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Institute of Sport Sciences and Physiotherapy, Faculty of Medicine, University of Tartu, Tartu, Estonia

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In Papers I, II, and III Martin Argus had primary responsibility for study protocol development, enrolment of the participants, performing measurements, data analysis, and writing the manuscripts.

ABBREVIATIONS

WHO	–	World Health Organization
MSD	–	musculoskeletal disorder
EU-OSHA	–	European Union Information Agency for Occupational Safety and Health
GDP	–	gross domestic product
COVID-19	–	SARS-CoV-2 coronavirus
ABW	–	activity-based workplace
BMI	–	body mass index
AROM	–	active range of motion
Fmax	–	maximal voluntary contraction force
JPE	–	joint position error
PPT	–	pain pressure threshold
COPSOQ III	–	Copenhagen Psychosocial Questionnaire, 3rd edition
FABQ	–	Fear Avoidance Beliefs Questionnaire
WAI	–	Work Ability Index

1. INTRODUCTION

During the last several decades, the way we work has changed tremendously. Due to rapid advancements in technology, the proportion of physical labour is declining, and the proportion of mental labour is on the rise (Frey & Osborne, 2013). To cope with the increasing amount of office workers and the fast-changing world, new office designs, mobile technology, and flexible work conditions are required. Due to the novelty of such work-related factors, their impact on musculoskeletal health is not yet well known.

Musculoskeletal disorders (MSDs) are health conditions that are typically characterized by pain and limitations in the performance of the locomotor system. The World Health Organization (WHO) recognizes musculoskeletal disorders as the leading contributor to disability and premature exit from the workforce. The prevalence of MSDs varies by age and diagnosis, however, people of all ages and locations are affected (WHO, 2022). In the context of occupational health, musculoskeletal disorders (MSDs) are the most common work-related health problem in the European Union. The influence of MSDs is noticeable on several levels. Besides causing negative outcomes for workers themselves, MSDs and their economic impact are a burden for enterprises, medical practitioners, and society as a whole (EU-OSHA, 2019). Office work requires less physical effort when compared with industry work, however, the prevalence of musculoskeletal disorders is similarly high (Govaerts et al., 2021; Collins & O'Sullivan, 2015).

Although MSDs are complex phenomena and often don't have a single direct cause, several individual and work-related risk factors have been reported that might have an impact on developing work-related MSDs. Individual risk factors include for example female gender, higher age, high body mass index and low physical activity, and sedentary lifestyle (Kaliniene et al., 2016; da Costa & Vieira, 2010; Holth et al., 2008; Thorp et al., 2011). Work-related risk factors which are associated with the development of MSDs include inadequate work equipment and ergonomics, more time spent working with a visual display unit, sustaining awkward postures, and high psychosocial work demands (da Costa & Vieira, 2010; Wu et al., 2012; Kaliniene et al., 2016).

Different aspects of the work environment have been associated with musculoskeletal disorders, however, some novel trends in working conditions don't yet have enough research to understand their effect on musculoskeletal health and associated factors. These novel trends in working conditions are implemented to grant better flexibility for the worker, and cost-effectiveness for the employer. Such directions include implementing teleworking, activity-based working, and using mobile, portable work equipment.

Due to advances in technology, working from a distance has become increasingly popular, and can provide benefits for the worker, organization, and society (Harpaz, 2002). This trend was enhanced by the SARS-CoV-2 coronavirus (COVID-19) pandemic, which required most office workers to shift to remote work. The situation was new for most workers, employers, and occupational health specialists, and provided new directions for research since research on the effect of teleworking on health has been scarce.

Several organizations have started implementing an activity-based workplace (ABW) concept, which is not allowing individual designated rooms or desks but instead provides places to work according to the current task and personal preference. The most common reasoning behind using this concept is offering flexible working conditions for the worker for better job satisfaction and also lowering operating costs for the organization by reducing office space (Danielsson & Bodin, 2008). Previous research on the effect of ABWs on workers' health has been controversial, indicating both positive (Haapakangas et al., 2018; Meijer et al., 2009; Candido et al., 2019) and negative (Bodin Danielsson et al., 2014; Pejtersen et al., 2011; Wijk et al., 2020) effects. Research about the effect of ABW on musculoskeletal health has mostly used ABW as a provisional intervention with mostly positive outcomes (Foley et al., 2016; Robertson et al., 2008), however, the effect on workers who have had longer exposure, is unknown.

A prerequisite for a mobile work environment is portable work equipment. Laptop computers are replacing desktop computers in the work environment because of several advantages including light weight, portability, and wireless internet access (Hough & Nel, 2017). Due to the physical properties of the laptop computer, several musculoskeletal health concerns have been introduced. Research has mainly focused on ergonomic concerns regarding the use of laptop computers, such as difficulty keeping a neutral posture, sustaining awkward postures, and adjustability restrictions (Moffet et al., 2002; Yu et al., 2018; Sommerich et al., 2002). Despite the ergonomic concerns, working with a mobile device might also have certain positive effects on musculoskeletal health, such as providing postural variability and increasing work-related physical activity (Davis & Kotowski, 2014).

This dissertation evaluated the presence of MSDs among office workers in relation to different working conditions, physical activity, functional characteristics of the neck and shoulder area, and COVID-19 lockdown.

2. LITERATURE REVIEW

2.1 Prevalence and risk factors of musculoskeletal disorders among office workers

MSDs are typically characterized by pain and functional limitations in the musculoskeletal system, comprising muscles, joints, bones, and other related structures. MSDs are the most common work-related health problem regardless of the physical demands and specifics of the work (EU-OSHA, 2019). The socio-economic impact of MSDs is wide, with an estimated cost of up to 2% of GDP due to absence from work and work disability (Bevan, 2015). MSDs are the highest contributor to the global need for rehabilitation and account for two-thirds of the rehabilitation needs among all adults (Cieza et al., 2021). The most common symptom of MSDs is pain, and musculoskeletal pain is the most common form of non-cancer pain. MSDs also increase the risk for other noncommunicable diseases, such as cardiovascular diseases or mental health problems (WHO, 2022). Among office workers, the prevalence of MSDs is high, with research indicating an annual prevalence between 63%–84.5%. The most problematic sites of MSDs among office workers include the lower and upper back, neck, and shoulders (Okezue et al., 2020; Etana et al., 2021; Janwantanakul et al., 2008; AlOmar et al., 2021). Recent cross-sectional studies using the Nordic Musculoskeletal Questionnaire have indicated the annual prevalence of lower back pain among office workers between 54–58.1%, upper back pain between 38.8–44.8%, neck pain between 43.3–50.1%, and shoulder pain between 37.9–50.5% (AlOmar et al., 2021; Etana et al., 2021; Kaliniene et al., 2016; Okezue et al., 2020). MSDs are highly common among office workers and lead to lower work ability, increased fatigue and mental distress, decreased productivity, and lower quality of life in general (Roux et al., 2005; Antonopoulou et al., 2009; Daneshmandi et al., 2017).

MSDs among office workers are most commonly non-specific pain problems, meaning a single direct cause is often difficult to identify. The risk factors for MSDs among office workers are multidimensional and can be divided into individual and work-related risk factors (Ye et al., 2017). Several individual and work-related risk factors are associated with the risk of developing or chronification of MSDs. Individual risk factors include both modifiable and non-modifiable factors. Non-modifiable risk factors include for example female gender, old age, certain ethnic and cultural background, history of trauma, injury or abuse, and genetics. Modifiable individual risk factors include high body mass index, poor mental health and sleep, presence of co-morbidities, low physical activity, and other lifestyle factors (van Hecke et al., 2013; Putsa et al., 2022). Work-related risk factors can be divided into ergonomics, work-related physical activity, and psychosocial domains. In the office settings, ergonomic risk factors include mostly inadequate or poorly adjusted work equipment and sustaining awkward postures resulting in postural strain (da Costa & Vieira, 2010; Wu et al., 2012; AlOmar et al., 2021). For office workers, the work-related physical activity category includes such risk factors as low physical activity during the workday, prolonged sedentary time, prolonged working with a visual display unit, and not taking breaks in between work sessions (da Costa & Vieira, 2010; Wu et al., 2012; Putsa et al., 2022; Ardahan & Simsek, 2016). Non-specific pain specific to MSDs among office workers has several psychosocial factors contributing to the pain experience. Psychosocial risk factors for developing or sustaining musculoskeletal disorders include weak social support, high work demands, low job satisfaction, and high perceived stress among other factors (Kaliniene et al., 2016; Deeney & O'Sullivan, 2009).

2.2 New trends in the settings of office work and its effect on musculoskeletal health

The advances in technology have granted more flexibility in the work culture and work environment. Mobile work equipment has made several jobs in different fields not dependent on the location. Being not dependent on the location of the work offers more flexibility for the worker and more recruitment options for the employer. Flexible options vary from working in an activity-based workspace to working part-time or full-time remotely. One of the main arguments for the employer for offering such flexible work conditions is the reduction in office space and expenses associated with maintaining the office. The proposed benefits of flexible work conditions for the employee include better work-life balance, an option to choose the environment best for the task, less time spent commuting when physical presence is not necessary, and possible health benefits (Harpaz, 2002; Appel-Muelenbroek et al., 2011). The primary drivers for moving towards activity-based or teleworking have been mostly economical and their effect on health has not been in focus (Engelen et al., 2018; Montreuil & Lippel, 2003; Henke et al., 2016). This thesis focuses on three major changes in office workers' work environment and work equipment during the past two decades and their effect on musculoskeletal health. These changes include remote work, activity-based workspace, and using a laptop computer.

Teleworking or remote work, as a way of doing the work, is not a novel concept. The first signs of using teleworking reach back to the 1970s and 1980s when telework was proposed as a future way of working (Illegems et al., 2001; Iscan & Naktiyok. 2005). Until 2019, remote work was more of an occasional work arrangement, however, since the COVID-19 outbreak, telework has suddenly become one of the most common arrangements of office work (Fana et al., 2020; Athanasiadou & Theriou, 2021). Due to the occasional nature of teleworking before the COVID-19 outbreak, its effect on musculoskeletal health is relatively unknown, however, certain beneficial factors and risk factors have been described. The proposed health benefits of remote work include lower stress due to less time spent commuting, fewer sick days due to less exposure to communicable diseases, lower risk of obesity, physical inactivity, and tobacco use (Montreuil & Lippel, 2003; Henke et al., 2016). The risk factors include the possibility of excessive working hours, working while ill ignoring health-related problems, ergonomic risks due to inadequate equipment, as well as psychosocial risks due to isolation and possible work-life conflict (Montreuil & Lippel 2003; de Macêdo et al., 2020).

Activity-based office, also known as "flex-office" is a work environment concept, where workers don't have personal designated desks but have the option to choose their room or work equipment that best suits their task or personal preference (Appel-Muelenbroek et al., 2011; Bodin Danielsson et al., 2014). This concept is described as a type of open office with a variety of different types of open, half-open, and closed working spaces. The terms "activity-based" and "flex" characterize the work environment as an office, where different workspaces match the requirements of different work-related tasks like concentrated work or collaboration. For example, such offices often include open working areas, spaces designed for teamwork, closed and soundproof cabinets for phone calls or videoconferences, and other designs for the workers to choose from (Wohlers & Hertel, 2017). Traditional open offices have demonstrated mostly negative effects on workers' health due to a higher chance of contracting a communicable disease or a higher exposure to noise and other stressors (Richardson et al., 2017; Bergström et al., 2015). A systematic review by Engelen and colleagues (2018) concludes, that the effect of activity-based work on the health of the employee, is equivocal. The results of individual studies on the effect of activity-based office on the general health of the worker are controversial, with authors suggesting positive effects (Danielsson & Bodin, 2008; Candido et al., 2019), no differences (Seddigh et al., 2014), and negative effects (Nijp et al., 2016). Research on the effect of ABW-s on musculoskeletal health is scarce (Engelen et al., 2018). A study by Foley and colleagues in 2016 suggested less low back pain among workers in ABW when compared with the usual office, but no differences in other body regions. In another study by Robertson and colleagues (2008), a reduction in musculoskeletal discomfort over several body regions was noticed among office workers who had exposure to ABW for 6 months, however, these results were not statistically tested and in addition to relocating to ABW, the intervention included ergonomics training which can also influence the outcome (Engelen et al., 2018). Other relevant risk factors contributing to poor musculoskeletal health are low physical activity and excessive sedentary behavior. Studies have demonstrated, that ABW might have a positive effect in this domain, suggesting lower self-reported sedentary behavior (Foley et al., 2016) and higher walking time (Hallman et al., 2018). A study using objective measures also suggested increased physical activity and reduced sedentary time among workers in newly renovated ABW compared with workers working in a traditional office (Jindo et al., 2019). Another study by Candido and colleagues (2019) demonstrated no differences in step count or distance traveled and sedentary time after relocating to ABW. Previous research on the effect of ABW on musculoskeletal health and its associated factors is limited, and the available research has several concerns, for example not using statistical analysis or using a very small sample size, therefore more research on this topic is needed.

