Sedentary Behavior and Musculoskeletal Pain:

a five-year longitudinal Icelandic study

Rúna Sif Stefánsdóttir

Thesis for the degree of Master of Public Health Sciences

Sport, Leisure Studies and Social Education

HÁSKÓLI ÍSLANDS
MENNTAVÍSINDASVIÐ

**Sedentary Behavior and Musculoskeletal Pain:
a five-year longitudinal Icelandic study**

Rúna Sif Stefánsdóttir

Thesis for the degree of Master of Public Health Sciences

Supervisor: Sigríður Lára Guðmundsdóttir

The Faculty of Sport, Leisure Studies and Social Education

School of Education, University of Iceland

June 2016

Sedentary Behavior and Musculoskeletal Pain

A five-year longitudinal study

© 2016 Rúna Sif Stefánsdóttir

All right reserved. This master's thesis in Public Health Science cannot be copied without prior permission

Printed by: Háskólaprent

Reykjavík, June 2016

Abstract

Background Despite knowledge on unfavorable health effects of sedentary behavior (SB), there is limited knowledge about its effect on the musculoskeletal system. The objective of the current research was to study the association between sedentary behavior and the risk of musculoskeletal pain (muscle inflammation, pain in back or shoulders, frequent headaches) over a five-year period in an Icelandic population.

Methods Data was obtained from the *Health and Wellbeing of Icelanders* survey conducted in 2007 and 2012. Subjects aged 18-79 years that reported no musculoskeletal pain in 2007 and participated in 2012 were included (N = 737). Sedentary behavior was categorized into low SB (0-3 h/day), moderate SB (4-7 h/day), and high SB (8+ h/day). Chi-square tests and multivariable logistic regression analyses were used to examine relationships between SB and musculoskeletal pain.

Results At baseline, 22.5% of participants reported low SB, 48.7% moderate SB, and 22.8% high SB. Pain in back or shoulders was most common, affecting 33.5% of participants while frequent headaches were least common, affecting 6.9%. High prevalence of SB was observed in younger age groups, in those with higher education and income, and lower physical activity. Unadjusted odds ratios were increased for high SB compared with low SB for headache (OR=2.78; CI:1.15-7.75) and muscle inflammation (OR:1.70; CI:1.03-2.83). In adjusted models however, this relationship became none-significant even though the odds were still increased among those with high SB.

Conclusion In this study there were indications that more hours of SB were associated with increased risk of developing musculoskeletal pain. Objective measures of SB may provide opportunities to study this subject further.

Ágrip

Kyrrseta og stoðkerfisverkir:

5 ára lýðgrunduð ferilrannsókn á Íslandi

Inngangur Þrátt fyrir að rannsóknir sýni að kyrrseta er tengd mörgum heilsukvillum er lítið vitað um áhrif kyrrsetu á stoðkerfisverki. Markmið rannsóknarinnar var að rannsaka tengsl kyrrsetu og áhættu þess að þróa með sér stoðkerfisverki (vöðvabólgu, verki í baki eða herðum, tíða höfuðverkir) á 5 ára tímabili á Íslandi.

Efniviður og aðferðir Gögnin voru fengin úr rannsókninni *Heilsa og Líðan Íslendinga* sem framkvæmd var af Embætti Landlæknis árin 2007 og 2012. Rannsóknin tók til allra þeirra sem svöruðu stoðkerfisverkjum neitandi árið 2007 og tóku þátt 2012 (N=737). Kyrrseta var flokkuð í litla (0-3 klst/dag), miðlungs (4-7 klst/dag), og mikla (8+ klst/dag). Tíðni stoðkerfisverkja í mismunandi flokkum kyrrsetu var borin saman með kí-kvaðrat prófi. Samband kyrrsetu og stoðkerfisverkja var metið með lógístískri aðhvarfsgreiningu.

Niðurstöður Við upphaf rannsóknarinnar sögðust 22,5% þátttakenda vera í lítilli kyrrsetu, 48,7% voru í miðlungskyrrsetu, og 22,8% í mikilli kyrrsetu. Verkir í baki eða herðum var algengasti verkurinn og hafði áhrif á 33,5% þátttakenda á meðan fæstir kvörtuðu undan tíðum höfuðverkjum eða 6,9%. Aukin tíðni kyrrsetu mældist hjá yngri þátttakendum, einstaklingum með hærri menntun og tekjur, og þeim sem hreyfðu sig minna. Hrátt gagnlíkindahlutfall sýndi að mikil kyrrseta jók áhættu höfuðverkja (OR:2,78; CI:1,15-7,75) og vöðvabólgu (OR:1,70; CI:1,03-2,83) en þessi áhætta var ekki tölfræðilega marktæk þegar líkönin voru leiðrétt, líkindin jukust samt sem áður við meiri kyrrsetu.

Ályktun Niðurstöður benda til þess að tengsl kunni að vera á milli aukinnar kyrrsetu og líkum á því að fá stoðkerfisverki þó svo að tölfræðileg marktækni hafi ekki fundist í leiðréttum líkönum. Hlutlægar mælingar á kyrrsetu kunna að auka möguleika vísindamanna til rannsókna á þessu sviði.

Acknowledgement

First and foremost I want to thank my supervisor Sigríður Lára Guðmundsdóttir for her guidance, support, understanding, advice, and importantly her patience throughout my work on this project. I cannot fully explain my gratitude and appreciation for all the hard work and extra hours she put in to help me finish this thesis. She was not only my mentor academically but also helped me grow as a person and always made time for me in her very busy schedule.

I want to thank the Icelandic Directorate of Health for providing the data and support for this project. I also have to especially thank Friðgeir Andri Sverrisson for amazing support and invaluable guidance during the statistical analysis. I cannot thank him enough for his willingness to help and assist in times when most needed. I would also like to thank Sigurbjörn Árni Arngrímsson for critical commentary on the manuscript.

I have to thank my parents for all their emotional support and help. I do not think I would have been able to finish this project without their support, belief, and encouragement. Lastly, I would like to thank my boyfriend, Pablo Punyed for being my rock throughout this journey. Thank you for always being there when I needed you. I lava you!

Table of Contents

ABSTRACT	3
ÁGRIP	4
ACKNOWLEDGEMENT	5
TABLE OF CONTENTS	7
LIST OF TABLES AND FIGURES	9
INTRODUCTION.....	11
1.1 THE EPIDEMIOLOGY OF SEDENTARY BEHAVIOR	12
1.2 NEGATIVE EFFECTS OF SITTING	13
1.3 MEASURING SEDENTARY BEHAVIOR	13
1.4 THE EPIDEMIOLOGY OF MUSCULOSKELETAL PAIN	15
1.4.1 Lower back pain	16
1.4.2 Frequent headaches.....	16
1.4.3 Neck and shoulder pain.....	17
1.5 RISK FACTORS FOR MUSCULOSKELETAL PAIN.....	17
1.6 MEASURING MUSCULOSKELETAL PAIN	18
1.7 PHYSIOLOGY OF SEDENTARY BEHAVIOR AND THE RISK OF MUSCULOSKELETAL PAIN	19
AIM.....	21
METHODS	22
STUDY DESIGN AND DATA	22
STUDY VARIABLES	23
DATA ANALYSIS.....	24
ETHICAL APPROVAL	25
REFERENCES.....	26
ARTICLE	33
ABSTRACT	34
INTRODUCTION.....	35
METHODS	36
STUDY DESIGN AND DATA	36
STUDY VARIABLES	37
DATA ANALYSIS.....	38

ETHICAL APPROVAL	39
RESULTS.....	39
DISCUSSION	43
ACKNOWLEDGEMENT	45
AFTERWORD	46
REFERENCES.....	47

List of tables and figures

Introduction

FIGURE 1: FLOWCHART DESCRIBING STUDY PARTICIPANTS.....	23
--	----

Article

FIGURE 2: FLOWCHART DESCRIBING STUDY PARTICIPANTS.....	37
TABLE 1: BASELINE CHARECTERISTICS OF THE STUDY SAMPLE AND SB.....	40
TABLE 2: STUDY DEMOGRAPHICS WITH P-VALUE FOR COMPARISONS OF SUBGROUPS....	41
TABLE 3: LOGISTIC REGRESSION.....	42

Introduction

Recent development in contemporary society has led to extended sitting throughout most settings of our lives, from the way we travel, to the workplace and even the home (1). New evidence shows that too much sitting or sedentary behavior is associated with a decline in health in the population and can affect health outcomes, including cardio-metabolic risk biomarkers, type 2 diabetes and premature mortality (2-4). Even after accounting for time spent in leisure-time physical activity, these unfavorable health associations remain significant (5, 6). The prevalence of sedentary behavior varies among countries (7), but no research has reported the prevalence of sedentary behavior among Icelandic adults.

Musculoskeletal pain affects the muscles, ligaments, tendons, bones and can be caused by a variety of reasons (8). Repetitive movements, overuse, or even prolonged immobilization can cause musculoskeletal pain (9), whose prevalence has been increasing in the last few decades (10-12). This study focuses on pain stemming from back, neck, shoulder, and head. These locations are chosen since research has shown that this is where musculoskeletal pain is most frequently reported (13-15) with considerable impact and enormous cost for individuals, health and social care systems (16).

Research conducted by Dittmer et al. proposed that immobilization of the musculoskeletal system could lead to decreased muscle strength and atrophy, decreased endurance, and osteoporosis. This can affect the person's ability to move and perform daily activities (9). A very recent study also reported that inactivity is associated with high-intensity low back pain and disability (17). Exercise could counteract this undesirable effect and a research concluded that small amount of physical activity per week was associated with lower risk of pain in the lower back, neck and shoulders (18). However, there is a lack of data on the potential association between sedentary behavior and overall musculoskeletal pain, and studies show heterogeneous results.

A large-scale population study reported that the prevalence of chronic musculoskeletal complaints was lower among physically active individuals than inactive individuals (19). However, two systematic reviews concluded that there was not enough evidence to confirm that sedentary behavior was a risk factor for developing lower back pain (LBP) (20) and that the data on the relationship between physical activity and LBP was too heterogeneous in order to get any conclusion (21). A similar systematic review did report that sitting does not increase the risk of LBP, but being sedentary for more than half the workday in combination with whole-body vibration (e.g. through a machine such as a vehicle or an exercise machine) did increase the risk of developing LBP (22). A more recent systematic review on occupational sitting and health risks reported that there was "limited evidence found to

support a positive relationship between occupational sitting and health risks” (23). Another systematic review looked specifically on those who have sedentary occupations. For this subgroup, being active during leisure time or avoiding inactivity was found to help reduce musculoskeletal morbidity (24). These systematic reviews target one specific location of musculoskeletal pain, the lower back; but more research is needed on musculoskeletal pain as a whole.

1.1 The epidemiology of sedentary behavior

Over the last 60 years, research involving physical activity and sedentary behavior has expanded considerably. Growing concern about increased sedentary behavior among populations has stimulated more research towards the unhealthy effects of sedentary behavior at work and during all aspects of daily life (25). Early epidemiological studies mainly focused on occupational activity and in their landmark study published in 1953, Morris et al. were able to observe higher rates of coronary heart disease among mail sorters and sedentary bus drivers than in more active bus conductors and postal workers (12). During the 1970s, more focus was aimed towards the health benefit of physical activity and up until the turn of the century, knowledge about moderate-to-vigorous physical activity kept increasing. With changing society affecting the way humans travel, work, and spend their leisure time, there has been growing concern about the health effects of sedentary behavior at work and the balance between active and sedentary time during work hours as well as leisure hours (25).

In recent years, this growing concern has lead to amplified research on sedentary behavior and many studies related to the health impact of sitting have been published. Along with the increasing interest in the area, the question about the definition of sedentary behavior has been raised. The Sedentary Behavior Research Network has suggested, “Sedentary behavior refers to any waking activity characterized by an energy expenditure ≤ 1.5 metabolic equivalent and a sitting or reclining posture” (27). In common words, this means that a person who is sitting or lying down is engaged in sedentary behavior. It is important to remember that sedentary behavior is different from physical inactivity, which is often conceived as a lack of moderate-to-vigorous physical activity (7). Everyday sedentary behaviors include watching television, playing video games, using a computer, driving vehicles, and reading.

