have to be worked out on the basis of the structure of risk factors in the workplace and the complaints of workers, including the measurement results of musculoskeletal pain and muscle strain. The design of workplaces has to be based on the individual features of workers. The prevention methods for different age groups of computer and industrial workers have to be investigated.

Forearm pain is a common symptom, which frequently results in interference with daily activities. However, forearm pain rarely occurs in isolation. Its onset was related to psychological factors, aspects of illness behaviour, other somatic symptoms, and work-related mechanical and psychosocial factors. The role of mechanical factors in the onset of forearm pain has long been suspected, particularly due to repetitive movements of the arms and wrists. It is a common symptom in occupations that involve writing or keyboard work, with particularly high exposures. The strongest psychosocial predictor was dissatisfaction with support from the work supervisors or colleagues, but aspects of demand such as stress, worry, job pace, and level of interest were also associated (although not significantly) with future symptoms.

Repetitive tasks with hands can cause often cause a loss of work capacity in long term practice. We need good tools to prevent and rehabilitate these conditions before the permanent loss of work capacity appears. The traditional spa therapy is quite expensive. We were looking for the effective methods of using the traditional spa treatments in the less expensive way in the outpatient practice.

A better understanding of the physiological background of the work-related musculoskeletal pain syndrome (e.g. microcirculation status) could help to prevent the musculoskeletal health problems in workplaces having ergonomic risks or plan an appropriate treatment for the persons with overuse syndromes.

The development of chronic WRMSDs is usually preceded by years of muscular pain and other complaints of the musculoskeletal system. For the purpose of prevention of musculoskeletal complaints, it is essential to determine the niduses of early complaints and pain either in the course of medical anamnesis or by means of the relevant questionnaires. Attention should be paid to the duration and recurrence of the complaints, and the possible relationship of the complaints with the nature of work should be determined. A significant place is occupied by differential diagnostics.

Based on the present study, it may be concluded that, in case of a MSD, pain complaints develop significantly sooner than muscle soreness or elevated muscle tone, which are usually determined by palpation. Myotonometry is a readily available and non-invasive tool for early detection of changes in muscle tone. The measuring of muscles is not a procedure requiring much time or conditions differing from a regular visit to a doctor or a nurse. As a result of the myotonometric study, we can assess the muscle condition and symptoms of the effect of physical overload in a particular worker. Myotonometric study can also be used for assessing muscle state under dynamic conditions, e.g. after a treatment or a change in the working order, as well as during physical examinations over a number of years. When conducting the study, it is also necessary that the person conducting the study has passed previous training, has a good knowledge of musculature and can choose the muscles subjected to a larger load in the given work process.

In the current research, the conceptual model for prevention of MSDs in different groups of workers and the healthcare of patients with occupational diseases are elaborated. The used research methods: the ART-tool for ascertaining the ergonomic situation at the workplaces, the Standardized Nordic musculoskeletal questionnaire and the VAS pain scale for taking into consideration the pain of workers, myotonometry for the experimental part of the work, WAI and Kiva questionnaires for the determination of the influence of psychosocial hazards on the development of musculoskeletal disorders and the use of the high-level statistics proved to be the tools for the improvement of workers' health at workplace.

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Overview of the approval of research results

All the results from the current study have been published (or accepted for publishing) and presented by the authors at the international scientific conferences and doctoral seminars (PhD colloquia), following the acceptance of peer-reviewed submitted abstracts.

- The presentation covering “Office and industrial workers complaint detection and prevention of professional upper limb overuse” (*Paper I*) took place in RIGA, Oct. 2014 on the RTU 56th Annual Conference and in London, April 2015 during the 10th IOHA International Scientific Conference.
- The results of *Paper II* (“Work-related musculoskeletal symptoms in industrial workers and the effect of balneotherapy”) were presented by the author at the 6th Conference on Biosystems Engineering in Tartu, May 2015 and in the International Conference on Ergonomics and Occupational Health CISEO 2014, Del Sur University, Lima, Nov. 2014.
- The results of *Paper III* (“Comparison of musculoskeletal disorders development in Estonian office and garment industry workers”) were presented by the author at the 7th Conference on Biosystems Engineering in Tartu, May 2016
- The presentation of the *Paper IV* (“Musculoskeletal disorders caused by the static posture of office and garment workers”) were presented in Riga, May 2016 during the International Conference on Biology and Biomedicine and PREMUS 2016 in Toronto in June 2016, the 9th International Scientific Conference on the Prevention of Work-related Musculoskeletal Disorders.
- The results of *Paper V* (*“*Myotonometry as a tool for determination of fatigue in the upper extremities of garment industry workers”) were presented in Oct. 2016 in Druskininkai, on the 11th International Conference on Biology and Biomedicine, BIOMDLORE 2016.
- The results of the *Paper VI* (“The prevention of computer workers health disturbances caused by physical and physiological risks”) were presented in Oct. 2013 in Torino, during the Annual Meeting of Human Factors and Ergonomics Society Europe Chapter 2013 Annual Meeting.