During the past several decades, advances in technology have moved towards smaller, mobile equipment. The most common technology used for work in an office setting is a personal computer. Since laptop computers have become reasonably priced and as capable as desktop computers, most new computers acquired for study or work are of laptop type (Kay & Lauricella, 2011). Laptop computers offer portability and wireless connectivity, which allows flexibility in the work environment. Laptop computers allow easy connectivity with different monitors, keyboards, and other external equipment, making desktop computers obsolete in most settings (Bowman et al., 2014). The design of the laptop computer has been created considering weight and dimensions suitable for a mobile device. When opened, and in a working position, certain ergonomic concerns arise. By design, the laptop computer, without an external visual display unit, keyboard, and mouse, is not intended for working for extended periods. When compared to the desktop computer, the most relevant ergonomic concerns are the low position of the screen, the keyboard and touchpad being attached to the rest of the computer, and limited adjustability (Straker et al., 1997; Moffet et al., 2002; Yu et al., 2018; Sommerich et al., 2002). Despite the ergonomic concerns, using a laptop computer for work can allow doing the work in different positions and postures. This might lead to more work-time physical activity and postural variability, which might have a positive effect on musculoskeletal health (Davis & Kotowski, 2014). The most problematic body regions for laptop users have been identified as the shoulders, neck, upper back, lower back, wrists, and fingers (Obembe et al., 2013; Gautam & Chacko, 2017). These results are similar to studies not differentiating between computer types when investigating the prevalence of MSDs among office workers (Collins & O'Sullivan, 2015; Noroozi et al., 2015). This suggests, that using a control group of desktop computer users is necessary before comparative conclusions can be made. Studies investigating the postural characteristics of using a laptop computer have shown slightly different patterns from the desktop computer or external monitor users. Using the laptop computer requires a larger flexion angle, and a smaller craniovertebral angle in the neck, which can lead to increased postural strain in the extensor muscles of the neck and back, possibly resulting in developing MSDs in the area (Yu et al., 2018; Alyami & Albarrati, 2016). While using the laptop, higher muscle activity has been recorded when compared with using external monitors (Farias Zuniga & Côté, 2017; Saied et al., 2013), however, the evidence is limited. A non-comparative analysis has found, that increased craniovertebral angle resulting in forward head posture, is associated with increased muscle activity in the neck, and therefore recommends using a neutral head posture to prevent MSDs (Lee et al., 2017). This is supported by a recent meta-analysis, which suggests, that among adults, neck pain and forward head posture are significantly correlated, however, the causal relationship is still not clear (Mahmoud et al., 2019). In addition to muscle activity, several other functional characteristics of the neck are associated with forward head posture and MSDs. Previous research has found forward head posture associated with lower MVC force of the neck extensor muscles (Goodarzi et al., 2018), reduced range of flexion (Kim et al., 2018), and worse position-sense of the neck

(Khan et al., 2020). In addition to the forward head posture, certain changes in functional characteristics are also associated with experiencing neck pain. Subjects suffering from neck pain have demonstrated reduced neck AROM (Stenneberg et al., 2017), MVC force (Ylinen et al., 2004), PPT (Nunes et al., 2021), and higher JPE of the neck (de Vries et al., 2015). Previous research concerning the musculoskeletal health of the laptop user has focused primarily on postural characteristics (Straker et al., 1997; Moffet et al., 2002; Yu et al., 2018; Sommerich et al., 2002; Intolo et al., 2019; Alyami & Albarrati, 2016; Lee et al., 2017; Lee et al., 2021). Based on previously referred neck posture and pain research, indirect associations can be made about the status of functional characteristics of the neck among laptop users. A hypothesis can be set, that using the laptop computer has a negative effect on the functional characteristics of the neck due to the postural differences when compared with desktop computer users. A meta-analysis by Coenen and colleagues (2019) concludes, that there is a shortage of evidence about the effect of contemporary mobile work equipment, such as laptop computers, on musculoskeletal symptoms. To confirm the previously set hypothesis and investigate the adaptive response of the musculoskeletal system to working with a laptop computer, original research is needed.

2.3 COVID-19 lockdown and musculoskeletal disorders among office workers

On March 11, 2020, the World Health Organization (WHO) declared a global pandemic due to COVID-19 (World Health Organization, 2020). The pandemic caused lockdowns all over the world. In Estonia, the emergency situation and lockdown were declared on March 12, 2020, and lasted for 66 days. Social distancing rules were implemented, travel and indoor or outdoor gatherings were restricted, and services requiring physical contact were severely limited (the Republic of Estonia Health Board, 2020). The situation had a huge effect on working life, and it is estimated, that the changes caused by the COVID-19 lockdown changed working life indefinitely (Savić, 2020). Besides working life, people's personal lives were also affected, including their physical activity. During the emergency situation in Estonia, the sports clubs and fitness centers were closed, however, outdoor activities were allowed if social distancing rules were followed. For office workers, the most important change in work life during the lockdown was the shift to teleworking, which was a new experience for a lot of workers and companies. The COVID-19 crisis provided opportunities to investigate the health effects of teleworking and lockdowns in general. Today, enough time has passed from the COVID-19 outbreak for longitudinal studies and systematic research to become available. Study II of the current thesis was among the earliest research investigating the impact of the COVID-19 lockdown on musculoskeletal health.

While remote work as a way of working was already used before the COVID-19 lockdown, several peculiarities of the lockdown increased certain risks to the workers' health and well-being. Major peculiarities are the sudden onset with low preparation time and the mandatory nature of the lockdown. After the declaration of the lockdown, most office workers were assigned to work from home starting the next day. Many workers who were not implementing remote work before the lockdown, faced not enough physical space and no dedicated workstation at home. Such conditions resulted in using an environment not designed for work, for example, such as the dining table, kitchen, sofa, or bed (Xiao et al., 2021). In addition to the inappropriate physical work environment, several psychosocial issues have been mentioned when working from home during the COVID-19 lockdown. Workers working from home before COVID-19 had an opportunity to socialize and engage in off-time activities outside of their homes. However, during the COVID-19 lockdown, this option was not present due to lockdown restrictions, mainly social distancing rules. Such extended stay at home can be associated with feelings of loneliness, social isolation, and depression (Mann & Holdsworth, 2003). Unclear work-life boundaries can result in increased stress and anxiety in an already uncertain and indefinite situation (Evanoff et al., 2020). Systematic research has also indicated, that non-mandatory telework can have a positive effect on workers' performance and productivity, however, mandatory telework due to external factors such as the COVID-19 pandemic can have a more negative impact (Hackney et al., 2022). Increased psychosocial demands together with an inappropriate physical work environment can lead to a decline in general well-being and various health conditions, including MSDs (Lang et al., 2012; Taibi et al., 2021).

The hypothesis of a decline in musculoskeletal health due to the COVID-19 lockdown can be supported by several review articles. A rapid review by Gomez and colleagues (2022) provides evidence, that musculoskeletal pain during the pandemic was significantly higher in the body areas of the neck, shoulders, and back when compared with the pre-pandemic period. However, these results must be interpreted with caution, since the variation of prevalence in the studies included was extremely high. A review by Santos and colleagues (2021) concluded, that the musculoskeletal health of workers whose work activities were performed remotely, worsened. Until now, systematic research on this topic has been diffuse, including original research with very different sample characteristics. Therefore it is difficult to make a generalization about a specific profession or subgroup. Original research has indicated a worsening of pain intensity during the lockdown (Ahmed et al., 2021; Manju & Suruliraman, 2022; Radulović et al., 2021), but the prevalence of MSDs was not compared with the pre-pandemic time. Another original research article suggested a decrease in the prevalence MSDs during the lockdown (Rodriguez-Nogueira et al., 2021), however, this was not statistically tested. Although retrospective data collection has a strong recall bias, research comparing the prevalence of MSDs before and during the COVID-19 lockdown can provide insight into the effect of such restrictions on musculoskeletal health.

Among office workers, one of the risk factors most associated with MSDs is sedentary behavior and low physical activity (Holth et al., 2008; Thorp et al., 2011). International evidence suggests, that musculoskeletal symptoms and physical activity levels are relevantly associated. People with higher physical activity levels tend to experience fewer musculoskeletal symptoms (Rhim et al., 2022). Early research during the COVID-19 pandemic indicated a decline in physical activity among adults in general, including people with chronic pain (Bourdas & Zacharakis, 2020; Fallon et al., 2021). Due to the non-physical nature of office work, even lower physical activity levels might lead to an increase in MSD prevalence and have a negative impact on associated factors, such as work ability or mental health (Martinez & Latorre, 2006; Mikkelsen et al., 2017). By now, systematic research has become available, suggesting a significant decrease in physical activity during the COVID-19 lockdown among many different populations (Stockwell et al., 2021; Zaccagni et al., 2021; Wunsch et al., 2022; Park et al., 2022). Investigating the physical activity of office workers during the lockdown is relevant for developing occupational health strategies for office workers, should other lockdowns occur, and for regular teleworkers to reduce the risks associated with working from home.

3. AIMS

The overall purpose of this thesis was to assess the prevalence of MSDs in office workers in relation to work-related factors, physical activity, functional characteristics of the neck and shoulder area, and COVID-19 lockdown.

The specific objectives of this thesis were:

1. To compare the prevalence and risk factors of MSDs, and physical activity among office workers with and without ABWs (Study I, Paper II).
2. To compare the prevalence of upper body MSDs, and functional characteristics of the neck and shoulder area among office workers using a laptop or desktop computer for work (Study I, Paper III).
3. To evaluate the impact of the COVID-19 lockdown on the prevalence of MSDs, physical activity, and workplace properties in office workers transitioning to working from home (Study II, Paper I).

4. MATERIALS AND METHODS

4.1 Subjects

This dissertation is based on two studies. Study I consisted of two between-group analyses. The first analysis was done to compare MSDs and risk factors among office workers with and without ABWs. The second analysis was done to compare MSDs and functional characteristics of the neck between workers using a laptop or desktop computer. Study II investigated how a COVID-19 lockdown influenced the prevalence of MSDs, physical activity, and workplace factors.

The inclusion criteria for both studies were job described as office work, working with a computer for at least 6 hours per day, and age 20–60 years for Study I and 18–60 years for Study II. The exclusion criteria were chronic neurological, orthopedic, metabolic, or inflammatory conditions, legally designated disability for both studies, plus BMI over 30 kg/m^2 for Study I. 10 participants out of 120 were excluded from the analysis in Study I due to missing questionnaire data or BMI over 30 kg/m^2. The participants were recruited by contacting their organization's health and safety officers. The participants worked in the sectors of telecommunication, banking, information technology, education, energy, and healthcare. A total of 5 organizations participated in Study I and 10 organizations participated in Study II. All participating organizations implemented a standard 8-hour workday with a 30-minute lunch with an opportunity to take smaller breaks on demand. In Study I, all participants had access to contemporary furniture and an external mouse, keyboard, and monitor. In study I, 42 subjects worked in an ABW, and 45 subjects preferred working with a laptop computer without using an external display. Participation in the studies was voluntary and the studies were approved by the Ethics Review Committee on Human Research, University of Tartu (Report nr 287/T-26) in accordance with the Declaration of Helsinki. The overall sample characteristics for both studies are presented in Table 1.

Table 1. Sample size and subject characteristics (mean±SD).

	Study I	**Study II**
Sample size (*n*)	110	161
Female (%)	80.9%	64.6%
Age (years)	41.0 ± 10.0 (range 23–60)	38.2 ± 9.5 (range 20–59)
Office work experience (years)	15.7 ± 10.3	13.1 ± 8.6

4.2 Study design

4.2.1 Design and data collection of Study I

Study I took place in the participants' workplace. A private room adjusted for this study was provided by the participating organizations. The data collection consisted of two parts. First, the questionnaires were filled out to determine the eligibility for participation and fill in the questionnaires used in this study. Study eligibility (Pre-Test) questionnaire, Nordic Musculoskeletal Questionnaire, Baecke Physical Activity Questionnaire, Copenhagen Psychosocial Questionnaire, Work-Ability Index, and Fear-Avoidance Beliefs Questionnaire were used.