It is also important to note that sitting while being active (pedalling a stationary cycle) and sitting still are two distinct behaviors. Sedentary behavior is sitting without being active, thus meaning sitting quietly and still. Future research needs to clarify the boundaries and define whether movements such as fidgeting and swinging the legs and arms are considered active sitting and whether those movements can amend the negative aspects of sitting (28).

Total estimated sedentary behavior or average time spent sitting varies among countries and age groups, but a multinational study highlighting the prevalence of sitting time for adults aged 18-65 years in 20 countries reported a median of 300 min (interquartile range 180–480

min) of sitting per day (7). This result shows that an average person sits for about 5 to 6 hours per day. Other objective measures from various countries show similar results. A study measuring the amount of time spent in sedentary behaviors in the United States reported overall sedentary time as being 7.7 hours/day (29). Another study from the United States using accelerometer-wear time showed an average of 8.44 hours/day was spent sedentary (30). An Australian study with participants aged 40-65 years reported median sitting time 5.33 hours/day (31) and another Australian study measuring older adults aged 65-93 years reported that total daily sedentary behavior was 9.60 h/day (SD=1.66, range=4.87 to 12.02 h/day) when measured with accelerometer (32). A similar Icelandic study on older adults aged 73-98 years reported that older adults spend on average 74.5% (about 10.5 hours) of their waking time as sedentary (33). A small study (n=21) from the United States examined the relationship between sitting on work days versus leisure days and reported that on average individuals sit more on work days (9.95 hours/day) compared to leisure days (8.1 hours/day) (34).

1.2 Negative effects of sitting

Sedentary behavior has been associated with increased risk of all-cause and cardiovascular disease (CVD) mortality (35), many different types of cancer (36, 37), the risk of metabolic syndrome (MetS) (38), and decreased bone mineral density (39). Further, prolonged sitting has also been associated with type 2 diabetes (40), overweight and obesity (41), insulin resistance (42), and metabolic risk (43). Recent studies also conclude that high level of sedentary behavior and overall leisure time spent sitting is associated with overall higher total mortality (44, 45). Osteoporosis as a result of immobilization may lead to fracture of the spinal vertebrae, which can result in chronic LBP (9, 46).

While extensive sitting time has been shown to decrease quality of life, longitudinal studies have reported that regular physical activity may extend life expectancy, reduce morbidity, reduce cardiovascular related deaths, improve physical ability in later life, and lower the risk of pain in lower back, neck or shoulder (18, 19, 47). These findings should encourage people at all ages to engage in moderate-to- vigorous physical activity throughout their lives.

1.3 Measuring sedentary behavior

Methods used to measure sedentary behavior vary from self-reported to device-based measures and their reliability and validity are frequently discussed. Currently, it is recommended to use both subjective and objective measures and utilize the growing technology that offers exciting opportunities (48, 49). The variable tools used in research on sedentary behavior make comparison between studies difficult. In a 2007 review, Clark et al. (50) discussed the validity and reliability of measures of sedentary behavior and suggested

that standardized approaches of measurements should be used, yet no standardized methods have been accepted by the research community. The authors mainly discussed the validity and reliability of measures of television viewing time and the need for further studies to focus also on computer use since screen time is increasing at a rapid pace (50). The authors mention that, “Television viewing time was the most frequently measured leisure-time sedentary behavior, followed by leisure-time sitting”. Almost every study used self-report questionnaire besides one that used a behavioral diary and one that observed sedentary behavior via video (50). The popularity of using questionnaires to collect data is not surprising since they can be implemented on a large scale, are fairly low cost, do not change the behavior being examined, and are fairly simple and easy to use (48).

Overall sedentary time can be assessed with a questionnaire that uses a single item question, or combines responses for activities. When using self-reported methods, questionnaires, behavioral diary, and short-term recalls are most common. These methods, however, have some limitations, as they are very susceptible to random and systematic errors. Healy et al. mention that short-term recall and behavioral diary can possibly reduce some reporting errors but administration costs are higher and thus large population-based research has limited the use of behavioral diaries. Advances in technology and better strategies may reduce this cost and enhance sedentary behavior measurements methods (48). Some questionnaires have been studied and one research concluded that the Flemish Physical Activity Computerized Questionnaire (FPACQ) is a reliable and reasonably valid questionnaire for assessing physical activity as well as sedentary behavior (51).

Another measure is video observation, which offers a new insight into objectively measured sedentary behavior. This method could give good insight into participant's activities but is not suitable for population-based epidemiological studies, since the method may reduce the ability to observe typical behavior and is very costly and time-consuming (50).

Many have advised using more than one method when measuring sedentary behavior and some studies have used heart rate monitors as well as accelerometers with good results (38, 42, 52). Although these methods have the limitation of not being able to differentiate between types of sedentary behavior, these limitations can be reduced by combining two or more methods such as using an accelerometer and a behavior diary (50). New technology that combines heart rate monitors and accelerometers (53) has proven to be a valid and reliable measurement, as well as studies on single unit monitor that are based on a uni-axial accelerometer like the activPAL (54).

New studies are currently being conducted on exciting new technologies and there is an ongoing constant improvement of questionnaires on sedentary behavior, and hopefully future studies can combine different techniques in order to collect the most accurate data. Human behavior is probably best captured through combination of self-reported and device-based

instruments and thus it is important that whenever possible, both measures should be used in population-based studies of sedentary time (48).

1.4 The epidemiology of musculoskeletal pain

Musculoskeletal pain can be triggered by a variety of reasons. The pain can stem from damaged muscle, connective tissue, daily wear and tear, trauma or accidents. The most common risk factors associated with musculoskeletal pain include: a) occupational factors; b) personal factors such as age, sex, and weight; and c) psychological factors such as stress and mental health (55). However, the scientific evidence of each risk factor varies and studies show heterogeneous results. Musculoskeletal pain is often described in a specific area or body location such as the neck or lower back. Repetitive movements, overuse, or even prolonged immobilization can cause musculoskeletal pain (9, 13) and research has shown that this has a considerable impact on individuals, health systems, and social care systems with enormous cost (10).

Population growth, urbanization, usage of motorized transportation and rising longevity, has led to rising burden due to musculoskeletal pain (56). In order to raise awareness of the importance of musculoskeletal conditions the decade 2000-2010 was declared the “bone and joint decade” by the United Nations, the World Health Organization (WHO), governments, and professional and patients' organizations in 37 countries (56, 57). Three of the ten leading causes of disability in the United States are musculoskeletal conditions: arthritis and rheumatism (affecting an estimated 19.9%), back or spine problems (16.8%), and stiffness and deformity of limbs (3.6%). These three conditions account for 39.4 % of all disabilities (58). In addition to disabilities, 15 million US adults report limitations in activities of daily living due to musculoskeletal conditions, and these conditions account for over 50% of lost workdays (437.6 million days) for US adults aged 18 and older (59). The UK Health and Safety Executive (HSE) reported that 5.7 million workdays were lost in 2001-2002 as a result of back pain. Additionally, an estimated 4.1 million workdays were lost through musculoskeletal disorders (MSD) that mainly affected the upper limbs and neck. The cost to individuals, industries and society was estimated to be around £5.7 billion per year. It is clear that musculoskeletal pain continues to be a massive source of disability and lost work, having a major impact on societies (60). The Fourth European working survey states that MSD “constitute the most frequently reported health complaint by European workers”. The survey concluded that 24.7% of employees reported backache and 22.8% muscular pain in the shoulder, neck or lower limbs (61). According to the report Global Burden of Disease Study 2013 (62), disability-adjusted life years due to years lived with disability (YLD) increased globally from 21.1% in 1990 to 31.2% in 2013. The leading causes of YLD included LBP and MSD, which were named one of the main causes of this increase (62).

The prevalence of musculoskeletal pain is common in many countries. A survey conducted in the Netherlands reported 74.5% of the Dutch population aged 25 years and over had some musculoskeletal pain during the past 12 months (14). A study researching pain in the German population aged 18-80 years old found that musculoskeletal pain was “overwhelmingly the most common pain” (63). Research has shown that the most common complaints of musculoskeletal pain stem from lower back, neck, shoulders, and head (13-15).

1.4.1 Lower back pain

LBP is a well-documented and an extremely common health problem (64, 65) but the burden is often overlooked as with many other musculoskeletal pains. It is the leading cause of activity limitation and work absence in big parts of the world (66) and causes enormous economic burden on communities as well as families and individuals (67). Nonspecific LBP is defined as pain experienced in the lumbosacral region in the absence of major identifiable pathology. The pain is typically in regions that include the areas of the back below the ribs and above the distal fold of the buttocks (68).

In an estimation of the global burden of LBP for The Global Burden of Disease 2005 Study, it was reported that 1-year incidence of people experiencing first episode of LBP varied from 6.3% to 15.4%, and the 1-year incidence of people with any LBP episodes varied from 1.5% to 36% (65). A review conducted in 1999, Looney and Stratford reported that the point prevalence was estimated to be 12% in Sweden, 13.7% in Denmark and 33% in Belgium (69). A more recent systematic review conducted in 2012 reported the mean lifetime prevalence of LBP to be 38.9% (70). A population-based survey from Germany reported point-prevalence 37.1%, yet 1-year prevalence rose to 76% and lifetime prevalence was 85.5% (71). Studies have also reported an increase in LBP prevalence, a survey conducted in the UK with a 10-year interval showed that one-year prevalence of LBP rose from 36.4% to 49.1% between 1987 and 1997 (72).

1.4.2 Frequent headaches

Headaches are often overlooked as health indicators although headache disorders have an impact on social activities, work and may lead to significant consumption of drugs (73). Globally, migraine is ranked 8th as cause of YLD according to WHO (74). The frequency and source of headaches varies from migraines to tension-type headaches. The estimated prevalence of migraines can range from 3%-35%, since studies differ in their use of methods and definitions (73). Tension-type headaches are even harder to measure since they vary widely in frequency, severity, and discomfort (73). A Danish population-based study reported that, of those who experienced tension-type headache, 59% reported having a headache for one day a month or less, but 37% had it several times per month. The same study reported that 3% of the total population had chronic tension-type headaches (75). Other population-

based studies seem to agree, with about 20-30% of people experiencing tension-type headaches once per month or less (76, 77). A large study of the epidemiology of headaches in Europe reported that one-year prevalence rate for headaches of both sexes in adults ranged between 29% and 77% and overall prevalence for migraines was between 9.6% and 24.6% (78). This confirms previous results showing that headaches are a highly predominant disorder affecting approximately 50% of the adult European population every year and have emerged as a major public health problem (78). In addition, studies have also shown that individuals suffering from frequent headaches were more likely to report other musculoskeletal pains than individuals free of headaches (79).

1.4.3 Neck and shoulder pain

The neck is made up of seven bones (vertebrae) that are stacked on top of each other and cushioned by discs of cartilage and bound with ligaments. Surrounding muscles provide additional support and movement. The neck can be more susceptible to injury because of its mobile, unstable features and the most common neck injuries are caused by trauma, disease or poor posture (80). Neck pain, like other musculoskeletal pains is common in the general population, with typical 12-month prevalence estimates from 30% to 50% (81).

The shoulder is one of the largest and most functional joints in the body. It is made up of three bones: the scapula, clavicle, and the humerus. A system of fine tuned muscles surrounding the shoulder provides movement. Shoulder pain can stem from various reasons but often occurs as a result of a disease or injury that affects the tendons, ligaments, muscles or bones (82). Shoulder pain is less common than other musculoskeletal pains but still a problem affecting the general population with prevalence as high as 6-11% in younger adults, and increasing to 16%–25% in elderly people (83).