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ELULOOKIRJELDUS

1. Isikuandmed

Ees- ja perekonnanimi	Viive Pille
Sünniaeg ja -koht,	12.07.1970, Eesti
Kodakondsus	Eesti
E-posti aadress	Viive.pille@regionaalhaigla.ee

2. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	Lõpetamise aeg	Haridus (eriala/kraad)
Tallinna Tehnikaülikool	2010-ka	doktoriõpe
Tartu Ülikool	1994	töötervishoiu residentuur
Tartu Ülikool	1994-1996	üldmeditsiini internatuur
Tartu Ülikool	1988-1994	Arstiteaduskond, ravi eriala

3. Keelteoskus

Keel	Tase
Eesti keel	emakeel
Inglise keel	hea
Vene keel	hea

4. Täiendusõpe

Õppimise aeg	Täiendusõppe korraldaja nimetus
2015	Occupational Diseases in the EU, Brussels
2011	Musculoskeletal Disorders – riskfactors and solutions at work. Nordic Institute for Advanced Training in Occupational Health (NIVA) Helsinki, Finland
2006-2008	Estonian-Finnish Twinning Project “Managing Occupational Risks Related to Asbestos” , series of training courses
2004	Toxicology. Ecotoxicology and Risk Assessment of Chemicals. Baltic University Programme. Uppsala Univesity, Sweden

5. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2001-ka	SA Põhja-Eesti Regionaalhaigla	töötervishoiuarst
2007-2010	TTÜ, Kliinilise meditsiini instituut	erakorraline lektor
1998-2001	Kutsehaiguste Kliinik	töötervishoiuarst

6. Valitud artiklid

1. Pille, V., Oha, K., Tint, P. 2013. Results of a myotonometrical muscle study in patients with work-related hand overload disorder.
   Occupational and Environmental Medicine, 2013, **70,** Suppl 1, 133.
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8. Tint, P., Traumann, A., Pille, V., Tuulik- Leisi, V-R., Tuulik, V. 2012. Computer users' health risks caused by the simultaneous influence of inadequate Indoor climate. *Agronomy Research*, *Biosystems Engineering Special Issue* 1, 261-268.

CURRICULUM VITAE

1. Personal data

Name	Viive Pille
Date and place of birth	12.07.1970 Estonia
E-mail address	Viive.Pille@regionaalhaigla.ee

2. Education

Educational institution	Graduation year	Education (field of study/degree)
Tallinn University of Technology of Faculty of Mechanical Engineering	2010 to date	PhD candidate
Tartu University	1996-1998	Residency in occupational medicine
Tartu University	1994-1996	Internship in general practice
Tartu University	1988-1994	Faculty of Medicine

3. Language Competence

Language	Level
Estonian	mother language
English	good
Russian	good

4. Special Courses

Period	Educational or other organisation
2015	Occupational Diseases in the EU, Brussels
2011	Musculoskeletal Disorders – risk factors and solutions at work. Nordic Institute for Advanced Training in Occupational Health (NIVA) Helsinki, Finland
2006-2008	Estonian-Finnish Twinning Project “Managing Occupational Risks Related to Asbestos” , series of training courses
2004	Toxicology. Ecotoxicology and Risk Assessment of Chemicals. Baltic University Programme. Uppsala University, Sweden

5. Professional Employment

Period	Organisation	Position
2001 to date	North Estonian Medical Centre	Head of the Centre of Occupational Diseases
2007-2010	Tallinn University of Technology	Lecturer on occupational health
1998-2001	Clinic of Occupational Diseases	Occupational health physician

6. Selected Papers

1. Pille, V., Oha, K., Tint, P. 2013. Results of a myotonometrical muscle study in patients with work-related hand overload disorder.
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ABSTRACT

Developing of a Model for the Prevention of Work-Related Musculoskeletal Overload Diseases in the Upper Extremities

Musculoskeletal disorders take the first place among the occupational diseases and work-related diseases in Estonia, Europe and in many countries around the world (US, Australia). The number of investigations in this area is large, but the nature of work as well as cultural differences have to be taken in consideration in the development factors analysis by countries.