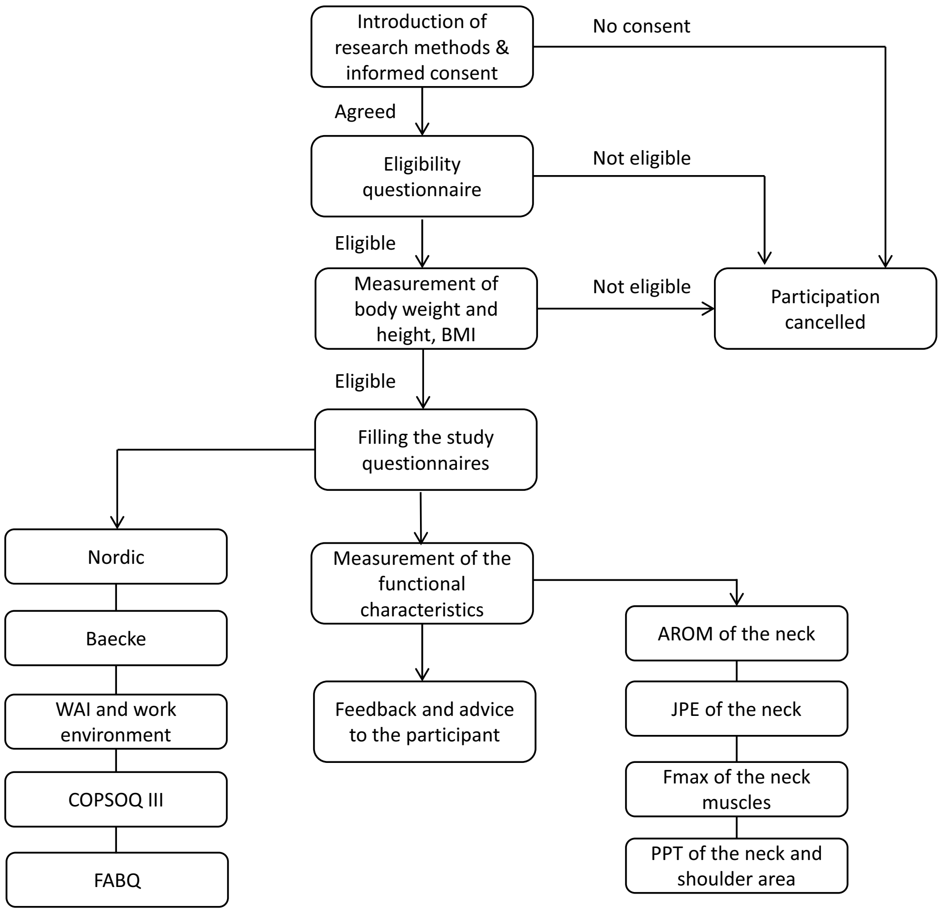

Figure 1. Order of procedures in Study I. BMI – body mass index; AROM – active range of motion; JPE – joint position error; Fmax – maximal voluntary contraction force; PPT – pain-pressure threshold; WAI – work ability index; COPSOQ – Copenhagen Psychosocial Questionnaire; FABQ – Fear Avoidance Beliefs Questionnaire.

The second part consisted of measuring weight, height, active range of motion (AROM) of the neck, maximal voluntary contraction force (Fmax) of the neck muscles, joint position error (JPE) of the neck, and pain-pressure threshold (PPT) of the soft tissues in the neck and shoulder area. The measurements were carried out during the mid-day lunch hours. All of the functional characteristics were measured on the same day. Participants had a five-minute rest before measuring the PPT. During the measurement of functional characteristics, the participant was sitting on an adjustable piano bench, with 90 degrees of flexion in the hip and knee joints, and feet fully supported on the ground. The participants were asked to keep their natural posture and support their forearms on their thighs.

4.2.2 Design and data collection of Study II

Study II was conducted as an online questionnaire, using Google Forms. The form consisted of five parts: informed consent, gender and age, MSDs, self-reported physical activity, and work environment. The study took place between May and June 2020. To inquire about the MSDs of the participants, a modified NORDIC musculoskeletal questionnaire was used. Given the purpose of this study, the answering options were modified to better capture the temporal trends of MSDs. Baecke Physical Activity Questionnaire was used to assess the self-reported physical activity of the subjects. The work environment section included questions about work experience, work settings, and self-reported ergonomics and comfort.

4.3 Methods

4.3.1 Nordic Musculoskeletal Questionnaire (Study I & II)

Nordic Musculoskeletal Questionnaire was used to assess the prevalence, location, and temporal properties of MSDs in both studies. Nordic Musculoskeletal Questionnaire is a well-known and reliable screening tool for determining the location and prevalence of musculoskeletal disorders in occupational health (Crawford, 2007). The original questionnaire by Kuorinka and colleagues (1987) inquired about MSDs in 9 body areas with illustrations and two temporal options: pain during the last 7 days or the last 6 months. Considering the objectives of this thesis, some of the answering options in the questionnaire were modified. In Study I, "pain today" was added to temporal answering options. Inquiring about pain during the day of measurement allows us to find associations with functional characteristics measured after filling out the questionnaires. The objectives of Study II required more detailed answering options to better identify the onset of MSDs and the impact of lockdown on MSDs. In Study II the temporal options were set to (1) no pain, (2) onset during 3 months before lockdown with pain disappearing during the lockdown, (3) onset during the lockdown, (4) onset before the lockdown, but the pain is still persistent. Using these 4 options it was also possible to converge the answers as pain before the lockdown (options 2 and 4) and pain during the lockdown (options 2 and 3). The questionnaire used in this study is based on an Estonian translation previously developed for the CUPID study (Coggon et al.,2012).

4.3.2 Baecke Physical Activity Questionnaire (Study I & II)

The objectives of the studies required a physical activity questionnaire, which can differentiate between work-related and other physical activities. To assess different domains of self-reported physical activity, the Baecke Physical Activity Questionnaire was used in this thesis. Baecke Physical Activity Questionnaire allows us to investigate self-reported physical activity in three different domains: work-related physical activity, sports-related physical activity, and leisure-locomotive physical activity, such as walking or cycling to school or work. Work-related physical activity domain includes questions about the physical demands of work, the sports-related physical activity domain inquires about the type, frequency, and intensity of sports participation, and the leisure-locomotive domain includes questions about everyday physical activity outside of work and sports. Most of the answer options are based on a 5-point Likert scale or a 5-point interval scale. An index can be calculated for each domain which sums up as Baecke Physical Activity Index (Baecke et al., 1982). In Study II, the questionnaire was duplicated, the first copy inquiring retrospectively about the period of 3 months before the COVID-19 lockdown and the second copy about the time during the COVID-19 lockdown. Baecke Physical Activity Questionnaire has proven to be a valid and reliable tool to assess self-reported physical activity among adults (Ono et al., 2007). An Estonian version translated for a previous study was used (Merisalu et al., 2016).

4.3.3 Work environment and work ability (Study I & II)

In this thesis, several variables of work environment and work ability were studied. Work experience as an office worker was acquired in both studies as a descriptive factor for the sample. In addition to general work experience, work experience in the current office type was inquired in Study I as a control factor for between-group analysis of subjects with or without ABW (Paper II). In both studies, information about the type of computer used for work was obtained to better understand ergonomic conditions in Study II and to divide the sample into laptop computer or desktop computer users for the analysis in Study I, Paper III. In Study I, the participants were also required to report their average daily screen time at work and average time spent working while standing as descriptive factors for the sample. The Work Ability Index (WAI) was used to assess the general work ability between groups in Study I, Paper II. WAI is a quick and reliable tool for assessing self-reported work ability. WAI can predict long-term sickness leave and which workers need support to prevent the loss of work ability (Tuomi et al., 1998; Schouten et al., 2016). WAI includes questions about the workers' health, mental resources, and both the physical and mental demands of work. An Estonian translation used in previous research was applied (Pille et al., 2016). The questionnaire in Study II also inquired about teleworking before the lockdown to exclude those participants from the analysis who worked remotely already before the lockdown. Study II also included questions about average hours of continuous work without taking a break, and self-reported comfort and ergonomics score on a five-point Likert scale to better understand how the subjects assess the change in their work environment and well-being doing work due to the lockdown.

4.3.4 Copenhagen Psychosocial Questionnaire (Study I)

The work-related psychosocial risks were assessed by using the Copenhagen Psychosocial Questionnaire, 3rd edition (COPSOQ III), middle version. The middle version of COPSOQ III includes 60 questions in 26 domains., which include job demands, job satisfaction, leadership, offensive behavior, well-being, etc. The answers are based on a 5-point Likert scale, and each domain will result in a domain score between 0 and 100. The overall COPSOQ III risk score is the mean of 26 domain scores. The Middle version was used in this study due to the long version is too time-consuming for the participants, and the short version is too superficial for research purposes. The COPSOQ III middle is an upgraded version of the COPSOQ II middle version, which has sufficient reliability for research purposes (Pejtersen et al., 2010). The Estonian version of COPSOQ III has been validated and is frequently used in practice to investigate the psychosocial risks among office workers (Randmann, 2021).

4.3.5 Fear Avoidance Beliefs Questionnaire (Study I)

To assess the fear avoidance behavior associated with musculoskeletal pain, the Fear Avoidance Beliefs Questionnaire (FABQ) was used. This questionnaire allows us to investigate work-related and physical activity-related pain beliefs separately, which is a necessary feature when investigating the effect of different work environments. FABQ consists of 16 examples of pain-related fear avoidance behavior. The participant is asked to express their opinion on the pain-related statements in the questionnaire. The participant can provide a numeric value on how much they agree or disagree, that their own pain experience can be supported or explained by the statement provided in the questionnaire. The answers are on a 6-point scale, where 0 equals complete disagreement and 6 equals complete agreement. FABQ was mandatory only for the subjects who had a recent experience with musculoskeletal pain. An Estonian version previously translated for a study on musculoskeletal pain among Estonian computer users was used in this dissertation (Oha et al., 2014).

4.3.6 Measurement of active range of motion of the neck (Study I)

To measure the active range of motion of the neck in Study I, a CROM cervical goniometer (Performance Attainment Associates, USA) was used. The physical settings of the measurement are described in chapter 4.2.2. Flexion, extension, lateral flexion, and rotation to both sides were measured. The reading was recorded when the participants reached the maximum possible active range of motion, perceived pain, or began to compensate with their trunks. The unit of measurement used was degrees of rotation (°). Every function was measured three times and the arithmetical mean was calculated for the statistical analysis.

4.3.7 Measurement of maximal voluntary contraction force of the neck muscles (Study I)

The maximal voluntary contraction (MVC) force of the neck muscles was measured using a hand-held digital dynamometer Lafayette Manual Muscle Testing System (Lafayette Instrument Company, USA). The settings of the measurement are described in chapter 4.2.2. The MVC force was measured in the directions of protraction, extension, and lateral flexion to the left and right, adapted from a protocol in previous research (Versteegh et al., 2015). The unit of measurement used for MVC force was kilograms (kg). The participants were asked to keep their trunks and limbs in place during the measurement and only use the neck to generate force. Depending on the direction measured, the dynamometer was held by the researcher against the participant's forehead, temporal region, or occipital region. The participants were asked to hold their heads in a neutral position and push against the dynamometer to build up to their maximal cervical muscle force over three seconds while maintaining the static neck position. During the procedure, the researcher applied counter-force to prevent the dynamometer from moving. Every direction was measured three times, with 60 seconds of rest between the repetitions. The maximum value was used in statistical analysis. The data were analyzed separately for both genders.

4.3.8 Measurement of joint position error of the neck (Study I)

The joint position error (JPE) was measured using a laser pointer mounted to the midline on the CROM cervical goniometer. The JPE target was attached to the wall at eye level approximately 90cm in front of the subject. The unit of measurement for JPE was millimeters (mm). The participants were asked to point the laser in the middle of the target, close their eyes, keep their trunks and limbs in place during the measurement, rotate the head to the side as far as possible, and return to the middle without opening their eyes. The final point was measured from the center of the target. JPE was measured six times on both sides and the arithmetical mean for each side was calculated for the statistical analysis.

4.3.9 Measurement of the pain-pressure threshold of the neck and shoulder area soft tissues (Study I)

Algometry was used to provide a quantitative measurement of sensory perception of mechanical stimuli. The PPT of the subjects was measured using a handheld digital algometer (SOMEDIC SenseLab AB, Sweden) with a rubber disk area of 1 cm^2. To assess the PPT, the rubber disk of the algometer was applied perpendicularly against the skin on the test area, and the pressure was applied at the rate of approximately 50 kPa/s. The PPT was defined as the pressure (kPa) where the pain was first experienced. The subjects were instructed to push a button, when they reached the PPT, locking the exact value on the display of the algometer. We included three test sites on both body sides. The first site was the midpoint of the upper trapezius, measured from the spinous process of C7 to acromion. The second site was the inferior end of the levator scapulae muscle near the superior angle of the scapula. The third point of measurement was the midpoint of neck extensor muscles, measured from the base of the neck to the base of the skull. The assessment consisted of three rounds of measurements with a 5-minute break in between. The mean PPT was included in the statistical analysis. The data were analyzed separately for both genders.

4.4 Statistical analysis

The process of data cleaning was carried out using MS Excel 2010. The statistical analysis was done using R Studio, version 4.0.3. The calculation of statistical power and the sample size was based on between-group analysis using a t-test or Wilcoxon test and was calculated by using the "pwr" package in R Studio. In Study I, approximately 60 subjects per group were necessary to obtain statistical power of 0.8 with an alpha level of 0.05 and the lowest relevant effect size as medium ($d = 0.5$). In Study II, 161 pairs allowed the lowest relevant effect size of $d = 0.22$ to be detected at an alpha level of 0.05 and statistical power of 0.8. The results for the prevalence data are presented as percentages and the results for other variables are presented as mean ± SD. The data were checked for normality by using histograms and the Shapiro-Wilks test. To determine the statistically significant differences in the prevalence data between the groups, Fisher's exact test or Chi-square test was used, depending on the frequency of prevalence in the groups. Odds ratios with 95% confidence intervals were used to express the magnitude of the difference among statistically significant results. In Study I, depending on the distribution and the type of variable, the Welch t-test or Wilcoxon test was used to determine the statistical significance when comparing the means of functional characteristics between the group. Multivariate logistic regression analysis was used in Study I to find associations between NSP as the dependent variable, type of computer used for work, and functional characteristics of the neck and shoulder region as independent variables, correcting for age, gender, BMI, screentime, and physical activity. In

Study II, depending on the distribution and the type of variable, a paired t-test or Wilcoxon test was used to determine the statistical significance of variables before and after the lockdown. The effect size was assessed using Cohen's *d* and the magnitude of the effect was classified by a standard of small (from $d = 0.2$), medium (from $d = 0.5$), and large (from $d = 0.8$). Depending on the distribution and type of variables, Spearman or Pearson correlation analysis was used to find relationships between the variables measured in Study II. The minimal statistical significance threshold was set to $p < 0.05$ in both studies.