Neck and shoulder pain (NSP) is common in the general public with a prevalence of 48.3% according to a recent study conducted in Japan (84). The study concludes, “NSP is a prevalent health problem that deteriorates the health-related quality of life in the general population” (84). A Nordic study observed that concurrent LBP and NSP were associated with higher risk for absence from work and for long-term absence (85). Multiple musculoskeletal pains thus seem to have massive impact on individuals’ health and work capacity.

1.5 Risk factors for musculoskeletal pain

Musculoskeletal pain can be influenced by many different aspects such as age, sex, body composition, psychological and socioeconomic factors (15). Studies show that occurrence of musculoskeletal pain increases with age (15, 57) and the peak prevalence seems to be around age 45 to 59 years old (86, 87). Numerous studies have reported higher prevalence of musculoskeletal pain among women compared with men across all age groups (57, 70, 73, 81,

84, 88). Cross sectional data from 2005 conducted by The Icelandic Social Insurance Administration shows that the occurrence of musculoskeletal pain is higher among women than men, and is the most common reason for disability among Icelandic women (35.1%) (89). A UK based study concluded “Women reported considerably higher rates of musculoskeletal pain in virtually all sites and for all age groups” (90). A Japanese general population study on NSP reported that the prevalence was 73.9% for women but only 26.1% for men (84). An Icelandic cohort study published in 1990 highlighted that more than 40% of Icelandic women reported pain from neck or shoulders in the last seven days (91). This difference could possibly be explained with sex-related reasons like pain related to menstruation and pregnancy (92) or social differences between the sexes when reporting pain (81, 88).

The relationship between body mass index (BMI) and LBP has been studied and results indicate that a high BMI is associated with increased prevalence of LBP both for men and women (93). A recent study that followed a Norwegian sample for 11 years found a significant positive association between BMI and LBP among individuals free of LBP at baseline and thus it seems that high value of BMI might be an indicator of LBP, 11 years later (94). A recent US study showed similar results where increased BMI was a risk factor for LBP and the results demonstrated a stepwise increase in risk of LBP with BMI. The prevalence of LBP ranged from 2.9% for subjects with normal BMI to 11.6% for morbidly obese subjects (95). A Swedish study that compared the prevalence of overall work-restricting musculoskeletal pain in an obese population versus a general population found that obese subjects had higher musculoskeletal pain than the general population (96). This study indicates that BMI may increase the risk of musculoskeletal pain and it is recommended to educate patient about physical activity as well as weight loss to reduce the risk of LBP. Studies have reported that lower income, lower level of education, and an overall lower socioeconomic status are associated with increased prevalence of musculoskeletal pain (15, 97, 98). Studies have also reported higher risk among individuals with psychological distress such as anxiety and depression (99), and high levels of stress (100).

1.6 Measuring musculoskeletal pain

There does not seem to be a universally accepted standard on how to measure musculoskeletal pain and studies have urged more consistency in measuring pain outcomes to enhance comparison between studies in this field. A systematic review conducted to increase the understanding of pain assessment in clinical trials concluded that even though the single-item Visual Analog Scale was used most frequently (in 60% of the included studies), there is a need for more consistency in the field (101).

When measuring and estimating musculoskeletal pain in a large group of people, studies have mainly used questionnaires since they offer an easy and convenient way to measure a

sizable group of people. A large cross-sectional study conducted in the Netherlands based on the Musculoskeletal Conditions and Consequences Cohort (DMC₃-study) used a questionnaire (14) including five pages of pictures where the participant used color codes to show their pain site along with questions. The authors pointed out that the prevalence of musculoskeletal pain in population-based surveys, strongly depends on the methods used, participants' definition of pain, and by the way the questions are worded. They concluded, however, that it is inevitable for pain assessment to have some sort of self-report (14). Van den Heuvel et al. (102) also used the data from the DMC₃-study and analyzed whether the pain reported on a manikin (a life-sized human model) was different than pain reported using written questions. They reported that the manikin gave comparable results as the written questions (102).

Some studies include a clinical examination where participants are examined and their pain evaluated. The limitations of this approach are the massive cost associated with performing these examinations and the vast amount of time it takes to gather the data. As mentioned before, clinical studies can provide detailed information but large-scale studies usually do not have the resources to perform the precise measurements needed to obtain such detailed information. Thus, when a large epidemiological study is conducted, it is common to use only a questionnaire to collect the data (12, 15, 97, 104, 105). The benefits in these latter studies are the larger study population and the quicker and less costly data collection than in clinical research. The obvious limitation in epidemiological studies is the self-reported data, which makes it very hard to rule out possible recall bias, participations over- or underestimation of pain, and possible confusion and misunderstandings of the questions. Overall, it is recommended that studies try to combine questionnaires with other forms of measurements (106-108).

1.7 Physiology of sedentary behavior and the risk of musculoskeletal pain

The idea that sedentary behavior may affect the musculoskeletal system has not been easy to confirm by physiological studies. Ringholm et al. studied the expression and activity of oxidative proteins in skeletal muscle for healthy adults during seven-day bed rest. Their main findings show that “only 7 days of physical inactivity reduces skeletal muscle metabolic capacity as well as abolishes exercise-induced adaptive gene responses, likely reflecting an interference with the ability of skeletal muscle to adapt to exercise” (108). A similar study exploring the functional impact of ten-day bed rest on healthy older adults reported that bed rest resulted in a considerable loss of lower body strength, power and aerobic capacity (110).

Latouche et al. (111) studied the important transcriptional events that are induced in skeletal muscle when humans take breaks during sedentary time and stand up for a small period of time. Their main findings indicate that breaking up sedentary time with small bouts changes the expression of skeletal muscle genes that are involved in cellular development,

growth, and metabolism (111). Dunstan et al. (112) used similar methods in their study and were able to conclude that taking small breaks from sitting lowered postprandial glucose and insulin levels in adults that are overweight or obese (112). These studies are in line with previous findings where it has been reported that increased sedentary time predicts higher levels of insulin (42) and that it is negatively associated with blood glucose (113).

However, the effects of long-term sedentary behavior on the musculoskeletal pain in humans are not well understood and studies usually depend on measures of physical activity rather than the measure of sedentary behavior. A large-scale population study investigated the association between physical exercise at baseline and the prevalence of musculoskeletal pain 11 years later (19). Interestingly, individuals who exercised more than three times a week were 28% less likely to report chronic musculoskeletal pain 11 years later, and thus the study concluded that the prevalence of chronic musculoskeletal complaints were lower among physically active individuals than inactive individuals (19). This association was also explored in a very recent study conducted by Teichtahl et al. (17) who looked at the association between physical inactivity and intervertebral disc height, paraspinal fat content, and LBP and disability. The study demonstrated that physical inactivity was associated with an increased risk for high-intensity LBP and disability (17). Morken et al. (114) studied the association between physical activity and its association with MSD among personnel in the Royal Norwegian Navy. They concluded that more physical activity was associated with a lower frequency of MSD, and an active lifestyle, both at work and during leisure hours, was associated with less musculoskeletal pain in most parts of the body (114). This association has also been studied in mice, where Sluka et al. (115) demonstrated that regular physical activity prevents the development of muscle pain. They deduced that physical inactivity was a risk factor for the development of chronic pain and could affect how the nervous system responds to low-intensity muscle discomfort (115). Scientists seem to agree that it is difficult to find a direct connection between sedentary behavior and musculoskeletal pain. Research shows that a physically active lifestyle has favorable effects on the musculoskeletal system, while physical inactivity seems to have some negative determinants on health.

Aim

The aim of this population-based study was to assess the association between sedentary behavior and the risk of musculoskeletal pain over a five-year period in the Icelandic population.

I hypothesized: 1) subjects that report more hours of sedentary behavior in 2007 are more likely to develop musculoskeletal pain five years later than subjects who reported less hours of sedentary behavior and 2) odds of pain increased with more sedentary behavior.

Methods

Study design and data

The current study is a longitudinal population-based cohort study. Data was collected from the *Health and Wellbeing of Icelanders* survey, conducted by the Icelandic Directorate of Health (115). A random sample of Icelanders aged 18-79 years was invited to participate in the survey in 2007 and again 5 years later, in 2012. Only those who answered both surveys were included in the current study. In 2007, the invited sample was 9,807 individuals with 5,509 responses of the mailed self-reported questionnaire retrieved (60.3% response rate). In 2012, the 3,676 of those who participated in 2007 and had agreed to partake in a follow up study received the follow up questionnaire. Participation response rate at follow up was 88.7%, therefore the final sample consisted of 3,246 participants. During interconnection of data from the two time points, eight participants had invalid responses and thus it was possible to interconnect responses from 3,238 participants who had data from both 2007 and 2012. A flowchart describing inclusion and exclusion of study participants is shown in Figure 1.

We excluded those who reported having any musculoskeletal pain in 2007, attempting to include only “healthy” (in terms of musculoskeletal pain) individuals at baseline. Participants with missing baseline values for any of the following: age, sex, income, education, mobility, BMI, musculoskeletal pain, and sedentary behavior were also excluded. The final study sample thus consists of 737 individuals, 291 (39%) women and 446 (61%) men, with a mean (SD) age of 53 years (± 16).

Figure 1: Flowchart describing inclusion and exclusion of study participants.

Study Variables

All data was obtained from a mailed questionnaire. The following question was used to assess sedentary behavior: “How many hours a day did you spend on average sitting last week (only count weekdays in your answer)” with the following categorical answer options: Less than one hour per day, 1 hour per day, 2-3 h/day, 4-5 h/day, 6-7 h/day, 8-10 h/day, 11-13 h/day, 14-16 h/day, more than 16 hours per day. Since there are no widely accepted standards on categorization on time spent in sedentary behavior (SB), three groups were formed to identify strata of sitting time: low SB (0-3 h/day), moderate SB (4-7 h/day), and high SB (8+ h/day) as has been done previously in longitudinal studies, such as The Australian Longitudinal Study on Women’s Health (116).

The outcome variables in the current study were musculoskeletal pain in three locations, assessed in the 2012 questionnaire by the question: “Have any of the following symptoms: muscle inflammation, pain in back/shoulders, and/or frequent headaches influenced your daily life, in the last 12 months / more than 12 months ago”. The question did not further define “frequent” when asking about headaches. Musculoskeletal pain was treated as a categorical variable, and those who answered “yes” (to whether musculoskeletal pain had

affected their life in the last 12 months or more than 12 months ago) were combined in one category, “yes”. The answers that were recorded as “no” were kept in the original coding.

Analyses were adjusted for age since sedentary behavior has been found to vary across age groups, although study results vary considerably (7, 29). Age at baseline was classified into three groups; 18-39 years old, 40-59 years old, and 60-79 years old. The data was also adjusted for sex since numerous studies have reported that the incidence rate of musculoskeletal pain is higher among women than men (14, 57, 73, 81, 84, 91, 117). Along with age and sex, other baseline factors adjusted for were BMI, mobility, income, education, and physical activity as these factors are known to affect sedentary behavior or musculoskeletal pain (7, 96, 118).

BMI (kg/m^2) was calculated based on self-reported weight and height. Impaired mobility was assessed with the question: “Have mobility limitation influenced your daily life in the last 12 months or more than 12 months ago?” Income was assessed by the question, “In what range do you estimate that your total income per month has been for the last 12 months?” and combined into 3 categories (0-279 thousand kr/month, 280-529 thousand kr/month, 530-700+ thousand kr/month). Education was classified into five categories ranging from compulsory education to University education.

Research has found that brisk physical activity may lower the risk of musculoskeletal pain (18, 119, 120) and thus activity was included in adjusted models. Physical activity was assessed with the questions: “How many of the last 7 days did you engage in vigorous physical activity for at least 10 minutes so that you became out of breath?” and “How many of the last 7 days did you engage in moderate physical activity for at least 10 minutes so that your pulse was raised?” with the answer options ranging from 0 to 7 days. The participants were also asked to write down the number of minutes they spent each day in physical activity. Vigorous and moderate activity were combined and based on the information on frequency and duration, the average number of minutes spent in moderate-to-vigorous physical activity per week was calculated.