Many factors that affect the formation of these diseases, such as low temperature, poor or not-rightly directed lighting, forced position, monotonous work, and psychological stress at work or outside it. However, forced position and monotonous work are considered the most important factors.

The present doctoral thesis focus on office (OW) and garment workers (GW) musculoskeletal diseases development, also the patients with occupational disease (OPD) are involved. The health disturbances (pain in the muscles of ODP) can be reduced with rehabilitation, but total rehabilitation is no more possible.

As in each country, there are different circumstances of work organization, climate conditions, cultural differences etc., and therefore conducting the study in Estonia is very reasonable.

The thesis is written based on six scientific papers.

The work has outlined a three-step musculoskeletal disease evolution scheme that consists of three stadiums. At the first stage, the rehabilitation is effective and the worker can return to work after a few weeks of treatment. At the second stage, treatment is possible, but it takes more time and sometimes the worker has to change the character of work in order not to be disabled in the future. In the case of occupational disease (the 3rd stage), the complaints and musculoskeletal changes are usually irreversible, but it is possible to use some rehabilitation methods to alleviate the sufferings of the patients. These people will not be able to work at full capacity. The loss of ability to work (the incapacity) is determined by the medical institutions.

A total of 505 employees were investigated. The most important method is myotonometry, whereby different upper body muscles' stiffness, decrement and frequency of oscillation of muscles is determined. These figures will change in the course of the monotonous work or static posture; these changes begin at ever-younger ages.

The pain spectrum of computer professionals, garment workers and patients with occupational disease (ODP) are different. Computer workers complain of pain in the neck and if the rehabilitation is applied, the pain will pass in a week. The pain in garment workers' neck muscles is long lasting (for 30 days or more), the same holds true for ODP. For OW the additional pain regions are shoulders and back; for GW and ODP the pain is felt in all the investigated regions (a bit weaker in elbow muscles of GW).

The workers' muscles stiffness, frequency and decrement were measured myotonometrically in the lying and sitting position, at the beginning and at the end of the workweek, before and after rehabilitation. The following muscles were investigated: M. *abductor pollicis brevis, M. adductor pollicis brevis* (thumb muscles)*, M. trapezius med* (back muscle)*, and M. erector spinae* (neck muscle), and the data are presented in the *Articles.*

Muscles rigidity increases due to monotonous work, static monotonous load on one hand (GW, gore machine), after the workweek. The increase for garment worker is usually bigger. Regards the changes in muscles' stiffness for the patients with occupational diseases, there is no change before and after the work. In some cases (GW, gore machine, OW) there are differences between left and right hand. In some case related to garment machines, both hands are loaded equally; in the case of office workers, the right hand is usually more loaded than the left.

To reach to the final aim of the present doctoral study a variety of questionnaires (VAS pain scale, Nordic questionnaire, Kiva, Work ability index) were used. Workplace ergonomy was examined with the ART-tool. The use of the last shows that the non-ergonomic risk in some sewing jobs is much higher than for the office workers. Computer workers' activities cause more monotonous work health disturbances than are connected with static posture; therefore, the risk level by Art-tool determination is lower.

The novelty of the thesis lies in the conceptual model, which links workers age, nature of work etc. with pain intensity at various regions of the upper body.

A variety of statistical methods (IBM SPSS Statistics 22.0 and R 2.15.2 correlation, *MANOVA, Factor Analysis* principal component method, Independent *t-test,* etc.) were used to demonstrate the dependencies and non-dependencies between the work character, workers age, body region and the stages of development of work-related musculoskeletal disorders.

KOKKUVÕTE

Tööga seotud käte ja õlavöötme ülakoormushaiguste ennetusmudeli väljatöötamine

Luu-lihaskonna haigused on esikohal kutsehaiguste ja tööga seotud haiguste hulgas Eestis, Euroopas ja paljudes teistes maailma riikides (USA, Austraalia). Uuringuid selles vallas on palju, kuid töökeskkonna samuti kultuuri keskkonna erisuste tõttu on nende haiguste kujunemise mehhanismid mõnevõrra erinevad. Tööga seotud luu-lihaskonna haiguste kujunemist soodustavad tegurid jagunevad kolme suurde rühma: füsioloogilised, psühho-sotsiaalsed ja individuaalsed tegurid. Vahel võivad vähest tähelepanu pälvivad tegurid, nagu madal temperatuur, ebasobiv valgustuse lahendus, soodustada sundasendis töötamist. Kõige tähtsamaks tööga seotud luu-lihaskonna haiguste tekkimisel peetakse siiski füsioloogilisi ohutegureid: korduvaid käte liigutusi haaramine, hoidmine, töötamist ebamugavates sundasendites ja töö monotoonsust.