5. RESULTS

5.1 Prevalence of musculoskeletal disorders among office workers with activity-based workplace and designated workspace (Study I, Paper II)

Figure 2 represents the prevalence of MSDs in different body regions among office workers with ABW and designated stationary workspace. No statistically significant differences were found in the prevalence of MSDs during data collection (Figure 2a), past 7 days (Figure 2b), or past 6 months (Figure 2c) between office workers with and without ABW when body sides were not differentiated.

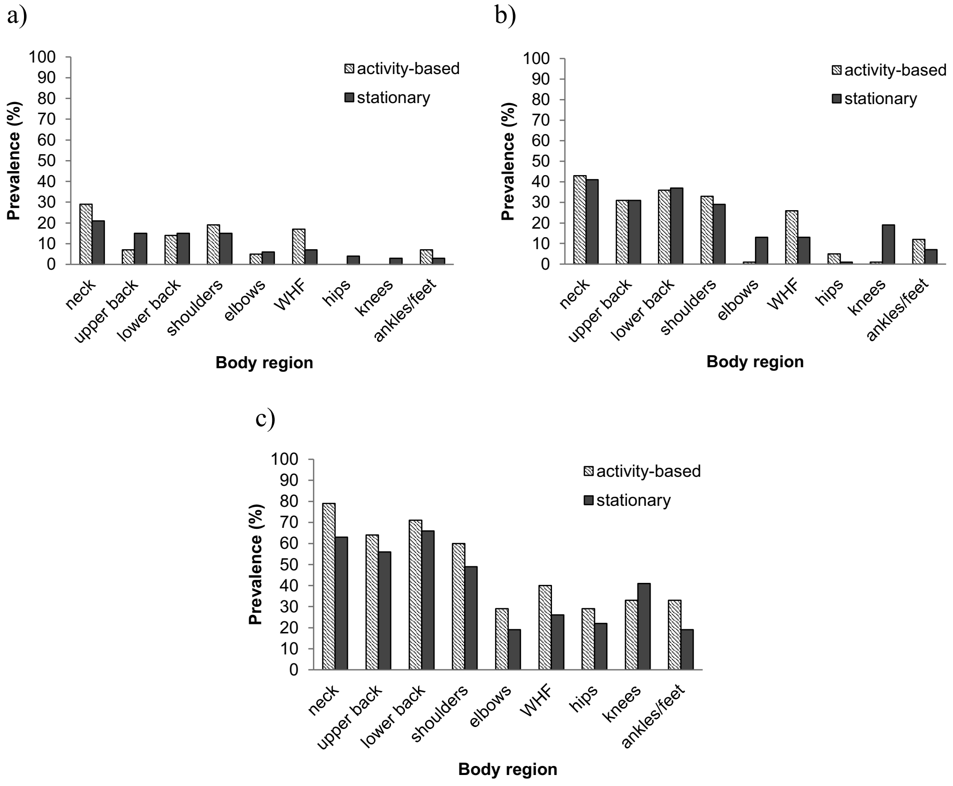

Figure 2. The prevalence of musculoskeletal disorders in office workers with activity-based (n = 42) and designated (n = 68) workplaces at the moment of data collection (Figure 2a), in the past 7 days (Figure 2b), and the past 6 months (Figure 2c). WHF – wrist, hands, and fingers.

When body sides were analyzed separately, workers with ABW experienced statistically significantly more ($p = 0.015$; OR = 2.88; 95% CI [1.21, 6.82] wrist, hand, and finger (WHF) pain in the right hand during the past 6 months when compared with workers with a designated stationary workplace (Figure 3).

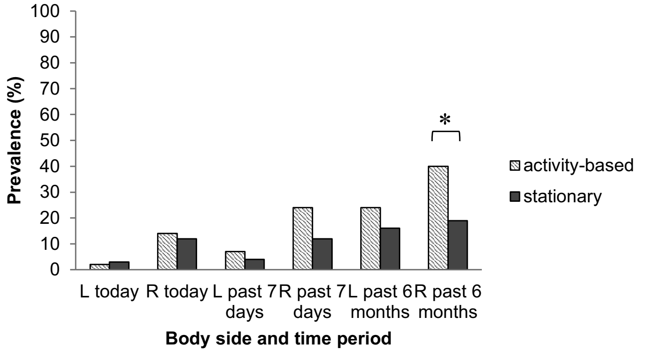

Figure 3. The prevalence of wrist, hand, and finger pain in office workers with activity-based ($n = 42$) and designated ($n = 68$) workplaces. *$p < 0.05$. L = left; R = right.

5.2 Physical and psychosocial factors associated with musculoskeletal disorders among office workers with and without activity-based workplace (Study I, Paper II)

Office workers with ABW presented statistically significantly higher work-related self-reported physical activity ($p = 0.011$; $d = 0.54$) and average daily time spent working while standing ($p = 0.008$; $d = 0.63$). There were no statistically significant ($p < 0.05$) results in WAI, self-reported screen time, COPSOQ III psychosocial risk score, and FABQ scores. (Table 2)

No statistically significant ($p < 0.05$) differences were found in neck and shoulder region PPT when ABW office workers were compared with non-ABW workers of the same gender (Table 3).

Table 2. Physical and psychosocial factors associated with musculoskeletal disorders among office workers with and without activity-based workplace (mean ± SD).

Feature	ABW (*n* = 42)	Control (*n* = 68)	*p*-value	95% CI
WAI	40.60 ± 3.97	40.80 ± 4.59	0.88	[–1.74 to 1.50]
BPAI work	2.08 ± 0.36	1.91 ± 0.29	0.01*	[0.04 to 0.30]
BPAI sports	2.94 ± 0.98	2.83 ± 1.13	0.59	[–0.29 to 0.51]
BPAI leisure	3.03 ± 0.49	3.21 ± 0.70	0.11	[–0.40 to 0.04]
BPAI total	8.08 ± 1.24	7.89 ± 1.53	0.56	[–0.37 to 0.68]
COPSOQ III score	68.41 ± 9.11	67.66 ± 11.41	0.71	[–3.12 to 4.61]
FABQ work score	8.88 ± 8.10 (*n* = 32)	7.73 ± 6.86 (*n* = 52)	0.51	[–1.80 to 4.09]
FABQ physical activity score	9.69 ± 5.43 (*n* = 32)	9.67 ± 5.62 (*n* = 52)	0.99	[–2.10 to 2.13]
FABQ total score	22.75 ± 13.23 (*n* = 32)	20.98 ± 10.28 (*n* = 52)	0.52	[–2.92 to 6.46]
Daily screentime at work	7.50 ± 1.33	7.88 ± 1.47	0.17	[–0.91 to 0.16]
Daily working while standing	0.85 ± 1.29	0.26 ± 0.61	0.01*	[0.16 to 1.00]

**p* < 0.05. ABW – activity-based workplace; BPAI – Baecke physical activity index; COPSOQ III – Copenhagen psychosocial questionnaire (3rd edition); FABQ – fear avoidance behavior questionnaire; WAI – work ability index.

Table 3. Pain-pressure threshold (kPa), of neck and shoulder area among office workers with and without activity-based workplace (mean ± SD).

Location	Female			Male		
	ABW (*n* = 33)	Control (*n* = 56)	*p*-value [95% CI]	ABW (*n* = 9)	Control (*n* = 12)	*p*-value [95% CI]
UT left	706 ± 315	670 ± 266	0.59 [–1.07 to 1.80]	732 ± 416	728 ± 500	0.98 [–1.72 to 1.81]
UT right	712 ± 334	648 ± 285	0.37 [–0.52 to 1.82]	712 ± 306	793 ± 606	0.70 [–2.57 to 0.92]
LS left	874 ± 432	812 ± 329	0.48 [–1.04 to 2.30]	718 ± 475	952 ± 701	0.37 [–4.63 to 0.15]
LS right	876 ± 428	770 ± 291	0.22 [–0.36 to 2.52]	681 ± 408	875 ± 651	0.41 [–4.01 to 0.03]
NE left	384 ± 202	361 ± 124	0.57 [–0.23 to 0.70]	250 ± 117	370 ± 252	0.16 [–1.94 to 0.52]
NE right	391 ± 190	345 ± 131	0.23 [–0.01 to 0.95]	253 ± 116	384 ± 239	0.11 [–2.03 to 0.66]

ABW – activity-based workplace; CI – confidence interval; LS – levator scapulae; NE – neck extensor; UT – upper trapezius.

5.3 Prevalence of musculoskeletal disorders among office workers working with a laptop or desktop computer (Study I, Paper III)

A higher prevalence of neck and shoulder region MSDs were reported among workers using a laptop computer when compared with the users of desktop computer. The difference was significant particularly in the right shoulder area, whereas the overall neck and shoulder MSD prevalence was slightly higher among laptop users, but did not reach statistical significance. Laptop users reported a significantly higher prevalence of right shoulder pain on the day of data collection ($p = 0.048$, OR = 4.41, 95% CI 0.98 to 27.40), in the previous 7 days ($p = 0.012$, OR = 3.69, 95% CI 1.24 to 12.03), and the previous 6 months ($p = 0.003$, OR = 3.53, 95% CI 1.49 to 8.63), when compared with the users of the desktop computer. Laptop users also had a significantly higher prevalence of left shoulder pain in the previous 7 days ($p = 0.049$, OR = 2.42, 95% CI 0.93 to 6.45) when compared with desktop computer users. Table 4 presents the prevalence of MSDs among office workers working with a laptop or desktop computer.

Table 4. Prevalence of musculoskeletal disorders among office workers working with a laptop (n = 45) or desktop (n = 65) computer.

Body area	1 day				7 days				6 months			
	Laptop *n* (%)	Desktop *n* (%)	OR (95%CI)	*p*	Laptop *n* (%)	Desktop *n* (%)	OR (95%CI)	*p*	Laptop *n* (%)	Desktop *n* (%)	OR (95% CI)	*p*
NS	17 (37.8)	18 (27.7)	1.58 (0.65 to 3.74)	0.302	28 (62.2)	33 (50.8)	1.59 (0.69 to 3.74)	0.249	40 (88.9)	51 (78.5)	2.18 (0.67 to 8.40)	0.203
Neck	14 (31.1)	12 (18.5)	1.98 (0.74 to 5.36)	0.171	20 (44.4)	26 (40.0)	1.20 (0.52 to 2.77)	0.697	33 (73.3)	43 (66.2)	1.40 (0.57 to 3.59)	0.530
Left shoulder	5 (11.1)	6 (9.2)	1.23 (0.28 to 5.20)	0.757	16 (35.6)	12 (18.5)	2.42 (0.93 to 6.45)	**0.049**	21 (46.7)	22 (33.8)	1.70 (0.73 to 4.00)	0.233
Right shoulder	8 (17.8)	3 (4.6)	4.41 (0.98 to 27.40)	**0.048**	14 (31.1)	7 (10.8)	3.69 (1.24 to 12.03)	**0.012**	26 (57.8)	18 (27.7)	3.53 (1.49 to 8.63)	**0.003**
Low back	7 (15.6)	9 (13.8)	1.14 (0.33 to 3.80)	0.791	15 (33.3)	25 (38.5)	0.80 (0.33 to 1.90)	0.688	26 (57.8)	49 (75.4)	0.45 (0.18 to 1.10)	0.062
Upper back	5 (11.1)	8 (12.3)	0.89 (0.21 to 3.36)	1.000	15 (33.3)	19 (29.2)	1.21 (0.49 to 2.96)	0.679	25 (55.6)	40 (61.5)	0.78 (0.34 to 1.82)	0.559
Left elbow	0 (0.0)	1 (1.5)	0.00 (0.00 to 56.28)	1.000	1 (2.2)	4 (6.2)	0.35 (0.01 to 3.69)	0.647	4 (8.9)	6 (13.3)	0.96 (0.19 to 4.34)	1.000
Right elbow	4 (8.9)	2 (3.1)	3.04 (0.41 to 35.06)	0.224	4 (8.9)	5 (7.7)	1.17 (0.22 to 5.80)	1.000	11 (24.4)	11 (16.9)	1.58 (0.55 to 4.52)	0.344
Left WHF	1 (2.2)	2 (3.1)	0.72 (0.01 to 14.19)	1.000	3 (6.7)	3 (4.6)	1.47 (0.19 to 11.52)	0.687	10 (22.2)	11 (16.9)	1.40 (0.48 to 4.07)	0.623
Right WHF	4 (8.9)	6 (9.2)	0.96 (0.19 to 4.34)	1.000	7 (15.6)	11 (16.7)	0.91 (0.27 to 2.83)	1.000	13 (28.9)	17 (26.2)	1.15 (0.45 to 2.90)	0.829

NS – neck & shoulder; WHF – wrist, hand, and fingers. Statistically significant results ($p < 0.05$) are presented in bold

5.4 Functional characteristics of the neck in office workers working with a laptop or desktop computer (Study I, Paper III)

There were no statistically significant differences in the functional characteristics of the neck between office workers working with a laptop or desktop computer. No statistically significant differences were noted in the AROM of the neck or JPE of the neck (Table 5). Also, there were no statistically significant differences in the MVC force of the neck muscles (Table 6) or PPT of the soft tissues in the neck and shoulder area (Table 7) between laptop and desktop computer users of the same gender. The results of the binary logistic regression analysis, investigating the associations between neck and shoulder pain, using a laptop for work, and functional characteristics of the neck, suggested significant associations between the acute neck and shoulder pain and AROM of the neck, however, the odds ratios indicate an irrelevant effect size for these associations (Table 8).