Data Analysis

Statistical analysis was conducted using “The R Foundation for Statistical Computing Platform” program, version 3.0.2. Frequency of musculoskeletal pain in the three sites (muscle inflammation, pain in back or shoulders, frequent headaches) for different levels of baseline variables was compared using Chi-square tests statistics and t-test. The association between sedentary behavior and musculoskeletal pain coded 0 (no pain) and 1 (pain) was evaluated with binary logistic regression separately for each of the three musculoskeletal pain sites as the outcome. For each site, three models were run; a crude model including only sedentary behavior (model I), age- and sex adjusted model (model II) and fully adjusted model (model III), also including BMI, mobility, income, education, and physical activity.

Odds ratios were calculated with 95% confidence intervals, statistical significance was set as $p < 0.05$.

Ethical approval

The Icelandic National Bioethics Committee approved the study. All participants signed an informed consent prior to participation and the study followed the guidelines set forth by the Declaration of Helsinki.

References

1. Owen N, Healy GN, Matthews CE, Dunstan DW. Too Much Sitting: The Population-Health Science of Sedentary Behavior. *Exerc Sport Sci Rev*. 2010 Jul;38(3):105.
2. Dunstan DW, Howard B, Healy GN, Owen N. Too much sitting – A health hazard. *Diabetes Res Clin Pr*. 2012 Sep 30;97(3):368-76.
3. Hamilton MT, Hamilton DG, Zderic TW. Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease. *Diabetes*. 2007 Nov 1;56(11):2655-67.
4. Blair SN, Kampert JB, Kohl HW, Barlow CE, Macera CA, Paffenbarger RS, et al. Influences of Cardiorespiratory Fitness and Other Precursors on Cardiovascular Disease and All-Cause Mortality in Men and Women. *JAMA*. 1996 Jul 17;276(3):205-10.
5. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. *Am J Prev Med*. 2011 Aug 31;41(2):207-15.
6. Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity - a focus on China. *Obes Rev*. 2008 Mar;9 Suppl 1:119-26.
7. Bauman A, Ainsworth BE, Sallis JF, Hagströmer M, Craig CL, Bull FC, Pratt M, Venugopal K, Chau J, Sjöström M, IPS Group. The descriptive epidemiology of sitting: a 20-country comparison using the International Physical Activity Questionnaire (IPAQ). *Am J Prev Med*. 2011 Aug 31;41(2):228-35.
8. Bouchard C, Blair SN, Haskell W. Physical activity and health: Human Kinetics; 2006.
9. Dittmer DK, Teasell R. Complications of immobilization and bed rest. Part 1: Musculoskeletal and cardiovascular complications. *Can Fam Physician*. 1993 Jun;39:1428.
10. Jiménez-Sánchez S, Jiménez-García R, Hernández-Barrera V, Villanueva-Martínez M, Ríos-Luna A, Fernández-de-las-Peñas C. Has the prevalence of invalidating musculoskeletal pain changed over the last 15 years (1993–2006)? A Spanish population-based survey. *J Pain* 2010 Jul 31;11(7):612-20.
11. Harkness EF, Macfarlane GJ, Silman AJ, McBeth J. Is musculoskeletal pain more common now than 40 years ago?: Two population-based cross-sectional studies. *Rheumatology*. 2005 Jul 1;44(7):890-5.
12. Freburger JK, Holmes GM, Agans RP, Jackman AM, Darter JD, Wallace AS, Castel LD, Kalsbeek WD, Carey TS. The rising prevalence of chronic low back pain. *Arch Intern Med*. 2009 Feb 9;169(3):251-8.
13. Bergman S. Management of musculoskeletal pain. *Best Pract Res Clin Rheumatol*. 2007 Feb 28;21(1):153-66.
14. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC 3-study. *Pain*. 2003 Mar 31;102(1):167-78.
15. McBeth J, Jones K. Epidemiology of chronic musculoskeletal pain. *Best Pract Res Clin Rheumatol*. 2007 Jun 30;21(3):403-25.
16. Brooks PM. The burden of musculoskeletal disease—a global perspective. *Clin Rheumatol*. 2006 Nov 1;25(6):778-81.

17. Teichtahl AJ, Urquhart DM, Wang Y, Wluka AE, O'Sullivan R, Jones G, Cicuttini FM. Physical inactivity is associated with narrower lumbar intervertebral discs, high fat content of paraspinal muscles and low back pain and disability. *Arthritis Res Ther*. 2015 Dec 1;17(1):1-7.
18. Nilsen TI, Holtermann A, Mork PJ. Physical Exercise, Body Mass Index, and Risk of Chronic Pain in the Low Back and Neck/Shoulders: Longitudinal Data from the Nord-Trøndelag Health Study. *Am J Epidemiol*. 2011 Jun 1;173(6):429-437.
19. Holth H, Werpen H, Zwart JA, Hagen K. Physical inactivity is associated with chronic musculoskeletal complaints 11 years later: results from the Nord-Trøndelag Health Study. *BMC musculoskeletal disorders*. 2008 Dec 1;9(1):1.
20. Chen SM, Liu MF, Cook J, Bass S, Lo SK. Sedentary lifestyle as a risk factor for low back pain: a systematic review. *Int Arch Occup Environ Health*. 2009 Jul 1;82(7):797-806.
21. Sitthipornvorakul E, Janwantanakul P, Purepong N, Pensri P, van der Beek AJ. The association between physical activity and neck and low back pain: a systematic review. *Eur Spine J*. 2011 May 1;20(5):677-89.
22. Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP. *Eur Spine J*. 2007;16(2):283-98.
23. Van Uffelen JG, Wong J, Chau JY, van der Ploeg HP, Riphagen I, Gilson ND, Burton NW, Healy GN, Thorp AA, Clark BK, Gardiner PA. Occupational sitting and health risks: a systematic review. *Am J Prev Med*. 2010 Oct 31;39(4):379-88.
24. Hildebrandt VH, Bongers PM, Dul J, Van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. *Int Arch Occup Environ Health*. 2000 Oct 1;73(8):507-18.
25. Brown WJ, Bauman AE, Owen N. Stand up, sit down, keep moving: turning circles in physical activity research? *Br J Sports Med*. 2009 Feb;43(2):86-8.
26. Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. *The Lancet*. 1953 Nov 28;265(6796):1111-20.
27. Cart LR. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". *Appl. Physiol. Nutr. Metab*. 2012;37:540-2.
28. Owen N, Sugiyama T, Eakin EE, Gardiner PA, Tremblay MS, Sallis JF. Adults' sedentary behavior: determinants and interventions. *Am J Prev Med*. 2011 Aug;41(2):189-96.
29. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, Troiano RP. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol*. 2008 Apr 1;167(7):875-81.
30. Harrington DM, Barreira TV, Staiano AE, Katzmarzyk PT. The descriptive epidemiology of sitting among US adults, NHANES 2009/2010. *J Sci Med Sport*. 2014 Jul 31;17(4):371-5.
31. Burton NW, Haynes M, Van Uffelen JG, Brown WJ, Turrell G. Mid-aged adults' sitting time in three contexts. *Am J Prev Med*. 2012 Apr 30;42(4):363-73.
32. Aguilar-Farías N, Brown WJ, Olds TS, Peeters GG. Validity of self-report methods for measuring sedentary behaviour in older adults. *J Sci Med Sport*. 2015 Nov 30;18(6):662-6.
33. Arnardottir NY, Koster A, Van Domelen DR, Brychta RJ, Caserotti P, Eiriksdottir G, Sverrisdottir JE, Launer LJ, Gudnason V, Johannsson E, Harris TB. Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study. *Age Ageing*. 2012 Oct 31;41:afs160.
34. McCrady SK, Levine JA. Sedentariness at work: how much do we really sit? *Obesity*. 2009 Nov 1;17(11):2103-5.

35. Dunstan DW, Barr EL, Healy GN, Salmon J, Shaw JE, Balkau B, Magliano DJ, Cameron AJ, Zimmet PZ, Owen N. Television viewing time and mortality the Australian diabetes, obesity and lifestyle study (AusDiab). *Circulation*. 2010 Jan 26;121(3):384-91.
36. Howard RA, Freedman DM, Park Y, Hollenbeck A, Schatzkin A, Leitzmann MF. Physical activity, sedentary behavior, and the risk of colon and rectal cancer in the NIH-AARP Diet and Health Study. *Cancer Causes Control*. 2008 Nov 1;19(9):939-53.
37. Patel AV, Rodriguez C, Pavluck AL, Thun MJ, Calle EE. Recreational physical activity and sedentary behavior in relation to ovarian cancer risk in a large cohort of US women. *Am J Epidemiol*. 2006 Apr 15;163(8):709-16.
38. Kim J, Tanabe K, Yokoyama N, Zempo H, Kuno S. Objectively measured light-intensity lifestyle activity and sedentary time are independently associated with metabolic syndrome: a cross-sectional study of Japanese adults. *Int J Behav Nutr Phys Act*. 2013;47:9-0.
39. Chastin SF, Mandrichenko O, Helbostadt JL, Skelton DA. Associations between objectively-measured sedentary behaviour and physical activity with bone mineral density in adults and older adults, the NHANES study. *Bone*. 2014 Jul 31;64:254-62.
40. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA*. 2003 Apr 9;289(14):1785-91.
41. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Joint associations of multiple leisure-time sedentary behaviours and physical activity with obesity in Australian adults. *Int J Behav Nutr Phys Act*. 2008 Jul 1;5(1):35.
42. Helmerhorst HJ, Wijndaele K, Brage S, Wareham NJ, Ekelund U. Objectively measured sedentary time may predict insulin resistance independent of moderate-and vigorous-intensity physical activity. *Diabetes*. 2009 Aug 1;58(8):1776-9.
43. Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes care*. 2008 Feb;31(2):369-71.
44. Patel AV, Bernstein L, Deka A, Feigelson HS, Campbell PT, Gapstur SM, Colditz GA, Thun MJ. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. *Am J Epidemiol*. 2010 Aug 15;172(4):419-29.
45. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. *Med Sci Sports Exerc*. 2009 May;41(5):998-1005.
46. Issekutz B, Blizzard JJ, Birkhead NC, Rodahl K. Effect of prolonged bed rest on urinary calcium output. *J Appl Physiol*. 1966 May 1;21(3):1013-20.
47. Chakravarty EF, Hubert HB, Lingala VB, Fries JF. Reduced disability and mortality among aging runners: a 21-year longitudinal study. *Arch Intern Med*. 2008 Aug 11;168(15):1638-46.
48. Healy GN, Clark BK, Winkler EA, Gardiner PA, Brown WJ, Matthews CE. Measurement of adults' sedentary time in population-based studies. *Am J Prev Med*. 2011 Aug;41(2):216-27.
49. Atkin AJ, Gorely T, Climes SA, Yates T, Edwardson C, Brage S, et al. Methods of Measurement in epidemiology: Sedentary Behaviour. *Int J Epidemiol*. 2012 Oct;41(5):1460-71.
50. Clark BK, Sugiyama T, Healy GN, Salmon J, Dunstan DW, Owen N. Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review. *Obes Rev*. 2009 Jan 1;10(1):7-16.
51. Matton L, Wijndaele K, Duvigneaud N, Duquet W, Philippaerts R, Thomis M, et al. Reliability and validity of the Flemish Physical Activity Computerized Questionnaire in adults. *Res Q Exerc Sport*. 2007;78(4):293-306.

52. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc.* 2007 Sep;39(9):1502-8.
53. Brage S, Brage N, Franks P, Ekelund U, Wareham N. Reliability and validity of the combined heart rate and movement sensor Actiheart. *Eur J Clin Nutr.* 2005;59(4):561-70.
54. Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. *Br J Sports Med.* 2006;40(12):992-7.
55. Malchaire J, Cock N, Vergracht S. Review of the factors associated with musculoskeletal problems in epidemiological studies. *Int Arch Occup Environ Health.* 2001;74(2):79-90.
56. Woolf AD, Åkesson K. Understanding the burden of musculoskeletal conditions. *BMJ.* 2001 May 5;322(7294):1079-80.
57. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bulletin of the World Health Organization.* 2003 Sep;81(9):646-56.
58. Centers for Disease Control and Prevention, USA. *MMWR Morb. Mortal. Wkly. Rep.* 2009; 58(16): 421-426.
59. Bone US, Decade J. The burden of musculoskeletal diseases in the United States. Rosemont, IL: American Academy of Orthopaedic Surgeons. 2008.
60. Buckle P. Ergonomics and musculoskeletal disorders: Overview. *Occup Med.* 2005;55(3):164-7.
61. Parent-Thirion A. Fourth European working conditions survey: European Foundation for the Improvement of Living and Working Conditions; 2007.
62. Vos T, Barber RM, Bell B, Bertozzi-Villa A, Biryukov S, Bolliger I, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet.* 2015 Aug 22;386(9995):743-800.
63. Chrubasik S, Junck H, Zappe HA, Stutzke O. A survey on pain complaints and health care utilization in a German population sample. *Eur J Anaesthesiol.* 1998 Jul;15(4):397-408.
64. Manchikanti L. Epidemiology of low back pain. *Pain physician.* 2000;3(2):167-92.
65. Hoy D, Brooks P, Blyth F, Buchbinder R. The epidemiology of low back pain. *Best Pract Res Clin Rheumatol.* 2010 Dec 31;24(6):769-81.
66. Lidgren L. The bone and joint decade 2000-2010. *Bulletin of the World Health Organization.* 2003 Sep;81(9):629-.
67. Steenstra I, Verbeek J, Heymans M, Bongers P. Prognostic factors for duration of sick leave in patients sick listed with acute low back pain: a systematic review of the literature. *Occup Environ Med* 2005;62(12):851-60.
68. Ehrman JK, Gordon PM, Visich PS, Keteyian SJ. *Clinical Exercise Physiology: Human Kinetics*; 2013.
69. Loney PL, Stratford PW. The Prevalence of Low Back Pain in Adults: A Methodological Review of the Literature. *Phys Ther.* 1999 Apr 1;79(4):384-96.
70. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, et al. A systematic review of the global prevalence of low back pain. *Arthritis Rheum.* 2012;64(6):2028-37.
71. Schmidt CO, Raspe H, Pfingsten M, Hasenbring M, Basler HD, Eich W, Kohlmann T. Back pain in the German adult population: prevalence, severity, and sociodemographic correlates in a multiregional survey. *Spine.* 2007 Aug 15;32(18):2005-11.
72. Palmer KT, Walsh K, Bendall H, Cooper C, Coggon D. Back pain in Britain: comparison of two prevalence surveys at an interval of 10 years. *BMJ.* 2000;320(7249):1577-8.
73. Rasmussen BK. Epidemiology of headache. *Cephalalgia.* 2001 Sep 1;21(7):774-7.

74. Mathers CD, Stein C, Ma Fat D, Rao C, Inoue M, Tomijima N, et al. Global Burden of Disease 2000: Version 2 methods and results. Geneva: World Health Organization. 2002 Oct.
75. Rasmussen BK, Jensen R, Schroll M, Olesen J. Epidemiology of headache in a general population—a prevalence study. *J Clin Epidemiol*. 1991;44(11):1147-57.
76. Pryse-Phillips W, Findlay H, Tugwell P, Edmeads J, Murray TJ, Nelson RF. A Canadian population survey on the clinical, epidemiologic and societal impact of migraine and tension-type headache. *Can J Neurol Sci*. 1992 Aug 1;19(03):333-9.
77. Göbel H, Petersen-Braun M, Soyka D. The epidemiology of headache in Germany: a nationwide survey of a representative sample on the basis of the headache classification of the International Headache Society. *Cephalalgia*. 1994;14(2):97-106.
78. Stovner LJ, Zwart JA, Hagen K, Terwindt G, Pascual J. Epidemiology of headache in Europe. *Eur J Neurol*. 2006;13(4):333-45.
79. Hagen K, Einarsen C, Zwart JA, Svebak S, Bovim G. The co-occurrence of headache and musculoskeletal symptoms amongst 51 050 adults in Norway. *Eur J Neurol*. 2002;9(5):527-33.
80. Antevil J. Anatomy recall. Philadelphia: Lippincott Williams & Wilkins; 2006.
81. Hogg-Johnson S, Van Der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J, et al. Burden and determinants of neck pain in the general population. *Eur Spine J*. 2008 Apr 1;17(1):39-51.
82. Klion M, Jacobs T. Triathlon anatomy. Champaign, Ill: Human Kinetics; 2013.
83. Bjelle A. Epidemiology of shoulder problems. *Baillière's Clin Rheumatol*. 1989;3(3):437-51.
84. Takasawa E, Yamamoto A, Kobayashi T, Tajika T, Shitara H, Ichinose T, et al. Characteristics of neck and shoulder pain in the Japanese general population. *J Orthop Sci*. 2015 Mar 1;20(2):403-9.
85. Nyman T, Grooten WJ, Wiktorin C, Liwing J, Norrman L. Sickness absence and concurrent low back and neck-shoulder pain: results from the MUSIC-Norrtälje study. *Eur Spine J*. 2007 May 1;16(5):631-8.
86. Papageorgiou AC, Croft PR, Ferry S, Jayson MI, Silman AJ. Estimating the prevalence of low back pain in the general population: evidence from the South Manchester Back Pain Survey. *Spine*. 1995;20(17):1889-94.
87. McPhail SM, Schippers M, Marshall AL. Age, physical inactivity, obesity, health conditions, and health-related quality of life among patients receiving conservative management for musculoskeletal disorders. *Clin Interv Aging*. 2014;9:1069-80.
88. Schneider S, Randoll D, Buchner M. Why do women have back pain more than men?: A representative prevalence study in the Federal Republic of Germany. *Clin J Pain*. 2006;22(8):738-47.
89. Thorlacius S, Stefánsson SB, Ólafsson S. Algengi örorku á Íslandi 1. desember 2005. *Læknablaðið*. 2007 Jan 1.
90. Urwin M, Symmons D, Allison T, Brammah T, Busby H, Roxby M, Simmons A, Williams G. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Ann Rheum Dis*. 1998 Nov 1;57(11):649-55.
91. Steingrimsdóttir ÓA, Rafnsson V. Einkenni frá hálsi og hnakka, herðum og öxlum: hóprannsókn á úrtaki Íslendinga II. *Læknablaðið*. 1990.
92. Svensson HO, Andersson GB, Hastad A, Jansson PO. The relationship of low-back pain to pregnancy and gynecologic factors. *Spine*. 1990 May 1;15(5):371-5.
93. Heuch I, Hagen K, Heuch I, Nygaard Ø, Zwart J-A. The impact of body mass index on the prevalence of low back pain: the HUNT study. *Spine*. 2010;35(7):764-8.

94. Heuch I, Heuch I, Hagen K, Zwart J-A. Body mass index as a risk factor for developing chronic low back pain: a follow-up in the Nord-Trøndelag Health Study. *Spine*. 2013;38(2):133-9.
95. Smuck M, Kao MC, Brar N, Martinez-Ith A, Choi J, Tomkins-Lane CC. Does physical activity influence the relationship between low back pain and obesity? *Spine J*. 2014 Feb 1;14(2):209-16.
96. Peltonen M, Lindroos AK, Torgerson JS. Musculoskeletal pain in the obese: a comparison with a general population and long-term changes after conventional and surgical obesity treatment. *Pain*. 2003 Aug 31;104(3):549-57.
97. Molarius A, Tegelberg Å, Öhrvik J. Socio-Economic Factors, Lifestyle, and Headache Disorders—A Population-Based Study in Sweden. *Headache: The Journal of Head and Face Pain*. 2008;48(10):1426-37.
98. Bergman S, Herrström P, Högström K, Petersson IF, Svensson B, Jacobsson L. Chronic musculoskeletal pain, prevalence rates, and sociodemographic associations in a Swedish population study. *J Rheumatol*. 2001;28(6):1369-77.
99. Lampe A, Doering S, Rumpold G, Sölder E, Krismer M, Kantner-Rumplmair W, et al. Chronic pain syndromes and their relation to childhood abuse and stressful life events. *J Psychosom Res*. 2003 Apr 30;54(4):361-7.
100. Hoogendoorn W, Bongers P, De Vet H, Ariens G, Van Mechelen W, Bouter L. High physical work load and low job satisfaction increase the risk of sickness absence due to low back pain: results of a prospective cohort study. *Occup Environ Med*. 2002;59(5):323-8.
101. Litcher-Kelly L, Martino SA, Broderick JE, Stone AA. A systematic review of measures used to assess chronic musculoskeletal pain in clinical and randomized controlled clinical trials. *J Pain* 2007;8(12):906-13.
102. Hoven LH, Gorter KJ, Picavet HS. Measuring musculoskeletal pain by questionnaires: the manikin versus written questions. *Eur J Pain*. 2010 Mar 1;14(3):335-8.
103. Yue P, Liu F, Li L. Neck/shoulder pain and low back pain among school teachers in China, prevalence and risk factors. *BMC public health*. 2012 Sep 14;12(1):1.
104. Dijken C, Fjellman-Wiklund A, Hildingsson C. Low back pain, lifestyle factors and physical activity: A population based-study. *J Rehabil Med*. 2008;40(10):864-9.
105. Oha K, Viljasoo V, Merisalu E. Prevalence of musculoskeletal disorders, assessment of parameters of muscle tone and health status among office workers. *Agron Res*. 2010;8(1):192-200.
106. Bruce B, Fries JF, Lubeck DP. Aerobic exercise and its impact on musculoskeletal pain in older adults: a 14 year prospective, longitudinal study. *Arthritis Res Ther*. 2005 Sep 19;7(6):R1263.
107. Cassou B, Derriennic F, Monfort C, Norton J, Touranchet A. Chronic neck and shoulder pain, age, and working conditions: longitudinal results from a large random sample in France. *Occup Environ Med*. 2002;59(8):537-44.
108. Ringholm S, Biensø RS, Kiilerich K, Guadalupe-Grau A, Aachmann-Andersen NJ, Saltin B, et al. Bed rest reduces metabolic protein content and abolishes exercise-induced mRNA responses in human skeletal muscle. *Am J Physiol Endocrinol Metab*. 2011 Oct 1;301(4):E649-58.
109. Kortebein P, Symons TB, Ferrando A, Paddon-Jones D, Ronsen O, Protas E, et al. Functional impact of 10 days of bed rest in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2008 Oct 1;63(10):1076-81.

110. Latouche C, Jowett JB, Carey AL, Bertovic DA, Owen N, Dunstan DW, et al. Effects of breaking up prolonged sitting on skeletal muscle gene expression. *J Appl Physiol*. 2013 Feb 15;114(4):453-60.
111. Dunstan DW, Kingwell BA, Larsen R, Healy GN, Cerin E, Hamilton MT, et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes care*. 2012 May 1;35(5):976-83.
112. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes care*. 2007 Jun 1;30(6):1384-9.
113. Morken T, Magerøy N, Moen BE. Physical activity is associated with a low prevalence of musculoskeletal disorders in the Royal Norwegian Navy: a cross sectional study. *BMC musculoskeletal disorders*. 2007 Jul 2;8(1):1.
114. Sluka KA, O'Donnell JM, Danielson J, Rasmussen LA. Regular physical activity prevents development of chronic pain and activation of central neurons. *J Appl Physiol*. 2013 Mar 15;114(6):725-33.
115. Guðlaugsson J, Magnússon K, Jónsson S. Heilsa og líðan Íslendinga 2012: Framkvæmdaskýrsla. Embætti landlæknis, Reykjavík. 2014.
116. Brown W, Bryson L, Byles J, Dobson A, Manderson L, Schofield M, Williams G. Women's health Australia: establishment of the Australian longitudinal study on women's health. *J Womens Health*. 1996 Oct;5(5):467-72.
117. Steingrimsdóttir ÓA, Rafnsson V, Sveinsdóttir Þ, Ólafsson MH. Einkenni frá hreyfi-og stoðkerfi: hóprannsókn á úrtaki Íslendinga I. *Læknablaðið*. 1988.
118. Stamatakis E, Grunseit AC, Coombs N, Ding D, Chau JY, Phongsavan P, Bauman A. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: the Social, Economic, and Environmental Factor (SEEF) Study. *Prev Med*. 2014 Jun 30;63:72-80.
119. Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems: what is the evidence? *Spine*. 2001;26(7):778-87.
120. van den Heuvel SG, Heinrich J, Jans MP, Van der Beek AJ, Bongers PM. The effect of physical activity in leisure time on neck and upper limb symptoms. *Prev Med*. 2005 Jul 31;41(1):260-7.