Käesolev doktoritöö keskendub eelkõige kontoritöötajate ja õmblustööstuse töötajate luu-lihaskonnahaiguste tekkepõhjuste võrdlemisele ja haigussümptomite avaldumisele. Võrdlusrühmana on uuritud kutsehaigeid. Väljakujunenud krooniliste ülekoormushaiguste nagu karpaalkanali sündroomi, epikondüliidi, sõrmede tenosünoviidi ravi on oluliselt kallim, aega nõudvam ja patsiendile koormavam võrreldus esmaste üldist laadi lihasvalu sümptoomide leevendamisega. Paljudel kutsehaigetel on välja kujunenud püsiv töövõimetus, mille tõttu nad vajavad kutserehabilitatsiooni, taastusravi ning medikamentooset ravi.

Eesmärgiks ülekoormushaiguste ennetamisel on tuvastada varakult käte ja õlavöötme lihaste ülekoormuse tunnused, millest võivad areneda lihaste, kõõluste, närvide või liigeste haigused. Teadaolevalt on luu-lihaskonna haigused juhtival kohal tööealise elanikkonna ajutise ja püsiva töövõimetuse põhjustajana. Kuna haiguse sümptomid esinevad remissioonidega, siis on sageli raske hinnata objektiivselt lihaste seisundit ja haigusjuhu prognoosi.

Käesoleva töö eesmärgiks oli välja tuua erinevaid võimalusi varajaste ülekoormushaiguse ilmingute tuvastamiseks:

1. Võrrelda ergonoomiliste riskitegurite erinevate tasemete ekspositsiooni mõju töötajate gruppidele, sellega seotud ülajäsemete kaebuste esinemise ulatust ning lihasvalu paikmete arvu seost ülekoormusilmingute erinevate staadiumidega, staaži ja töötajate vanusega;
2. Hinnata lihasvalude esinemist ja valude tugevust käte, õlavöötme piirkonnas kontoritöötajatel ja tööstustöölistel, ning hinnata eelpool nimetatud näitajate põhjal balneoteraapia efekti töötajate tervisele;
3 Tööst põhjustatud ülekoormushaiguse kujunemise mudeli väljatöötamine võttes aluseks lihasvalude esinemist ja müotonomeetrilisi lihasparameetrite mõõtmistulemusi;
4. Hinnata erinevate töötajate gruppide töövõimet töövõime indeksi küsimustiku alusel, hinnata töövõime taseme, luu-lihaskonna kaebuste esinemise, staaži, töötajate vanuse ja lihastoonuse muutuste seoseid.

Doktoritöö on kirjutatud kuue teadusartikli põhjal.

Töös on välja toodud kolmeastmeline luu-lihaskonna haiguse kujunemise skeem. Varajases ehk esimeses staadiumis on töökorralduse muutmisega ja raviga võimalik töötajal kiiresti taastuda. Teise staadiumi korral, kui haigussümptomid on pikemat aega kestnud võib ravi ja taastumine nõuda rohkem aega, esineb oht spetsiifilise ülekoormushaiguse välja kujunemiseks. Luu-lihaskonna ülekoormusehaiguse diagnoosimise korral võime haigestumist käsitleda kolmanda staadiumina. Tunnusteks on käte, õlavöötme piirkonnas kestvad, hulgipaikme valud, võimalikud on liigeste funktsioonihäired. Välja võib kujuneda püsiv töövõime kaotus.

Valim koosnes 505 inimesest. Uuriti kontoritöötajaid, õmblustööstuse töölisi ning võrdlusrühm koosnes kutsehaigetest. Ankeetküsitlusena täitsid uuritavad Nordic luu-lihaskonna kaebuste ankeedi, töövõime indeksi küsimustiku ja valu hindamine toimus valu visuaal-analoog skaala alusel. Müotonomeetria meetodil mõõdeti lihaste jäikust ja toonust.

Töökoha ergonoomia uurimiseks on kasutatud ART tool'i. Nimetatud metoodika alusel ilmneb, et riskitase õmblustöötajate töökohtadel on kõrgem kui arvutiga töötajatel.

Valude spekter arvutitöötajatel, õmblejatel ja kutsehaigetel oli erinev. Arvutitöötajatel esines sageli kaelavalu, mis oli enamasti isemööduv. Uuritud õmblejate ja kutsehaigete rühmas oli valude esinemise kestvus pikem (30 päeva või rohkem). Arvutitöötajad deklareerisid valu kaela, õla, käte ja selja piirkondades vähem võrreldes õmblejate ja kutsehaigetega.