Table 5. Active range of motion and joint position error of the neck in desktop users and laptop users (mean ± SD).

Function	Desktop users (*n* = 65)	Laptop users (*n* = 45)	*p*-value	95% CI
Flexion (°)	57.30 ± 9.43	56.58 ± 10.38	0.71	–3.13 to 4.57
Extension (°)	70.15 ± 14.58	72.81 ± 11.13	0.28	–7.52 to 2.21
Left LF (°)	50.07 ± 10.26	52.12 ± 10.16	0.30	–5.97 to 1.88
Right LF (°)	46.04 ± 10.35	46.55 ± 10.72	0.80	–4.58 to 3.56
Left rotation (°)	68.67 ± 9.31	70.92 ± 9.26	0.27	–5.82 to 1.32
Right rotation (°)	68.19 ± 8.55	70.20 ± 9.91	0.27	–5.63 to 1.60
Left rotation JPE (°)	51.67 ± 20.79	46.61 ± 13.30	0.30	–1.39 to 11.51
Right rotation JPE (°)	53.08 ± 14.59	49.64 ± 14.88	0.25	–2.25 to 9.11

LF – lateral flexion; JPE – joint position error.

Table 6. Maximal voluntary contraction force of the neck muscles in office workers based on the type of computer used for work (mean ± SD).

Function	Desktop users (*n* = 65, 86% females)	Laptop users (*n* = 45, 73% females)	*p*-value	95% CI
Protraction (kg)				
Female	8.46 ± 8.76	7.61 ± 2.14	0.60	–1.60 to 3.30
Male	11.44 ± 4.29	11.49 ± 3.38	0.98	–3.74 to 3.65
Extension (kg)				
Female	9.02 ± 2.77	9.59 ± 2.74	0.34	–1.76 to 0.62
Male	10.84 ± 3.67	12.97 ± 2.83	0.17	–5.27 to 1.02
Left LF (kg)				
Female	6.55 ± 1.77	6.95 ± 2.10	0.62	–1.26 to 0.47
Male	9.60 ± 3.26	10.38 ± 3.06	0.59	–3.73 to 2.18
Right LF (kg)				
Female	6.23 ± 1.89	6.81 ± 1.94	0.23	–1.42 to 0.26
Male	8.89 ± 2.76	10.33 ± 3.52	0.31	–4.32 to 1.43

LF – lateral flexion.

Table 7. Pain-pressure threshold of different neck and shoulder regions among office workers based on the type of computer used for work (mean ± SD).

Location	Desktop users (*n* = 65, 86% females)	Laptop users (*n* = 43, 72% females)	*p*-value	95% CI
Left UT (kg)				
Female	6.99 ± 2.61	6.99 ± 3.40	0.68	–1.41 to 1.42
Male	8.86 ± 6.35	6.37 ± 2.62	0.72	–2.52 to 7.48
Right UT (kg)				
Female	6.90 ± 2.56	6.68 ± 3.94	0.25	–1.37 to 1.80
Male	8.79 ± 7.28	6.94 ± 2.32	0.97	–3.82 to 7.53
Left LS (kg)				
Female	8.62 ± 3.72	8.05 ± 3.63	0.44	–1.06 to 2.21
Male	9.79 ± 8.16	7.86 ± 4.55	0.97	–4.67 to 8.53
Right LS (kg)				
Female	8.25 ± 3.68	8.13 ± 3.40	0.94	–1.44 to 1.69
Male	8.81 ± 7.42	7.52 ± 4.22	0.81	–4.73 to 7.30
Left NE (kg)				
Female	3.77 ± 1.70	3.75 ± 1.39	0.76	–0.65 to 0.94
Male	3.38 ± 2.61	3.15 ± 1.83	0.81	–1.95 to 2.43
Right NE (kg)				
Female	3.64 ± 1.61	3.76 ± 1.55	0.69	–0.83 to 0.58
Male	3.37 ± 2.39	3.33 ± 1.91	0.91	–2.03 to 2.11

UT – upper trapezius; LS – levator scapulae; NE – neck extensors.

Table 8. Multivariate logistic regression model for neck and shoulder pain with different duration in office workers (*n* = 108, 80.6% females).

Factor	NSP at the moment		NSP in the previous 7 days		NSP in the previous 6 months	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Laptop	2.25	0.86 to 6.44	1.54	0.65 to 3.74	2.14	0.64 to 8.24
Total neck ROM	**0.98**	**0.97 to 0.99**	**0.99**	**0.98 to 1.00**	0.99	0.98 to 1.00
Total neck MVCF	1.01	0.97 to 1.06	1.01	0.97 to 1.06	0.96	0.91 to 1.02
Total neck JPE	1.00	0.98 to 1.01	1.00	0.99 to 1.02	1.02	0.99 to 1.04
Total neck PPT	0.97	0.94 to 1.00	1.00	0.98 to 1.03	1.03	0.99 to 1.08

Statistically significant results ($p < 0.05$) are presented in bold. NSP – neck and shoulder pain; ROM – range of motion; MVCF – maximal voluntary contraction force; JPE – joint position error; PPT – pain pressure threshold.

5.5 Prevalence of musculoskeletal disorders in office workers before and during COVID-19 lockdown (Study II, Paper I)

No statistically significant change was present in the prevalence of musculoskeletal disorders before and during the COVID-19 lockdown in different body areas and total pain prevalence among office workers (Figure 4).

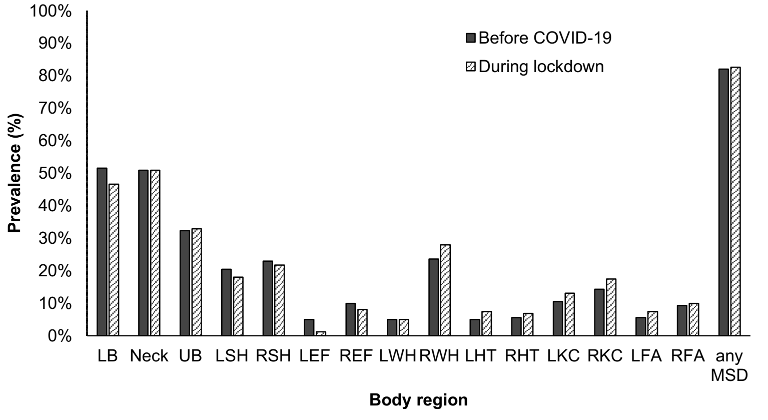

Figure 4. The prevalence of musculoskeletal disorders in office workers (n = 161) before and during COVID-19 lockdown in different body regions. LB – low back, UB – upper back, LSH – left shoulder, RSH – right shoulder, LEF – left elbow & forearm, REF – right elbow & forearm, LWH – left wrist & hand, RWH – right wrist & hand, LHT – left hip & thigh, RHT – right hip & thigh, LKC – left knee & calf, RKC – right knee & calf, LFA – left foot & ankle, RFA – right foot & ankle, MSD – musculoskeletal disorder.

The average number of body regions suffering from MSDs before and during the COVID-19 lockdown was not statistically significant. The temporal features of MSDs are presented in Figure 5.

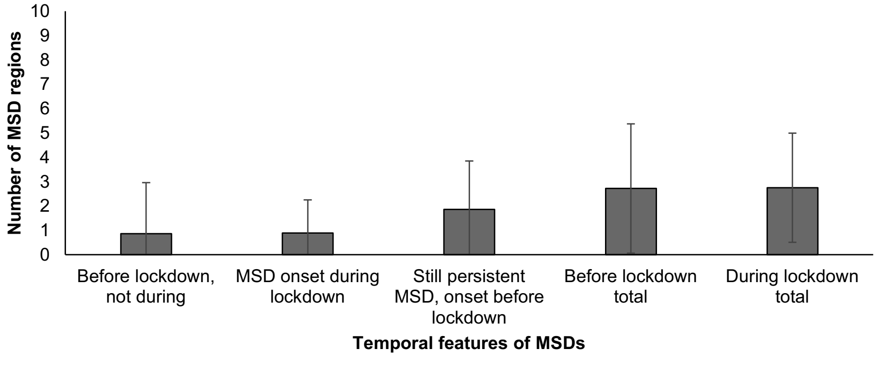

Figure 5. The mean number of body regions with musculoskeletal disorders with different temporal features in office workers. (n = 161). MSD – musculoskeletal disorder.

5.6 Self-reported physical activity in office workers before and during COVID-19 lockdown (Study II, Paper I)

Table 9 presents the self-reported physical activity of the office workers three months before the COVID-19 lockdown and during the lockdown. The overall self-reported physical activity was statistically significantly lower ($p < 0.001$) when compared with the period of three months before the lockdown. The main contributor to lower overall self-reported physical activity was statistically significantly lower ($p < 0.001$) sports scores. The work score had statistically significantly increased ($p < 0.001$) during the lockdown. There was no statistically significant change in the leisure score.

Table 9. Self-reported physical activity of office workers (n = 161) before and during the COVID-19 lockdown (mean ± SD).

Self-reported physical activity	Before COVID-19	During lockdown	Change (95% CI)	*p*-value	Cohen's *d*
BPAI work	2.27 ± 0.32	2.45 ± 0.40	+0.18 ± 0.54 (0.10 to 0.26)	<0.001	0.50 ††
BPAI sport	2.94 ± 1.31	2.42 ± 1.18	–0.52 ± 0.98 (–0.67 to –0.37)	<0.001	0.42 †
BPAI leisure	2.74 ± 0.62	2.67 ± 0.63	–0.07 ± 0.59 (–0.16 to 0.02)	0.15	0.11
BPAI total	7.95 ± 1.60	7.54 ± 1.55	–0.41 ± 1.37 (–0.62 to –0.19)	<0.001	0.26 †

BPAI – Baecke Physical Activity Index; † – small effect; †† – medium effect.

5.7 Associations between changes in musculoskeletal disorders, physical activity, and work-related factors among office workers during COVID-19 lockdown (Study II, Paper I)

The change in self-reported sports physical activity and the change in the numbers of body regions with MSDs during the lockdown was weakly ($\rho = –0.206$, $p < 0.01$) negatively correlated. A weak negative correlation ($\rho = –0.262$, $p < 0.001$) was also present between the change in workplace comfort score and the number of body regions with musculoskeletal pain onset during the lockdown. A weak negative correlation ($\rho = –0.231$, $p < 0.01$) was present between the change in workplace ergonomics score and the number of body regions with MSD onset during the COVID-19 lockdown.

6. DISCUSSION

6.1. Prevalence of musculoskeletal disorders and associated factors among office workers in an activity-based work environment (Study I, Paper II)

In this analysis, we compared the prevalence of MSDs, WAI, work-related psychosocial risk scores, self-reported physical activity, PPT of the neck and shoulder area, daily screentime, and time spent standing while working between office workers with and without ABW. The main findings were:

- There was no significant difference in the prevalence of MSDs in most body regions among office workers with ABW or without ABW.
- During the past 6 months, office workers with ABW demonstrated a statistically significantly higher prevalence of MSDs in the right wrist, hand, and fingers.
- Office workers in an ABW had a statistically significantly higher self-reported work-related physical activity and daily time spent standing while working.
- No statistically significant differences were present in WAI, self-reported screentime at work, COPSOQ III work-related psychosocial risk score, FABQ scores, and PPT of the neck and shoulder area.

No statistically significant differences were present in most body regions when workers with ABW were compared with workers without ABW, however, the overall prevalence of MSDs was high in both groups. The most problematic body regions were the neck, shoulder, upper- and lower back, with a 6-month prevalence above 50% for all of these sites. These results are similar to previous research investigating the prevalence of MSDs among office workers without considering the specifics and type of the work environment (AlOmar et al., 2021; Etana et al., 2021; Kaliniene et al., 2016; Okezue et al., 2020). When the groups were compared, workers with ABW had a tendency towards more neck (difference of 23%, OR = 2.1) and wrist, hand, and fingers (difference of 42%, OR = 1.9) area MSDs, however, these differences did not reach statistical significance and the larger sample size is needed to confirm a difference. Despite the tendency towards a higher prevalence of neck pain among workers with ABW, the comparison of PPT results between the groups did not indicate any difference in soft tissue sensitivity in this region. Due to the physical aspects of office work not being symmetrical for the wrist, hand, and fingers, we decided to do a secondary analysis to compare body sides separately for MSDs in these areas. We found statistically significantly more wrist, hand, and finger area MSDs on the right side among workers with an ABW when compared with workers without ABW. The high overall prevalence of MSDs in both groups indicates, that having an ABW alone might not prevent MSDs, however, longitudinal studies are needed due to our subjects in the ABW group having significantly less work experience in their specific work environment when compared with our non-ABW subjects resulting in an insufficient adaptation period. The higher incidence of wrist, hand, and finger pain in the ABW group might be caused by the inconvenience of having to switch between different workstations and work equipment. Although workers had an opportunity to use external equipment, they might have not used it consistently and settled with slight discomfort. The result of almost no difference between groups can be compared with previous research by Robertson and colleagues (2008), who found ABW has a positive effect on MSDs if used together with ergonomics training. Their conclusion on the positive effect of ABW together with ergonimics training must be interpreted carefully since the baseline prevalence of MSDs in their study was noticeably higher for the ABW plus ergonomics training group where this statistically significant improvement was suggested when compared with ABW only, and control group. They also measured the intensity of discomfort on a 6-point Likert scale and a similar tendency was present. However, this similar tendency had the same bias of higher baseline discomfort. A strong comparison cannot be made since the methodology used was different from this thesis, also we did not use ABW as an intervention, but acquired information from workers who had been working in this new environment for a slightly longer period.