Article

To be submitted to the The Journal of the International Association for the
Study of Pain

Sedentary Behavior and Musculoskeletal Pain: a five-year longitudinal Icelandic study

Runa S. Stefansdottir¹, Sigríður L. Guðmundsdóttir¹

¹ School of Education, Department of Sport, Leisure studies and Social Education, University
of Iceland, 105 Reykjavík, Iceland

Correspondence: Sigríður L. Guðmundsdóttir, School of Education, department of Sport,
Leisure studies and Social Education, University of Iceland/Stakkahlíð, 105 Reykjavík,
Iceland. Tel.: +354 - 525-5950 fax: +354 - 525-5599

Email: slg@hi.is

Abstract

Despite knowledge on unfavorable health effects of sedentary behavior (SB), there is limited knowledge about its effects on the musculoskeletal system. The objective of the current research was to study the association between sedentary behavior and the risk of musculoskeletal pain (muscle inflammation, pain in back or shoulders, frequent headaches) over a five-year period in an Icelandic population. Data was obtained from the *Health and Wellbeing of Icelanders* survey conducted in 2007 and 2012. Subjects aged 18-79 years that reported no musculoskeletal pain in 2007 and participated in 2012 were included (N=737). Sedentary behavior was categorized into low SB (0-3 h/day), moderate SB (4-7 h/day), and high SB (8+ h/day). Chi-square tests and multivariable logistic regression analyses were used to examine relationships between SB and musculoskeletal pain. At baseline, 22.5% of participants reported low SB, 48.7% moderate SB, and 22.8% high SB. Pain in back or shoulders was most common, affecting 33.5% of participants, while frequent headaches were least common, affecting 6.9%. High prevalence of SB was observed in younger age groups, those with higher education and income, and lower physical activity. Unadjusted odds ratios were increased for high SB compared with low SB for headache (OR=2.78; CI:1.15-7.75) and muscle inflammation (OR:1.70; CI:1.03-2.83). In adjusted models however, this relationship became none-significant even though the odds were still amplified with high SB. In this study there were indications that more hours of SB were associated with increased likelihood of developing musculoskeletal pain. Objective measures of SB may provide opportunities to study this subject further.

Introduction

Recent societal development has led to extended sitting throughout most settings of our lives, our workplace, home, and transport (1). Evidence suggests that prolonged sitting or sedentary behavior (SB) is associated with declining population health and can affect various health outcomes, including cardio metabolic risk, type-2 diabetes and premature mortality (2-4). These unfavorable associations remain significant after accounting for leisure-time physical activity (5, 6). The prevalence of SB varies among countries (7), but the prevalence of SB among Icelandic young and middle-aged adults has not been investigated.

Researchers debate on appropriate definition and measurements of SB (8, 9). The Sedentary Behavior Research Network suggests, “Sedentary behavior refers to any waking activity characterized by an energy expenditure ≤ 1.5 metabolic equivalent and a sitting or reclining posture” (10). Thus, SB is different from physical inactivity, often conceived as a lack of moderate-to-vigorous physical activity (7).

Musculoskeletal pain affects the muscles, ligaments, tendons, bones and can be caused by a variety of reasons such as repetitive movements, overuse, or even prolonged immobilization (11, 12). The occurrence of musculoskeletal pain has increased in the last few decades (13-15). The prevalence of lower back pain (LBP) has been reported as 38.9% (16), neck and shoulder pain as 48.3% (17) and the Fourth European working survey concluded that 24.7% of employees reported backache and 22.8% muscular pain in the shoulder, neck, or lower limbs (18). Pain stemming from back, neck, shoulder, and head is most frequently reported (19-21) with considerable impact and enormous cost on individuals, health and social care systems (22).

Lower levels of physical activity have been associated with an increased risk of severe LBP and disability, even after adjusting for age, sex and body mass index (BMI) (23). Also, a narrower average lumbosacral intervertebral disc height has been found in the least active participants compared with the more active ones (23). Two studies based on data from the North-Trøndelag Health Survey found that hours of physical exercise per week were inversely related to risk of chronic musculoskeletal pain (24, 25). In obese individuals, who had approximately 20% increased risk of chronic pain, exercising for one or more hours per week compensated for the unfavorable effect of high BMI on risk of chronic pain (24). However, studies on the potential association between SB and musculoskeletal pain are scarce. Many of the published studies have focused on LBP and those show heterogeneous results. Systematic reviews argue that there is not enough evidence to confirm that SB is a risk factor for developing LPB (26-28) and the relationship of SB with other common symptoms of the musculoskeletal system is unknown.

Thus, the aim of this population-based study was to assess the association between SB and the risk of musculoskeletal pain over a five-year period in the Icelandic population. We

hypothesized that 1) subjects that report more hours of sedentary behavior in 2007 are more likely to develop musculoskeletal pain five years later than subjects who reported less hours of sedentary behavior and 2) odds of pain increased with more sedentary behavior.

Methods

Study design and data

The current study is a longitudinal population-based cohort study. Data was collected from the *Health and Wellbeing of Icelanders* survey, conducted by the Icelandic Directorate of Health (29). A random sample of Icelanders aged 18-79 was invited to participate in the survey in 2007 and again 5 years later, in 2012. Only those who answered both surveys were included in the current study. In 2007, the invited sample was 9,807 individuals with 5,509 responses of the mailed self-reported questionnaire retrieved (60.3% response rate). In 2012, the 3,676 of those who participated in 2007 and had agreed to partake in a follow up study received the follow up questionnaire. Participation response rate at follow up was 88.7%; therefore the final sample consisted of 3,246 participants. During interconnection of data from the two time points, eight participants had invalid responses and thus it was possible to interconnect responses from 3,238 participants who had data from both 2007 and 2012. A flowchart describing inclusion and exclusion of study participants is shown in figure 1.

We excluded those who reported having any musculoskeletal pain in 2007, attempting to include only “healthy” (in terms of musculoskeletal pain) individuals at baseline. Participants with missing baseline values for any of the following: age, sex, income, education, mobility, BMI, musculoskeletal pain, and sedentary behavior were also excluded. The final study sample thus consists of 737 individuals, 291 (39%) women and 446 (61%) men, with a mean (SD) age of 53 years (± 16).

Figure 1: Flowchart describing inclusion and exclusion of study participants.

Study Variables

All data was obtained from a mailed questionnaire. The following question was used to assess sedentary behavior: “How many hours a day did you spend on average sitting last week (only count weekdays in your answer)” with the following categorical answer options: Less than one hour per day, 1 hour per day, 2-3 h/day, 4-5 h/day, 6-7 h/day, 8-10 h/day, 11-13 h/day, 14-16 h/day, more than 16 hours per day. Since there are no widely accepted standards on categorization on time spent in sedentary behavior, three groups were formed to identify strata of sitting time: low SB (0-3 h/day), moderate SB (4-7 h/day), and high SB (8+ h/day) as has been done previously in longitudinal studies, such as The Australian Longitudinal Study on Women’s Health (30).

The outcome variables in the current study were musculoskeletal pain in three locations, assessed in the 2012 questionnaire by the question: “Have any of the following symptoms: muscle inflammation, pain in back/shoulders, and/or frequent headaches influenced your daily life, in the last 12 months / more than 12 months ago”. The question did not further define “frequent” when asking about headaches. Musculoskeletal pain was treated as a categorical variable, and those who answered “yes” (to whether musculoskeletal pain had

affected their life in the last 12 months or more than 12 months ago) were combined in one category, “yes”. The answers that were recorded as “no” were kept in the original coding.

Analyses were adjusted for age since SB has been found to vary across age groups, although study results vary considerably (7, 31). Age at baseline was classified into three groups; 18-39 years old, 40-59 years old, and 60-79 years old. The data was also adjusted for sex since numerous studies have reported that the incidence rate of musculoskeletal pain is higher among women than men (17, 20, 32-36). Along with age and sex, other baseline factors adjusted for were BMI, mobility, income, education, and physical activity as these factors are known to affect SB or musculoskeletal pain (7, 37, 38).

BMI (kg/m^2) was calculated based on self-reported weight and height. Impaired mobility was assessed with the question: “Have mobility limitation influenced your daily life in the last 12 months or more than 12 months ago?” Income was assessed by the question, “In what range do you estimate that your total income per month has been for the last 12 months?” and combined into 3 categories (0-279 thousand kr/month, 280-529 thousand kr/month, 530-700+ thousand kr/month). Education was classified into five categories ranging from compulsory education to University education.

Research has found that brisk physical activity may lower the risk of musculoskeletal pain (24, 39, 40) and thus activity was included in adjusted models. Physical activity was assessed with the questions: “How many of the last 7 days did you engage in vigorous physical activity for at least 10 minutes so that you became out of breath?” and “How many of the last 7 days did you engage in moderate physical activity for at least 10 minutes so that your pulse was raised?” with the answer options ranging from 0 to 7 days. The participants were also asked to write down the number of minutes they spent each day in physical activity. Vigorous and moderate activity were combined and based on the information on frequency and duration, the average number of minutes spent in moderate-to-vigorous physical activity per week was calculated.

Data Analysis

Statistical analysis was conducted using “The R Foundation for Statistical Computing Platform” program, version 3.0.2. Frequency of musculoskeletal pain in the three sites (muscle inflammation, pain in back or shoulders, frequent headaches) for different levels of baseline variables was compared using Chi-square tests statistics and t-test. The association between SB and musculoskeletal pain coded 0 (no pain) and 1 (pain) was evaluated with binary logistic regression separately for each of the three musculoskeletal pain sites as the outcome. For each site, three models were run; a crude model including only SB (model I), age- and sex adjusted model (model II) and fully adjusted model (model III), also including BMI, mobility, income, education, and physical activity. Odds ratios were calculated with 95% confidence intervals, statistical significance was set as $p < 0.05$.

Ethical approval

The Icelandic National Bioethics Committee approved the study. All participants signed an informed consent prior to participation and the study followed the guidelines set forth by the Declaration of Helsinki.

Results

Baseline characteristics of the study sample and SB are presented in Table 1. The mean age was 54.6 years for men and 50.7 years for women ($p < 0.001$). The average BMI was slightly higher for men (27.1 kg/m^2) than for women (26.4 kg/m^2), but this difference was non-significant ($p = 0.07$). At baseline, 22.5% of participants were classified as having low SB (0-3 h/day), 48.7% having moderate SB (4-7 h/day), and 22.8% high SB (8+ h/day). High occurrence of SB was observed in younger age groups, those with higher education and income, and lower physical activity (Table 1).