Lihaste jäikust, toonust ja dekrementi mõõdeti müotonomeetriliselt. Mõõtmised viidi läbi lamades ja istudes, töönädala alguses ja lõpus, enne ja peale taastusravi. Uuriti järgmisi lihaseid: *M. abductor pollicis brevis, M. adductor pollicis* (pöidlalihased)*, M. trapezius med* (seljalihas)*, M. erector spinae* (seljalihas) ning andmed on esitatud artiklites, mille põhjal töö kokkuvõte on kirjutatud.

Uuringust selgus, et lihaste jäikus suureneb monotoonse ja staatilise lihastöö puhul üldiselt töönädala lõpuks. Mõnel juhul oli erinevusi vasaku ja parema käe lihaste jäikuses. Õmblustööstuses on töötajatel käed reeglina võrdselt koormatud, kontoritöötajatel on tavaliselt rohkem koormatud parem käsi. Kätelihaste seisundi hindamine on informatiivne ka individuaalse füüsilise koormuse hindamiseks. Õlavöötme-selja lihaste puhul tuleb arvestada, et trapetslihase toonusele ja jäikusele avaldavab mõju psühhoemotsinaalne stress rohkem kui käte lihastele.

Müotonomeetria on innovatiivne meetod ja väärib enam uuringuid ja rakendamise võimaluste loomist töötervishoius luu-lihaskonna haiguste ennetamiseks. Meetod võimaldab täpsustada individuaalselt töötaja lihaste seisundit. Müotonomeetrilised mõõtmised on kergesti teostatavad ja korratavad ning võimaldavad jälgida lihaste seisundit dünaamikas nii töökoormuse muutuste kui ka ravi effekti hindamiseks

Käesoleva uurimistöö tulemusena on välja töötatud kontseptuaalne mudel, mis seostab töö ergonoomilist riski taset, staaži, töötajate vanuse ja lihasvalude tugevuse ning kestvuse kolme haigusstaadiumiga.

Kasutatud on erinevaid statistilisi meetodeid (IBM SPSS Statistics 22.0 ja R 2.15.2 korrelatsioon, *MANOVA, Factor Analysis* printsipaal komponendi meetod, sõltumatu *T-test jne*.).

Tulemused:

1 Uuritud kontori ja õmblustööstuse töötajate hulgas on lihasvalud laialt levinud. Suurema füsioloogilise ohuteguri riski tasemega õmblustöötajatel esineb enam valukaebusi ja lihasvalude kestus on pikem.

2 Käte, õlavöötme, selja piirkonnas nelja ja enama valupaikme esinemise korral võib täheldada riski töövõime vähenemisele.

3 Lihasparameetrite mõõtmistulemuste alusel esinesid kõrgemad lihastoonuse ja jäikuse nähud pöidlalihastel kutsehaigetel ja õmblustööstuse töötajatel ning madalamad parameetrid oli tuvastatud kontoritöötajate rühmas. Trapetslihase mõõtetulemuste osas oli vastupidiselt enam väljendunud lihasjäikuse nähud kontoritöötajate rühmas.

4 Töövõime indeksi järgi (maksimaalne töövõime 49 ja minimaalne 7 palli) hinnatud töövõime oli kõige kõrgem kontoritöötajate rühmas (keskmine 40 palli), õmblejate rühmas keskmine 37 palli ehk samuti hea ja kutsehaigete rühmas keskmine tulemus 19 palli. Suurel osal kutsehaigetest esines Sotsiaalkindlustusameti ekspertiisi poolt määratud püsiv töövõime kaotus.

5 Taastusravi tulemused nii valu esinemise ja valu tugevuse hinnangul ning lihasparameetrite paranemise alusel oli positiivsed töötajatel, kellel olid vaevused kestnud lühemat aega ja valupaikmete arv oli väiksem. Krooniliste lihaskonna vaevuste esinemise (lihasvalude esinemine üle 30 päeva või peaaegu iga päev) korral oli taastusravi efekt positiivne töötaja poolt hinnatud valu kaebuste esinemise alusel, kuid mitte lihasparameetrite järgi.

6 Müotonomeetria kasutamisel on oluline täpne uuritavate lihaste valik vastavalt tööliigutuste koormusest lihasgruppidele.

7 Varajane tähelepanu pööramine töötajate lihasvalu kaebustele ja hulgipaikme valude esinemisele on oluline krooniliste ülekoormushaiguste ennetuse seisukohast ja lihasparameetrite määramine aitab täiendava meetodina hinnata lihaste seisundit, töökorralduse muutuse ning ravi efekti.

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