The overall self-reported physical activity was similar between both groups, indicating that the specifics of the office work environment might not alter overall daily physical activity by a significant margin. Since physical activity is considered an important factor in both, MSD prevention and treatment (Blangsted et al., 2008; Moreira-Silva et al., 2016), several aspects of physical activity, including work-, sports- and leisure-related physical activity were compared between workers with and without ABW. Despite no difference in the overall self-reported physical activity, sports-related physical activity, and leisure time physical activity, a statistically significant difference ($p = 0.011$) with a medium effect ($d = 0.54$) was present when work-related physical activity indexes were compared. This difference is present mainly due to the ABW group spending less time sitting and more time standing while working. The ABW group had a three-fold increase in self-reported time spent standing while working when compared with the control. The result is similar to a study by Foley and colleagues (2016) who also found a decrease in sedentary behavior among workers transitioning to an ABW. In contrast, several studies using objective measurement methods, such as accelerometry or step count, have reported no difference in physical activity among workers who transitioned to an ABW (Candido et al., 2019; Foley et al., 2016). In this study, work-related physical activity was approximately 9.4% higher in the ABW group, which might not make a clinical difference in short-term health outcomes. As this difference was mainly the result of more time spent standing, instead of sitting, we can hypothesize, that there is no relevant difference in the overall energy expenditure during work. More time spent standing while working in the ABW group can indicate a higher usage of sit-to-stand desks, however, this is not ABW-specific as they can be used in any kind of office environment. This difference can also be accounted for a better-established safety and ergonomics culture in the organization since implementing a novel work environment requires more progressive and innovative leadership. Our finding of no difference in screen time during work suggests, that using an ABW does not change the general physical demands of office work. Since working with a visual display unit requires most of the workday regardless of the environment, a relevant increase in physical activity cannot be expected from an ABW. Despite workers with an ABW having the possibility of changing their places of work, they might not use this opportunity in the middle of working to not interfere with the workflow. This is supported by previous authors, who propose, that workers in an ABW might not take advantage of the various opportunities provided, and still might work stationary for the whole day (Appel-Meulenbroek et al., 2011; Haapakangas et al., 2018). Since even smaller doses of physical activity can have a positive impact on long-term health outcomes (Eijsvogels & Thompson, 2015), our finding of slightly higher work-time physical activity needs longitudinal investigation with objective methods.

When workers with and without ABW were compared, no statistically significant differences were found in COPSOQ III psychosocial risk score or FABQ scores, both of which assess the magnitude of work-related psychosocial risks associated with the development or sustenance of MSDs, and decreased work ability (Vargas-Prada & Coggon, 2015; Menzel, 2007; Fernandes & Pereira, 2016, Kaliniene et al., 2016; Deeney & O'Sullivan, 2009). This result is due to the questionnaires covering several different psychosocial domains, with few of them associated with the type of physical work environment directly. Previous research has found both positive (Candido et al., 2019; Haapakangas et al., 2018; Rolfö et al., 2018) and negative (Appel-Muelenbroek et al., 2011; Wijk et al., 2020) effects of ABW on certain psychosocial factors, such as a feeling of fatigue, job satisfaction, increased productivity, and others. Since previous research results in controversial conclusions, the result of no difference suggested in this dissertation might indicate several other individual and organizational factors playing a more relevant role in developing psychosocial risks. Since different job management might influence MSD-related fear avoidance behavior, especially work-related fear avoidance behavior, FABQ scores were compared between workers with ABW and without ABW. The result of no difference between the groups was not surprising, since the physical activity questionnaires indicated only a small difference in the physical settings of work, and COPSOQ III psychosocial questionnaire suggested no differences in the overall psychosocial domains of work. Also, no differences in WAI were found, predicting no difference in long-term work ability and sickness leave, however, this must be interpreted with caution due to the ABW group in this study having significantly less exposure to ABW compared with the experience of the control group in non-ABW environment.

6.2 The comparison of musculoskeletal disorders and functional characteristics of the neck and shoulder between office workers using a laptop or desktop computer (Study I, Paper III)

In the second analysis of Study I, we compared the prevalence of MSDs and the functional characteristics of the neck and shoulder area between office workers using a laptop or desktop computer. The main findings were:

- Office workers using the laptop computer for work had significantly more MSDs in the right shoulder area.
- The functional characteristics of the neck and shoulder area did not differ significantly between laptop and desktop computer users.

The overall prevalence of MSDs was high in both groups with 98% of subjects in both groups reporting experiencing MSDs during the previous 6 months, and 80% of laptop and 78% of desktop computer users reporting experiencing MSDs in the previous 7 days. This general result is an indication, that the type of computer used for work might not be a significant factor in overall MSD prevalence. Considering the specifics of laptop design, and the users' posture, the distribution of MSDs might differ from the desktop computer users. Since using the laptop computer is associated with changes in working posture particularly in the upper body and spine (Erdinc, 2011), the prevalence of MSDs in this study was investigated in those specific body regions. We hypothesized a higher prevalence of neck and shoulder area MSDs in the laptop group due to the increased neck flexion posture required for working (Yu et al., 2018). Our hypothesis was partially confirmed, as the laptop group experienced statistically significantly more MSDs in the right shoulder area during every inquired time period, and in the left shoulder during the past 7 days. The prevalence of MSDs in the neck region was also higher in the laptop group, however, the difference did not reach statistical significance. Previous research on the prevalence of MSDs among laptop users has suggested an even higher weekly prevalence of neck pain over 70% (Erdinc, 2011), compared with 44.4% in this dissertation. Methodological differences must be considered since a different questionnaire was used. As Nordic Musculoskeletal Questionnaire counts the upper trapezius muscle as the shoulder area, we also calculated the combined prevalence of neck and shoulder area MSDs. The combined prevalence of neck and shoulder area MSDs was higher in the laptop group but did not reach statistical significance. Previous research has also found no association between the type of computer used for work and combined neck and shoulder area MSDs (Du et al., 2022). The result of a higher prevalence of MSDs in the right shoulder area can be supported by previous research on the postural strain of the neck and shoulder muscles. Using a laptop-type computer can result in a forward head posture, which causes higher postural strain in the upper trapezius muscles (Lee et al., 2017). In addition to the altered neck posture, using the laptop without an external mouse and keyboard can result in awkward upper limb positions, such as elevated shoulders, resulting in an additional increase in the activity of the upper trapezius muscle (Lee et al., 2021). Increased prevalence of MSDs in particularly the right shoulder can be a result of the activity and positions of the dominant hand since 93.3% of our sample was right-handed. Considering this possible mechanism, our result of higher shoulder pain prevalence in the laptop group is supported by previous evidence, which considers prolonged upper trapezius activity as an associated factor in developing neck and shoulder pain (Hanvold et al., 2013). In this study, we did not find any significant differences when other body regions were compared besides the shoulders. A minor difference was present in the prevalence of lower back pain during the previous 6 months, with desktop computer users having a higher incidence (75% vs 57%). The difference did not achieve statistical significance ($p = 0.062$) and a higher sample size is needed to investigate this possible difference. Considering previous research, presumably using a laptop might increase postural variety, reduce static postures, and reduce the overall chance of developing low back pain when compared with desktop computer usage (Davis & Kotowski, 2014). The overall high prevalence of lower back pain in both groups of our study is comparable with research on the prevalence of MSDs among office workers in general, indicating an annual incidence rate of over 50% (Collins & O'Sullivan, 2015; Kaliniene et al., 2016).

No statistically significant differences between groups were found in any functional characteristics measured. The AROM of the neck did not differ between the groups, suggesting the type of computer and the corresponding posture might not be relevant factors that would cause changes that lead to limitations in AROM. We measured the MVC force of the neck muscles to understand if the different working postures can alter the neck muscles' ability to generate force. We found no differences between the laptop and desktop user groups, nor an association between neck and shoulder pain and combined isometric strength of the neck muscles in the regression analysis. Both of these results are supported by the previous evidence suggesting that forward head posture is not associated with altered muscle performance, pain, or disability (Ghamkhar & Kahlaee, 2019). The force production ability of the neck muscles can be disturbed by chronic neck pain (Rezasoltani et al., 2010), however, in this study, the prevalence of neck pain in the past 6 months was similar in both groups. The significant difference in the prevalence of shoulder area MSDs suggests measuring the MVC force of the shoulder area muscles in future studies. It is known, that subjects experiencing neck pain have disturbances in the JPE of the neck (Ylinen et al., 2004). Since the prevalence of neck MSDs did not differ between the groups in our study, no difference in JPE suggests, that the type of computer and neck posture while working might not be relevant in developing altered JPE. There is some evidence of laptop users have better scores of JPE when compared with dual monitor users, but interpretation must be cautious due to the small sample size used ($n = 27$) (Zuniga & Côté, 2017). Because laptop users experienced more MSDs in the shoulder area, the neck JPE test could be used with lateral flexion instead of rotation to induce more discomfort in the upper trapezius region. Using lateral flexion might include more shoulder region influence on the outcomes of the test due to inducing more discomfort in that area. Algometry was used to measure the pressure sensitivity of the neck and shoulder region soft tissues in this study. We hypothesized, that using a laptop for work increases neck flexion and forward head posture, which can cause additional static muscle activity in the neck extensors and shoulder muscles (Intolo et al., 2019), resulting in lowered PPT as a symptom of soft tissue overload (Rosenberg & Sipko, 2016). We expected to find differences in the upper trapezius muscle PPT due to the laptop group experiencing more acute MSDs in this area, however, there were no statistically significant differences between the groups in any sites measured. This might be due to the muscle fatigue building up while working with a screen and alleviating during rest, which is when the measurements were taken. This is supported by previous research which suggests, that in most cases, musculoskeletal discomfort will alleviate during the next 6 hours after using the laptop computer (Bodwal et al., 2017). Since the results indicate, that there are differences between laptop and desktop users in the prevalence of MSDs, but no differences in the functional characteristics measured, the effect of working with a laptop computer on the musculoskeletal system is more subjective, and no adaptations in the functional characteristics of the neck are suggested.

6.3 Impact of the COVID-19 lockdown on the prevalence of MSDs, physical activity, and workplace properties in office workers transitioning to working from home (Study II, Paper I)

Study II aimed to assess the changes in MSD prevalence, physical activity domains, work environment, and their in-between relationships in office workers transitioning to working from home due to the COVID-19 lockdown. The main findings were:

- No statistically significant differences in the prevalence of MSDs were noted among office workers before and during the lockdown.
- During the lockdown, overall and sports-related physical activity decreased, and work-related physical activity increased.
- Transitioning to teleworking caused a decrease in self-reported ergonomics and comfort scores.
- A larger decrease in sports-related physical activity is associated with a higher chance of developing MSDs in multiple body regions.
- During the lockdown period, lower comfort and ergonomics scores were associated with a higher MSD prevalence.

The result of no difference in the prevalence of MSDs before and during the lockdown was surprising because we hypothesized an increased MSD prevalence due to recent findings on the negative impact of the lockdown on mental health (Torales et al., 2020). Since MSDs are a biopsychosocial phenomenon and highly associated with mental health problems such as stress, depression, and anxiety (Vargas-Prada & Coggon, 2015; Gatchel et al., 2007), an increase in the MSD prevalence was expected. Another factor contributing to our hypothesis was the sudden transition to working in a home environment which, as expected, resulted in lower comfort and self-assessed ergonomic settings. Due to this study taking place in the early phase of the COVID-19 outbreak, little research on its impact on the musculoskeletal system had been published. A study by Torpak Celenay and colleagues (2020) taking place in Turkey found, that during the lockdown the incidence of low back pain was higher among workers who stayed at home when compared with workers who continued to work. Also, the rates of neck, upper back, shoulder, and hip/thigh pain were lower and the rate of low back pain was higher in workers who stayed at home during the lockdown, while the incidence of neck, upper back, shoulder, and elbow pain were lower among workers who continued to work during the lockdown when compared with the pre-lockdown period. The authors suggested increased sedentary behavior as a factor contributing to increased low back pain among workers who stayed at home, and possibly lower work hours and lower work-related physical stress as a reason for the lower incidence of MSDs among workers who continued to work (Toprak Celenay et al., 2020). When their results are compared with this dissertation, methodological differences must be taken into account, such as the heterogeneity of the sample, which included workers from many different sectors and occupations, including medicine, transportation, etc who work in a non-office environment. Early research has also suggested the worsening of mental health problems and pain in the neck and low back regions (Moretti et al., 2020), however, a small sample size ($n = 51$) and a different questionnaire used in this study must be considered when interpreting these results. Considering future research, measuring the intensity of pain might provide additional valuable information since the prevalence data refers to solely the onset of pain. Taking into account the results of the current dissertation and given, that research published after the submission of Paper III has results of changes in either direction (Gomez et al., 2022, Santos et al., 2021, Rodriguez-Nogueira et al., 2021), we consider the 66 days of lockdown in Estonia insufficient time to result in changes in MSD prevalence.