Table 1: Baseline characteristics of the study sample and SB

	Total n = 737	Sedentary behavior		
		Low SB n = 166	Moderate SB n = 359	High SB n = 212
Age (years)				
18-39	172 (23%)	31 (18%)	78 (45%)	63 (37%)
40-59	260 (35%)	60 (23%)	122 (47%)	78 (30%)
60-79	305 (41%)	75 (25%)	159 (52%)	71 (23%)
Sex				
Male	446 (61%)	116 (26%)	202 (45%)	128 (29%)
Female	291 (39%)	50 (17%)	157 (54%)	84 (29%)
BMI (kg/m2)				
Mean (SD)	27 (± 5)	26 (± 4)	27 (± 5)	27 (± 6)
Income (isk thus)				
0-279	348 (47%)	93 (27%)	186 (53%)	69 (20%)
280-529	302 (41%)	60 (20%)	141 (47%)	101 (33%)
530-700+	87 (12%)	13 (15%)	32 (37%)	42 (48%)
Education				
Compulsory Education	224 (30%)	63 (28%)	115 (51%)	46 (21%)
Trade School	14 (2%)	6 (43%)	7 (50%)	1 (7%)
High School	244 (33%)	64 (26%)	119 (49%)	61 (25%)
Technical College	36 (5%)	9 (25%)	14 (39%)	13 (36%)
University	219 (30%)	24 (11%)	104 (47%)	91 (42%)
Limited Mobility				
Yes	54 (7%)	6 (11%)	30 (56%)	18 (33%)
No	683 (93%)	160 (23%)	329 (48%)	194 (28%)
Moderate-Vigorous Physical Activity (min/w)				
Mean (SD)	320 (±565)	460 (±692)	316 (±581)	225 (±391)

Baseline characteristics and incidence of reported pain with p-value for comparisons of subgroups are presented in Table 2. After five years of follow up, having or having had pain in back or shoulders, was reported by 33.5% of the participants, while 20.2% reported muscle inflammation and 6.9% of the participants reported having frequent headaches. More women than men reported musculoskeletal pain in any of the three sites and the mean age was lower for those participants who had developed musculoskeletal pain than for those who reported not to have such pain (Table 2).

The incidence of muscle inflammation was significantly higher in those who were most sedentary compared with those who were least sedentary. A similar trend was observed for frequent headaches but the incidence of pain in back or shoulders did not differ across categories of SB. The incidence of musculoskeletal pain did not differ across categories of BMI, income, education, mobility, or physical activity for any of the body sites under study (Table 2).

Table 2: Study demographics with p-value for comparisons of subgroups

	Muscle inflammation			Frequent headache			Pain in back/shoulders		
	Yes n=149	No n=588	p-value	Yes n=51	No n=686	p-value	Yes n=247	No n=490	p-value
Age (years)									
18-39	50 (29%)	122 (71%)	<0.001	21 (12%)	151 (88%)	<0.01	66 (38%)	106 (62%)	0.089
40-59	57 (22%)	203 (78%)		11 (4%)	249 (96%)		92 (35%)	168 (65%)	
60-79	42 (14%)	263 (86%)		19 (6%)	286 (94%)		89 (29%)	216 (71%)	
Sex									
Male	63 (14%)	383 (86%)	<0.001	19 (4%)	427 (96%)	<0.001	130 (29%)	316 (71%)	<0.01
Female	86 (30%)	205 (70%)		32 (11%)	259 (89%)		117 (40%)	174 (60%)	
BMI (kg/m²)									
Mean (SD)	27 (± 4)	27 (± 5)	0.96	27 (± 4)	27 (± 5)	0.98	27 (± 5)	27 (± 5)	0.63
Income (isk. thousands)									
0-279	67 (19%)	281 (81%)	0.52	28 (8%)	320 (92%)	0.15	118 (34%)	230 (66%)	0.61
280-529	67 (22%)	235 (78%)		21 (7%)	281 (93%)		104 (34%)	198 (66%)	
530-700+	15 (17%)	72 (83%)		2 (2%)	85 (98%)		25 (29%)	62 (71%)	
Education									
Compulsory Education	52 (23%)	172 (77%)	0.33	17 (8%)	207 (92%)	0.83	88 (39%)	136 (61%)	<0.01
Trade School	1 (7%)	13 (93%)		1 (7%)	13 (93%)		5 (36%)	9 (64%)	
High School	41 (17%)	203 (83%)		15 (6%)	229 (94%)		60 (25%)	184 (75%)	
Technical College	7 (19%)	29 (81%)		1 (3%)	35 (97%)		15 (42%)	21 (58%)	
University	48 (22%)	171 (78%)		17 (8%)	202 (92%)		79 (36%)	140 (64%)	
Sedentary behavior									
Low SB	29 (17%)	137 (83%)	<0.05	6 (4%)	160 (96%)	0.086	51 (31%)	115 (69%)	0.67
Moderate SB	64 (18%)	295 (82%)		25 (7%)	334 (93%)		122 (34%)	237 (66%)	
High SB	56 (26%)	156 (74%)		20 (9%)	192 (91%)		74 (35%)	138 (65%)	
Limited mobility									
Yes	10 (19%)	44 (81%)	0.86	4 (7%)	50 (93%)	0.78	16 (30%)	38 (22%)	0.65
No	139 (20%)	544 (80%)		47 (7%)	636 (93%)		231 (34%)	457 (78%)	
Moderate-vigorous physical activity (min/week)									
Mean (SD)	316 (±589)	321 (±560)	0.60	286 (±492)	323 (±571)	0.67	319 (±562)	320 (±567)	0.35

The results of the logistic regression analyses are presented in Table 3. In the crude model, odds of muscle inflammation were significantly increased with high SB compared with low SB. The odds were still increased in adjusted models but the results were no longer statistically significant. High SB was associated with increased odds of frequent headaches compared with low SB in the crude model. In adjusted models however, this relationship became none-significant even though the odds were still amplified with high SB. The association between SB and pain in back or shoulders did not reach statistical significance in any of the models. Additional analyses run separately for women and men did not result in meaningfully different results from those presented above (data not shown).

Table 3: Logistic regression

Logistic Regression	Muscle inflammation OR (95% CI)	Frequent headache OR (95% CI)	Pain in back/shoulders OR (95% CI)
Model I crude			
Low SB (0-3 h/day)	1	1	1
Moderate SB (4-7 h/day)	1.02 (0.64-1.68)	2.00 (0.86-5.46)	1.16 (0.78-1.73)
High SB (8+ h/day)	1.70 (1.03-2.83)	2.78 (1.15-7.75)	1.21 (0.78-1.87)
Model II*			
Low SB (0-3 h/day)	1	1	1
Moderate SB (4-7 h/day)	0.89 (0.54-1.48)	1.71 (0.72-4.73)	1.09 (0.73-1.63)
High SB (8+ h/day)	1.45 (0.87-2.46)	2.39 (0.97-6.74)	1.12 (0.72-1.74)
Model III**			
Low SB (0-3 h/day)	1	1	1
Moderate SB (4-7 h/day)	0.97 (0.58-1.67)	1.72 (0.72-4.80)	1.08 (0.71-1.66)
High SB (8+ h/day)	1.55 (0.89-2.75)	2.40 (0.96-6.92)	1.15 (0.71-1.84)

*Adjusted for age and sex

**Adjusted for age, sex, BMI, income, education, limited mobility, and physical activity.

Discussion

This population-based study examined the association between sedentary behavior and the risk of musculoskeletal pain over a five-year period. To the best of our knowledge, this is the first research reporting the prevalence of SB among young middle-aged Icelanders. In summary, we found that half of the study population reported 4-7 hours of SB per day, one third reported pain in back or shoulders, a higher proportion of women than men reported pain in any of the three sites, and the mean age of participants who developed musculoskeletal pain was lower than of those who did not. We also found higher unadjusted odds ratios for both frequent headache and muscle inflammation in those with high SB compared with low.

In this sample, 48.7% of study participants reported 4-7 hours of SB per day. Due to the data being collected as categorical parameter we cannot calculate mean sedentary time but our results seem comparable with 5 hours of sitting per day reported in a multinational survey of adults aged 18-65 years in 20 different countries (7). Objective measures from various countries show similar results, although when measured with accelerometers the average sitting time seems to be somewhat greater or 7.7-8.4 hours/day (31, 41) and even more so in older adults aged 65-98 years or 9.6-10.5 h/day (42, 43).

Pain in back or shoulders was most common in our study, affecting 33.5% of the participants at some point during the follow up. The questionnaire in our study did not specifically estimate LBP, making direct comparison to other studies difficult. In particular, an Icelandic study has reported the prevalence of chronic LBP being 16.2% (44). Numerous studies indicate the lifetime prevalence of LBP to be around 38.9-85.5%, point prevalence around 37.1% (16, 45) and even an increase over a 10-year interval where one-year prevalence of LBP in UK rose from 36.4% to 49.1% between 1987 and 1997 (46).

Muscle inflammation affected 20.2% of study participants. Although the typical Icelandic use of the phrase “vöðvabólga” (e. muscle inflammation) refers to the trapezius and surrounding muscles, the questionnaire did not further define specific location when asking about muscle inflammation and therefore we cannot make direct comparisons to other studies.

Frequent headaches were the least common complaint in the current study, reported by 6.9% of the study participants. Comparing the prevalence of headache can be complicated since studies differ in their use of methods and definitions. A large study of the epidemiology of headache in Europe reported that one-year prevalence rate for headache of both sexes in adults ranged between 29 and 77% and overall prevalence for migraine was between 9.6 and 24.6% (47).

Our results show higher prevalence of musculoskeletal pain among women compared with men in all of three sites, which is consistent with numerous other studies (16, 17, 32-34, 48). However, the relationship between SB and pain did not seem to differ when additional analyses were run separately for women and men.

Participants who had developed musculoskeletal pain during the follow up time had lower mean age than those who reported not to have such pain. This is not in line with other research reporting that the occurrence of musculoskeletal pain increases with age (21, 32) and the peak prevalence seems to be around age 45 to 59 years old (49, 50). This difference could stem from the reason that our study was included only individuals who were pain-free at baseline in order to examine the prospective effect of SB on pain-free (healthy) individuals. The prerequisite of only using pain-free individuals could also be the reason why more men than women were included in the study.

When measuring pain it is important to realize that pain is personal and often subjective, and thus patients' self-reports are usually a valid measurement (51). There does not seem to be a universally accepted standard on how to measure musculoskeletal pain and many multidimensional scales are available (52). There is also potential bias in using self-reporting methods for SB. Celis-Morale et al. found that when using the International Physical Activity Questionnaire, reported sitting time was 13% lower than accelerometer-derived sedentary time. Thus, using self-report methods to determine SB may lead to under-reporting of sedentary behavior (53). The current study also reported sitting time during weekdays only. However, previous results indicate that average SB varies only slightly between weekdays and weekends (54, 55) and thus the lack of weekend data unlikely influences the results.

We hypothesized that subjects who reported more hours of SB at baseline had higher odds of developing musculoskeletal pain during the follow up. Crude analyses indicated that high SB was associated with more frequent muscle inflammation and frequent headaches, these associations became non-significant after adjusting for age and sex although the trend of increased odds remained for these two outcomes. Thus, these results do not support the hypothesis of increased odds of musculoskeletal pain with increased SB.

Unfortunately, there are very few previous studies that we can compare with that explore this possible association between SB and musculoskeletal pain. The study of SB is a developing research field and for the time being, our results can merely be related to research on physical inactivity where it has been reported that the prevalence of chronic musculoskeletal complaints was lower among physically active individuals than inactive individuals (25). Morken et al. studied this association and concluded that more physical activity was associated with a lower frequency of musculoskeletal disorders, and an active lifestyle, both at work and during leisure hours, was associated with less musculoskeletal pain in most parts of the body (56). This association has also been studied in mice, where Sluka et al. demonstrated that regular physical activity prevented the development of muscle pain; and

thus concluded that physical inactivity is a risk factor for the development of chronic pain and could affect how the nervous system responds to low-intensity muscle discomfort (57).

The main strength of the current study lies in a relatively large population based sample. The study also excluded all individuals with known musculoskeletal pain at baseline and consists of a pain-free sample. The prospective assessment of the effect of SB on musculoskeletal pain hopefully contributes to minimizing bias in the selection of events as well as in reporting of SB.

The study may be limited by factors that confound the relationship between SB and musculoskeletal pain but were not accounted for in the study. The use of self-reported questionnaires may lead to over- or under reporting of both SB and pain and this may have affected our results. Further, the Icelandic population is rather homogeneous in terms of ethnicity and culture and thus the findings may not be generalizable to other populations.

Future studies need to focus more on the measurement of SB. In a new era of inactivity and sedentary physiology, standardized tools to explore SB and its effects on the human musculoskeletal system are needed. Further, high quality longitudinal studies are required to determine the cause and effect relationship of this potential association. In this current study, there were indications that more hours of SB were associated with increased likelihood of developing musculoskeletal pain but after adjusting for age and sex the relationships were non-significant.