Since physical activity levels are associated with MSD prevalence and physical activity being used both as a prevention and treatment option (Blangsted et al., 2008; Moreira-Silva et al., 2016; Nijs et al., 2015; Rodrigues et al., 2014), we hypothesized a decrease in physical activity and an increase in MSD prevalence due to the sudden change caused by the lockdown. We also believed, that due to the closing of sports facilities, people compensate for their workouts by increasing milder physical activity, such as going for a walk. We hypothesized an increase in work-time physical activity as a result of a more flexible schedule and a smaller boundary between work, family, and housekeeping tasks. The hypothesis became partly true, as the sport-related self-reported physical activity score had statistically significantly decreased during the lockdown, but the effect size was small ($d = 0.42$). However, the leisure time self-reported physical activity score was not significantly different, suggesting that the lockdown did not change the subjects' leisure-locomotive habits. The lockdown caused a significant decrease in overall self-reported physical activity among our participants, which is similar to the results of other early research, which unfortunately did not investigate the subclasses of physical activity (Bourdas & Zacharakis, 2020; Fallon et al., 2021). The overall rate of participation in sports remained similar (78% before and 81% during the lockdown), but the self-reported sports-related physical activity score was significantly lower during the lockdown. To better comprehend this result, a secondary analysis was done on the individual questions in the Baecke Physical Activity Questionnaires sports section. The secondary analysis suggested two reasons for this phenomenon. First appeared to be the lower participation rate in more than one sport activity. Before the lockdown 96% of subjects used to participate in more than one sport activity. During the lockdown, the rate of participation in more than one sport activity decreased to 62%. The second reason appeared to be statistically significantly lower ($p < 0.001$) sport intensity and frequency. This decrease might indicate the subjects switched their habitual activity for another, with fewer sessions per week and lower physical demands. The reason for significantly higher self-reported work-related physical activity scores appeared to be lower sedentary time and more time spent standing during work hours, while time spent walking or lifting heavy objects during work appeared lower when working from home during the lockdown. Less sedentary time and less walking seem controversial, however, this might be due to the peculiarity of the Baecke Physical Activity Questionnaire, where subjects might not consider taking a few steps in their home as walking. On the other hand, walking to a colleague at the office or going outside for lunch can be better described as walking, since it has a longer duration when compared with taking a few steps at home. Therefore objective measurements, for example, step count, could bring different results. Since there was no difference in the duration of continuous work, and there was a decrease in sedentary time and an increase in standing time, the subjects might have used other positions for working than sitting. Also, the subjects might not have counted work interruptions at home as taking a break which could also explain the result of no difference in the duration of continuous work duration. In this study, no data was acquired about the personal status and household members. Since the mean age was 38.2 years, we can assume that many of the subjects had school-aged children who had to study from home. This can lead to parents having overlapped responsibilities of working from home and minding their children at the same time (Bouziri et al., 2020). Mixing work and family life might lead to less continuous screen time and slightly more physical activity during working hours, but might cause more psychosocial strain. When looking at the associations between physical activity and MSDs, the correlation analysis suggested that a greater decrease in sport-related physical activity scores is associated with an increase in the number of MSD regions. This indicates, that a sudden drop in sport-related physical activity might lead to an increased sensibility to musculoskeletal pain. We did not include the measurement of the intensity of pain in this study, therefore we are uncertain how this change in sport-related physical activity might affect already existing conditions. Several physical and psychosocial factors might be associated with this finding. Exercise is considered an effective prevention and treatment method for a wide range of MSDs due to its hypoalgesic properties (Drury et al., 2005; Koltyn et al., 2014). Considering this mechanism, a decrease in the intensity and frequency of exercise might lead to an increase in the sensitization to noxious stimuli, as less exercise might lead to increased sensitivity and pain response. This is also supported by previous systematic evidence suggesting a relationship between fitness and pain (Vaegter & Jones, 2020). From the psychosocial perspective, exercise is often either a social occasion or a personal time away from other stressors. The loss of exercising in a group could contribute to psychosocial risks related to isolation, such as feelings of loneliness, stress, and depression, which are associated with MSDs (Ng et al., 2019; Smith et al., 2019). Early research has indicated similar findings among people suffering from chronic pain during the lockdown, as decreases in physical activity were related to an increased perception of pain (Fallon et al., 2021). Considering the results and other related research, physical activity has a significant role in maintaining health during a lockdown.

Because the lockdown was implemented less than 24 hours after the government's announcement of the emergency situation, the decline in workplace comfort and ergonomics score was expected due to very low preparation time. Several changes in the work environment might cause this. Working from home was a new experience for many of the office workers, which together with the low preparation time indicates, that many workers might not have a designated workstation at home. This includes not having an external display, keyboard, or mouse, which leads to teleworkers using a laptop computer. Our data suggests, that the amount of laptop users increased by 25.5% during the lockdown. Research from Japan has suggested a high prevalence of using the laptop, with during the COVID-19 pandemic, 50% of teleworkers using a laptop computer without an external display (Du et al., 2022). Using a laptop computer instead of the desktop computer might lead to working in more awkward postures and in surroundings that are not intended for work, such as a coffee table, couch, or bed. During the COVID-19 lockdown, teleworkers who used tables with disproportionate height for work were at higher odds of experiencing severe neck/shoulder or lower back pain (Du et al., 2022). Early research also suggests that increased laptop usage is associated with the worsening of neck pain during the lockdown (Moretti et al., 2020). Recently published research also suggests, that workers who used a laptop computer when working from home during the pandemic in 2021 had a higher overall prevalence of MSDs during the past 3 months (82% vs 65%) when compared with the users of desktop computers, however, this data was obtained during non-lockdown settings (Dockrell & Culleton-Quinn, 2023). In the current thesis, an association was found suggesting a higher decrease in comfort and ergonomics scores is associated with a higher chance of MSD onset during the lockdown.

This relationship highlights the importance of an ergonomic and comfortable workspace in MSD prevention. Based on the results, teleworkers need better working conditions and more support, since previous research has also concluded, that adequate work equipment and ergonomics support can result in even higher-rated working conditions at home when compared with traditional office space (Montreuil & Lippel, 2003).

6.4 Strengths and limitations

The strengths of Study I include comparisons with the control group, using previously validated questionnaires and measurement methods that provide reproducibility. The novelty of this study lies in using methods from different domains to investigate MSDs. MSDs are a complex phenomenon that requires understanding a variety of biopsychosocial aspects. We used diverse methods of assessing MSDs from the biopsychosocial perspective, including both objective and subjective methods. Another strength is the sample size when considering the measurement of the functional characteristics. We used over 100 participants in this study which is more than most of the original research on functional characteristics (Ylinen et al., 2004; de Vries et al., 2015; Nunes et al., 2021). Study I has also several limitations. When 100 participants are considered an over-average sample for the measurement of the functional characteristics, then at the same time it is considered a relatively small sample size when investigating the prevalence of MSDs, suggesting that strong conclusions about the prevalence data on this study cannot be made. Another major limitation in such studies is exposure control. When comparing the ABW with traditional office space, the amount of exposure in the ABW group is also a limitation. Subjects in the ABW had twice less exposure to their current office environment as the control group since ABW is a relatively new phenomenon in Estonia and the participating organizations were one of the first to implement this new style of working. Two out of five organizations in this study used an ABW, which can also have an effect on the results since differences in organizational culture and company resources must be considered. In addition, we did not gather data about the behavior at the workplace and therefore have no information on how the workers used different workspaces and digital tools. These limitations suggest, that strong inferences cannot be drawn from this data about the long-term effects of ABW. When comparing the users of laptop computers with the users of desktop computers, exposure control is a major issue. It is almost certain, that the type of computer used for work is also used for other purposes, such as entertainment or hobbies. It is also highly likely, that some of the subjects used different types of computers or smart devices outside of work. Since the laptop computer provides mobility, we are not certain how much work was done in which positions. In non-laboratory settings this kind of exposure control is impossible to implement, therefore the results must be interpreted with caution. Another limitation is the low number of male participants. This might have an effect on skewing the data towards a higher prevalence of MSDs since the female gender is considered a risk factor for developing MSDs (Kaliniene et al., 2016; Shiri et al., 2019). Also, the low number of male participants makes the data analysis of variables highly affected by gender unreliable when male groups are compared. For future research, adding the measurement of pain intensity is suggested, since this might provide valuable information about different exposures to already existing pain. Also, a more detailed exposure measurement is suggested to better understand what physical settings the subjects are exposed to both at work and home.

The main strength of Study II is the novelty of the topic and early phase data collection. Since after the declaration of the emergency situation, it was unknown for how long it would persist, making quick data collection preferable. A definite limitation of this study was the retrospective questions which makes this study rely on the recall ability of the participants, making the results vulnerable to recall bias. Also since the data was collected during the lockdown, the subjects might have been more negatively minded towards the lockdown which might affect the results. Considering the methods, the strength of the Baecke Physical Activity Questionnaire is its structure of three different domains which allows the investigation of work- sports- and leisure-related physical activity separately. However, the interpretation of the total physical activity index can be misleading, since the questionnaire does not consider the energy expenditure of the activities accurately when different activities in different sections are compared. This makes the work index, sports index, and leisure index not comparable with each other and therefore makes the validity of the total physical activity index questionable. Since it was important to collect the data during the lockdown and not to generate double recall bias, the questionnaire was closed on the last day of the lockdown, making acquiring a larger sample not possible at that time. Additional studies among the population working from home are recommended to better distinguish between lockdown-related and non-lockdown-related factors influencing the musculoskeletal health of teleworkers.

7. CONCLUSIONS

1. Office workers with and without ABW have a similar prevalence of MSDs, WAI, psychosocial risks, and daily screentime.
2. Office workers in an ABW have higher work-related physical activity and daily time spent standing when compared with office workers without ABW.
3. Using a laptop computer for work might increase the risk of developing shoulder area MSDs in office workers. Using the laptop computer is not associated with negative changes in the AROM and position sense of the neck, or isometric strength and pressure sensitivity of the neck muscles.
4. COVID-19 lockdown did not influence the prevalence of MSDs among office workers transitioning to working from home. Working from home during the lockdown caused an increase in work-related physical activity and a decrease in sports-related and overall physical activity with a deterioration of working conditions.

8. PRACTICAL APPLICATIONS

The results of this thesis can provide practical applications for various specialists including physiotherapists, occupational therapists, occupational health and safety specialists, and health promotion experts. Since organizations often face decisions where a balance must be achieved between optimal costs and a healthy work environment, research about the health effects of an activity-based office is valuable when considering transitioning to this kind of work environment. Previous research on the health effects of activity-based offices has been scarce and the outcomes have been very different. Our study indicated that activity-based office had no major effects on musculoskeletal health. Considering previous research and our results, an activity-based office might have neither significant positive nor negative effects on the musculoskeletal health of the office worker. This suggests, that other factors can be more relevant for decision-making when considering transitioning to an activity-based office. Our study on the musculo-skeletal health effects of using a laptop computer for work suggests, that there is a higher chance of experiencing discomfort in the neck and shoulder area when compared with using an external display. Despite there being no differences in the objectively measured functional characteristics of the neck, the external display should be used for less discomfort and possibly better productivity when working for a longer period. The results of Study II provide knowledge from the first international lockdown of the contemporary era, suggesting, that when working from home, attention should be drawn to the physical activity level and adequate work environment. This allows more conscious preparation for both workers and employers if future pandemics should occur. Since working from home has become increasingly popular after the lockdown, both employers and workers should consider improving the work environment and work culture at home, including a designated place for working and adequate work equipment.

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SUMMARY IN ESTONIAN

Luu- ja lihaskonna vaevused kontoritöötajatel seoses tööalaste tegurite, kehalise aktiivsuse, funktsionaalsete karakteristikute ning COVID-19 karantiiniga

Viimase paari aastakümne jooksul on töö tegemise viisid märkimisväärselt muutunud. Tänu tehnoloogia kiirele arengule on füüsilise töö osakaal vähenenud ning vaimse töö osakaal suurenenud (Frey & Osborne, 2013). Järjest suureneva kontoritöötajate hulgaga toimetulekuks kasutatakse järjest enam uusi kontorite disainilahendusi, mobiilseid töövahendeid ja paindlikke töötingimusi. Kuna paljud lahendused on võrdlemisi uued, puuduvad piisavad teadmised nende mõjust luu- ja lihaskonna tervisele.

Maailma Terviseorganisatsiooni (WHO) andmetel on luu- ja lihaskonna vaevused tööturult kõrvale jäämise ja puude tekkimise peamiseks põhjuseks. Euroopa Liidus on luu- ja lihaskonna vaevused enamlevinumad tööga seotud terviseprobleemid. Luu- ja lihaskonna vaevuste mõju on laiaulatuslik, need mõjutavad nii inimest ennast, tööandjat kui ka meditsiinisüsteemi ja kogu ühiskonda (EU-OSHA, 2019). Kuigi kontoritöö on kehale oluliselt vähem koormav kui füüsiline töö, on luu- ja lihaskonna häirete levimus ka kontoritöö puhul sarnaselt sage (Govaerts et al., 2021; Collins & O'Sullivan, 2015). Luu- ja lihaskonna vaevused on kompleksprobleemid, millel ei ole alati ainsat selget põhjust. Siiski on leitud mitmeid individuaalseid ja tööga seotud riskitegureid mis on seotud luu- ja lihaskonna vaevuste väljakujunemisega. Individuaalseteks riskiteguriteks on näiteks naissugu, kõrgem vanus, kõrge kehamassiindeks, madal kehaline aktiivsus ja istuv eluviis (Kaliniene et al., 2016; da Costa & Vieira, 2010; Holth et al., 2008; Thorp et al., 2011). Tööga seotud riskiteguriteks loetakse muuhulgas ebasobivaid töövahendeid ja halba ergonoomikat, liialt suurt ekraaniga töötamise aega, ebaloomulikes asendites viibimist ning suurt psühhosotsiaalset koormust (da Costa & Vieira, 2010; Wu et al., 2012; Kaliniene et al., 2016).

Töömaailma muutumine on toonud kaasa mitmeid uusi töötamise suundumusi mille alusideeks on luua töötajale paindlikumad töötingimused ning tööandjale väiksemad kulud. Põhilised uued suunad on töötamine kodukontoris ja tegevuspõhises kontoris ning mobiilsete töövahendite kasutamine. Tänu tehnoloogia arengule on kaugtöö muutumas järjest populaarsemaks ning võib tuua kasu nii töötajale, organisatsioonile kui ka laiemale üldsusele (Harpaz, 2002). Kaugtöö suundumust muutis märkimisväärselt sagedasemaks COVID-19 pandeemia, mille tõttu pidi ühtäkki enamik kontoritöötajaid töötama kodunt. Pandeemia ja sellega kaasnev ühiskonna sulgemine võimaldas koguda olulisel määral andmeid kaugtöö kohta, kuna teaduskirjandust kaugtöö kohta pandeemiaeelsel ajal on väga vähe.

Tegevuspõhine kontor on kontseptsioon, kus töötajale ei ole määratud individuaalset töökohta. Tegevuspõhine kontor sisaldab eri tüüpi tööruume ja -tingimusi, mida töötaja saab valida olenevalt oma tööülesandest ja isiklikust eelistusest.

Peamised põhjused sellise lahenduse kasutamiseks on võimaldada töötajale töötingimustes valikuvõimalusi, tõstes sellega ka tööga rahulolu, samas hoides individuaalsete kabinettide arvelt kokku kontoripinnaga seotud tegevuskulusid (Danielsson & Bodin, 2008). Senines teaduskirjanduses tegevuspõhise kontori tervisemõju kohta on vastuolulisi tulemusi ning tuuakse välja nii positiivset (Haapakangas et al., 2018; Meijer et al., 2009; Candido et al., 2019) kui ka negatiivset mõju tervisele (Bodin Danielsson et al., 2014; Pejtersen et al., 2011; Wijk et al., 2020). Uuringud tegevuspõhise kontori mõjust luu- ja lihaskonna tervisele on põhiliselt kasutanud tegevuspõhjust kontorit kui sekkumismeetodit, mis on saavutanud lühiajalises plaanis positiivseid tulemusi (Foley et al., 2016; Robertson et al., 2008). Pikaajalisem mõju töötaja luu- ja lihaskonna tervisele on seni teadmata.

Paindliku töökeskkonna eelduseks on mobiilse tehnoloogia kasutamine tööks. Sülearvutitel on lauaarvutite ees mitmeid eeliseid, mistõttu töötatakse järjest enam just sülearvutiga. Sülearvutite põhiliseks eeliseks on kerge mass, teisaldatavus ja juhtmeta internetiühendus (Hough & Nel, 2017). Sülearvuti füüsiline disain on tekitanud mitmeid ergonoomilisi riske, näiteks neutraalse rühi säilitamise keerukus, suurem tõenäosus töötada ebaloomulikus asendis ning minimaalsed ergonoomilised reguleerimisvõimalused (Moffet et al., 2002; Yu et al., 2018; Sommerich et al., 2002). Samas võib sülearvuti kasutamisel olla ka teatud positiivset mõju luu- ja lihaskonna tervisele, näiteks võimaldab see muuta tööasendeid ja töö tegemise kohti oluliselt lihtsamini, tõstes sellega töö füüsilist variatiivsust ja tööga seotud kehalist aktiivsust (Davis & Kotowski, 2014).

Uurimistöö eesmärgid

Doktoritöö eesmärk oli selgitada välja luu- ja lihaskonna vaevuste levimus kontoritöötajatel seoses tööalaste tegurite, kehalise aktiivsuse, kaela- ja õlapiirkonna funktsionaalsete karakteristikute ning COVID-19 karantiiniga.

Uurimistöös püstitatud ülesanded:

1. Võrrelda luu- ja lihaskonna vaevuste esinemissagedust, riskifaktoreid ning kehalist aktiivsust tegevuspõhises ja mittetegevuspõhises kontoris töötajatel.
2. Võrrelda luu- ja lihaskonna vaevuste esinemissagedust ülakeha piirkonnas ning kaela- ja õlapiirkonna funktsionaalseid karakteristikuid sülearvutit ja lauaarvutit tööks kasutavatel kontoritöötajatel.
3. Hinnata COVID-19 karantiini mõju luu- ja lihaskonna vaevuste esinemissagedusele, kehalisele aktiivsusele ja töökeskkonna omadustele kontoritöötajatel.

Uuritavad ja metoodika

Doktoritöö põhineb kahel erineval uuringul (vt tabel 1). Esimene uuring põhineb kahel gruppidevahelisel analüüsil. Esiteks võrreldi tegevuspõhises ja mittetegevuspõhises kontoris töötavate inimeste luu- ja lihaskonna vaevuste esinemissagedust ja riskitegureid. Teiseks võrreldi tööks sülearvuti ja lauarvuti kasutajate luu- ja lihaskonna vaevuste esinemissagedust ning kaela- ja õlapiirkonna funktsionaalseid karakteristikuid. Teine uuring hindas, kuidas COVID-19 karantiin mõjutas kontoritöötajate luu- ja lihaskonna vaevuste esinemissagedust, kehalist aktiivsust ning töökeskkonna omadusi. Esimese uuringu metoodika koosnes ankeetküsimustikust ning kaela- ja õlapiirkonna funktsionaalsete karakteristikute mõõtmisest. Teises uuringus on kasutatud üksnes veebiküsimustikku.

Tabel 1. Doktoritöös osalenud uuritavate arv, sugu, vanus ning kontoritöö kogemus (keskmine ± SD).

	Uuring I	**Uuring II**
Uuritavate arv (*n*)	110	161
Naised (%)	80.9%	64.6%
Vanus (a)	41.0 ± 10.0 (vahemik 23–60)	38.2 ± 9.5 (vahemik 20–59)
Kontoritöö kogemus (a)	15.7 ± 10.3	13.1 ± 8.6

Järeldused

1. Tegevuspõhises ja mittetegevuspõhises kontoris töötajatel on sarnane luu- ja lihaskonna vaevuste esinemissagedus, töövõime indeks, psühhosotsiaalsed riskid ning päevane ekraaniaeg.
2. Tegevuspõhises kontoris töötajatel on võrreldes mittetegevuspõhises kontoris töötajatega kõrgem tööga seotud kehaline aktiivsus ning päevane seismisaeg.
3. Kontoritöötajatel võib sülearvuti kasutamine võib tõsta õlapiirkonna luu- ja lihaskonna vaevuste riski. Sülearvuti kasutamine ei ole seotud negatiivsete muutustega kaela aktiivses liigesliikuvuses, asenditundlikkuses ega ka kaela-õlavöötme lihaste isomeetrilises maksimaaljõus või survetundlikkuses.
4. COVID-19 karantiin ei mõjutanud kontoritöötajate luu- ja lihaskonna vaevuste esinemissagedust. Karantiini ajal kodus töötamine tõi kaasa tööga seotud kehalise aktiivsuse tõusu ning spordiga seotud ja üleüldise kehalise aktiivsuse languse ning töökeskkonna tingimuste halvenemise.

Praktiline väärtus

Doktoritöö tulemusi saavad praktikas kasutada töötervishoiu ja terviseedendusega seotud erinevad spetsialistid. Kuna ettevõtted peavad sageli otsima tasakaalu rahakulu ja tervislike töötingimuste vahel, on tegevuspõhise kontori tervisemõju uurimine taoliste otsuste langetamiseks vajalik. Doktoritöös saadud tulemus, kus tegevuspõhise kontori mõju luu- ja lihaskonna tervisele on sarnane mitte-tegevuspõhise kontori mõjuga, võimaldab tegevuspõhisesse kontorisse kolimise otsuse langetamisel arvestada pigem teiste faktoritega, nagu näiteks kulutõhusus või mõju töötaja produktiivsusele. Doktoritöö näitas, et sülearvuti kasutamine toob kaasa kõrgema riski kaela-õlavöötme luu- ja lihaskonna vaevuste esinemiseks, kuid see ei ole seotud muutustega kaela- ja õlapiirkonna objektiivselt mõõdetud näitajates. Seega ei pruugi sülearvuti tööks kasutamine avaldada pikaajalist mõju luu- ja lihaskonna kohanemisele, kuid ebamugavustunde vältimiseks ja kõrgemaks produktiivsuseks on mõistlik pikaajlisel töötamisel kasutada lisaekraani. Doktoritöö teine uuring oli üks esimesi uuringuid kontoritöötajate luu- ja lihaskonna vaevuste kohta karantiinisituatsioonis. Uuring võimaldab pöörata tähelepanu karantiinis tekkinud luu- ja lihaskonna tervise riskifaktoritele ning parandada nii töötajate kui ka tööandjate valmisolekut uuteks võimalikeks pandeemiateks.

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Publications

Argus, M., Pääsuke, M., Ereline J. (2020) Prevalence of Playing-related Musculoskeletal Pain and Associated Factors among Professional Violinists. *Occupational Medicine & Health Affairs*, 8(2), 1000305.

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Argus, M., Pääsuke, M. (2020) "How Covid-19 lockdown influenced the physical activity, work environment and musculoskeletal pain in Estonian office workers: possible key factors to consider for preventing musculoskeletal pain". Baltic Congress of Physiotherapy 2020, Riga. Oral presentation.
Argus, M., Pääsuke, M. (2021) "Musculoskeletal disorders and factors among activity-based office workers". IASP Virtual World Congress on Pain, Online. Poster presentation.
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2023–...	Tallinna Tervishoiu Kõrgkool, teadusnõunik
2021–2023	Medihub Töötervishoiukliinik, tööfüsioterapeut
2021–...	Eesti Füsioterapeutide Liit, juhatuse liige
2020–...	Tartu Ülikool, Meditsiinivaldkond, Sporditeaduste ja füsioteraapia instituut, teadusliku ja praktilise valukäsitluse lektor
2018–...	Rehabilitatsioonikeskus Terveline, füsioterapeut
2016–2021	Qvalitas Arstikeskus, füsioterapeut
2016–...	Physionomics OÜ, asutaja, füsioterapeut
2015	Eesti Korvpalliliit, U18 poistekoondise füsioterapeut
2013–2014	Põhja-Eesti Regionaalhaigla, füsioterapeut

Peamised uurimisvaldkonnad

Luu- ja lihaskonna vaevused, töötervishoid, valu mehhanismid, krooniline valu, kehaline aktiivsus, biomehaanika

Publikatsioonid

Argus, M., Pääsuke, M., Ereline J. (2020) Prevalence of Playing-related Musculoskeletal Pain and Associated Factors among Professional Violinists. *Occupational Medicine & Health Affairs*, 8(2), 1000305.

Argus, M., Pääsuke, M. (2021) Effects of COVID-19 lockdown on musculoskeletal pain, physical activity, and work environment in Estonian office workers working from home. *Work*, 69(3), 741–749.

Argus, M., Pääsuke, M. (2022) Musculoskeletal disorders and associated factors among office workers in an activity-based work environment. *International Journal of Occupational Safety and Ergonomics*, 28(4), 2419–2425.

Argus, M., Pääsuke, M. (2023) Musculoskeletal disorders and functional characteristics of the neck and shoulder: comparison between office workers using a laptop or desktop computer. *Work*, Jan 20, Online ahead of print.

Ettekanded konverentsidel

Argus, M., Pääsuke, M. (2020) "How Covid-19 lockdown influenced the physical activity, work environment and musculoskeletal pain in Estonian office workers: possible key factors to consider for preventing musculoskeletal pain". Baltic Congress of Physiotherapy 2020, Riga. Suuline ettekanne.

Argus, M., Pääsuke, M. (2021) "Musculoskeletal disorders and factors among activity-based office workers". IASP Virtual World Congress on Pain, Online. Posterettekanne.

Argus, M., Pääsuke, M. (2022) "Effect of non-specific neck pain on the functional characteristics of the neck". The 12th Congress of the European Pain Federation EFIC, Dublin. Posterettekanne.

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