Conflict of interest statement

The authors declare that they have no conflict of interest with regards to this work.

Acknowledgement

The authors would like to thank the Icelandic Directorate of Health for providing access to the data from the health surveys. The authors gratefully acknowledge the statistical assistance of Friðgeir Andri Sverrisson. We also thank Sigurbjörn Árni Arngrímsson for critical commentary on the manuscript.

Afterword

Previous studies on the potential association between sedentary behavior and musculoskeletal pain are scarce and unknown. In this population-based cohort study there were indications that more hours of SB were associated with increased likelihood of developing musculoskeletal pain but after adjusting for age and sex the relationships were non-significant, even though the odds were still increased with high SB. Previous studies have found that prolonged sitting or high sedentary behavior is harmful for various health outcomes but whether it could also have deleterious effects on individual's musculoskeletal health requires further investigation. Our findings hopefully encourage further investigations on the effects of sedentary behavior on the musculoskeletal system. Further, standardized tools to measure SB are needed and future studies should try to determine the cause and effect of this potential association.

References

1. Owen N, Healy GN, Matthews CE, Dunstan DW. Too Much Sitting: The Population-Health Science of Sedentary Behavior. *Exerc Sport Sci Rev*. 2010 Jul;38(3):105.
2. Dunstan DW, Howard B, Healy GN, Owen N. Too much sitting – A health hazard. *Diabetes Res Clin Pr*. 2012 Sep 30;97(3):368-76.
3. Hamilton MT, Hamilton DG, Zderic TW. Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease. *Diabetes*. 2007 Nov 1;56(11):2655-67.
4. Blair SN, Kampert JB, Kohl HW, Barlow CE, Macera CA, Paffenbarger RS, et al. Influences of Cardiorespiratory Fitness and Other Precursors on Cardiovascular Disease and All-Cause Mortality in Men and Women. *JAMA*. 1996 Jul 17;276(3):205-10.
5. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary Behaviors and Subsequent Health Outcomes in Adults: A Systematic Review of Longitudinal Studies, 1996–2011. *Am J Prev Med*. 2011 Aug 31;41(2):207-15.
6. Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity - a focus on China. *Obes Rev*. 2008 Mar;9 Suppl 1:119-26.
7. Bauman A, Ainsworth B, Sallis J, Hagströmer M, Craig C, Bull F et al. The Descriptive Epidemiology of Sitting: A 20-Country Comparison Using the International Physical Activity Questionnaire (IPAQ). *Am J Prev Med*. 2011;41(2):228-235.
8. Clemes SA, David BM, Zhao Y, Han X, Brown W. Validity of two self-report measures of sitting time. *J Phys Act Health*. 2012 May;9(4):533-9.
9. Healy GN, Clark BK, Winkler EA, Gardiner PA, Brown WJ, Matthews CE. Measurement of Adults' Sedentary Time in Population-Based Studies. *Am J Prev Med*. 2011 Aug;41(2):216-27.
10. Cart LR. Letter to the editor: standardized use of the terms “sedentary” and “sedentary behaviours”. *Appl. Physiol. Nutr. Metab*. 2012;37:540-2.
11. Bouchard C, Blair SN, Haskell W. Physical activity and health: Human Kinetics; 2006.
12. Dittmer D, Teasell R. Complications of immobilization and bed rest. Part 1: Musculoskeletal and cardiovascular complications. *Can Fam Physician*. 1993;39:1428.
13. Jiménez-Sánchez S, Jiménez-García R, Hernández-Barrera V, Villanueva-Martínez M, Ríos-Luna A, Fernández-de-las-Peñas C. Has the prevalence of invalidating musculoskeletal pain changed over the last 15 years (1993–2006)? A Spanish population-based survey. *J Pain* 2010 Jul 31;11(7):612-20.
14. Harkness E, Macfarlane G, Silman A, McBeth J. Is musculoskeletal pain more common now than 40 years ago?: Two population-based cross-sectional studies. *Rheumatology*. 2005;44(7):890-5.
15. Freburger JK, Holmes GM, Agans RP, Jackman AM, Darter JD, Wallace AS, et al. The Rising Prevalence of Chronic Low Back Pain. *Arch Intern Med*. 2009;169(3):251-8.
16. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, et al. A systematic review of the global prevalence of low back pain. *Arthritis Rheum*. 2012;64(6):2028-37.

17. Takasawa E, Yamamoto A, Kobayashi T, Tajika T, Shitara H, Ichinose T, et al. Characteristics of neck and shoulder pain in the Japanese general population. *J Orthop Sci.* 2015 Mar 1;20(2):403-9.
18. Parent-Thirion A. Fourth European working conditions survey: European Foundation for the Improvement of Living and Working Conditions; 2007.
19. Bergman S. Management of musculoskeletal pain. *Best Pract Res Clin Rheumatol.* 2007;21(1):153-66.
20. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC 3-study. *Pain.* 2003 Mar 31;102(1):167-78.
21. McBeth J, Jones K. Epidemiology of chronic musculoskeletal pain. *Best Pract Res Clin Rheumatol.* 2007 Jun 30;21(3):403-25.
22. Brooks PM. The burden of musculoskeletal disease—a global perspective. *Clin Rheumatol.* 2006;25(6):778-81.
23. Teichtahl AJ, Urquhart DM, Wang Y, Wluka AE, O’Sullivan R, Jones G, Cicuttini FM. Physical inactivity is associated with narrower lumbar intervertebral discs, high fat content of paraspinal muscles and low back pain and disability. *Arthritis Res Ther.* 2015 Dec 1;17(1):1-7.
24. Nilsen TI, Holtermann A, Mork PJ. Physical Exercise, Body Mass Index, and Risk of Chronic Pain in the Low Back and Neck/Shoulders: Longitudinal Data from the Nord-Trøndelag Health Study. *Am J Epidemiol.* 2011 Jun 1;173(6):417-25.
25. Holth HS, Werpen HK, Zwart J-A, Hagen K. Physical inactivity is associated with chronic musculoskeletal complaints 11 years later: results from the Nord-Trøndelag Health Study. *BMC musculoskeletal disorders.* 2008;9(1):159.
26. Chen SM, Liu MF, Cook J, Bass S, Lo SK. Sedentary lifestyle as a risk factor for low back pain: a systematic review. *Int Arch Occup Environ Health.* 2009 Jul;82(7):797-806.
27. Hildebrandt VH, Bongers PM, Dul J, Van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. *Int Arch Occup Environ Health.* 2000 Oct 1;73(8):507-18.
28. Sitthipornvorakul E, Janwantanakul P, Purepong N, Pensri P, van der Beek AJ. The association between physical activity and neck and low back pain: a systematic review. *Eur Spine J.* 2011 May 1;20(5):677-89.
29. Guðlaugsson J, Magnússon K, Jónsson S. Heilsa og líðan Íslendinga 2012: Framkvæmdaskýrsla. Embætti landlæknis, Reykjavík. 2014.
30. Brown W, Bryson L, Byles J, Dobson A, Manderson L, Schofield M, et al. Women's Health Australia: Establishment of the Australian Longitudinal Study on Women's Health. *J Womens Health.* 1996;5(5):467-72.
31. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, Troiano RP. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol.* 2008 Apr 1;167(7):875-81.
32. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bulletin of the World Health Organization.* 2003;81(9):646-56.
33. Rasmussen BK. Epidemiology of headache. *Cephalalgia.* 2001 Sep 1;21(7):774-7.
34. Hogg-Johnson S, Van Der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J, et al. The burden and determinants of neck pain in the general population. *Eur Spine J.* 2008 Apr 1;17(1):39-51.
35. Steingrimsdóttir ÓA, Rafnsson V. Einkenni frá hálsi og hnakka, herðum og öxlum: hóprannsókn á úrtaki Íslendinga II. *Læknablaðið.* 1990.

36. Steingrimsdóttir ÓA, Rafnsson V, Sveinsdóttir Þ, Ólafsson MH. Einkenni frá hreyfi-og stoðkerfi: hóprannsókn á úrtaki Íslendinga I. Læknablaðið. 1988.
37. Stamatakis E, Grunseit AC, Coombs N, Ding D, Chau JY, Phongsavan P, Bauman A. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: the Social, Economic, and Environmental Factor (SEEF) Study. *Prev Med.* 2014 Jun 30;63:72-80.
38. Peltonen M, Lindroos AK, Torgerson JS. Musculoskeletal pain in the obese: a comparison with a general population and long-term changes after conventional and surgical obesity treatment. *Pain.* 2003 Aug 31;104(3):549-57.
39. Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems: what is the evidence? *Spine.* 2001;26(7):778-87.
40. van den Heuvel SG, Heinrich J, Jans MP, Van der Beek AJ, Bongers PM. The effect of physical activity in leisure time on neck and upper limb symptoms. *Prev Med.* 2005 Jul 31;41(1):260-7.
41. Harrington DM, Barreira TV, Staiano AE, Katzmarzyk PT. The descriptive epidemiology of sitting among US adults, NHANES 2009/2010. *J Sci Med Sport* 2014 Jul 31;17(4):371-5.
42. Aguilar-Farías N, Brown WJ, Olds TS, Peeters GG. Validity of self-report methods for measuring sedentary behaviour in older adults. *J Sci Med Sport.* 2015 Nov 30;18(6):662-6.
43. Arnardóttir NY, Koster A, Van Domelen DR, Brychta RJ, Caserotti P, Eiriksdóttir G, et al. Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study. *Age Ageing.* 2012 Oct 31;41:160.
44. Björnsdóttir S, Jónsson S, Valdimarsdóttir U. Functional limitations and physical symptoms of individuals with chronic pain. *Scand J Rheumatol.* 2013;42(1):59-70.
45. Schmidt CO, Raspe H, Pflingsten M, Hasenbring M, Basler HD, Eich W, Kohlmann T. Back Pain in the German Adult Population: Prevalence, Severity, and Sociodemographic Correlates in a Multiregional Survey. *Spine.* 2007 Aug 15;32(18):2005-11.
46. Palmer KT, Walsh K, Bendall H, Cooper C, Coggon D. Back pain in Britain: comparison of two prevalence surveys at an interval of 10 years. *BMJ.* 2000;320(7249):1577-8.
47. Stovner LJ, Zwart JA, Hagen K, Terwindt G, Pascual J. Epidemiology of headache in Europe. *Eur J Neurol.* 2006;13(4):333-45.
48. Schneider S, Randoll D, Buchner M. Why do women have back pain more than men?: A representative prevalence study in the Federal Republic of Germany. *Clin J Pain.* 2006;22(8):738-47.
49. Papageorgiou AC, Croft PR, Ferry S, Jayson MI, Silman AJ. Estimating the prevalence of low back pain in the general population: evidence from the South Manchester Back Pain Survey. *Spine.* 1995;20(17):1889-94.
50. McPhail SM, Schippers M, Marshall AL. Age, physical inactivity, obesity, health conditions, and health-related quality of life among patients receiving conservative management for musculoskeletal disorders. *Clin Interv Aging* 2014;9:1069-80.
51. Melzack R, Katz J. The McGill Pain Questionnaire: Appraisal and current status. Guilford Press; 2001.
52. Litcher-Kelly L, Martino SA, Broderick JE, Stone AA. A systematic review of measures used to assess chronic musculoskeletal pain in clinical and randomized controlled clinical trials. *J Pain* 2007;8(12):906-13.

53. Celis-Morales CA, Perez-Bravo F, Ibanez L, Salas C, Bailey ME, Gill JM. Objective vs. self-reported physical activity and sedentary time: effects of measurement method on relationships with risk biomarkers. *PloS one*. 2012 May 9;7(5):e36345.
54. Miller R, Brown W. Steps and sitting in a working population. *Int J Behav Med*. 2004;11(4):219-24.
55. Chau JY, van der Ploeg HP, Merom D, Chey T, Bauman AE. Cross-sectional associations between occupational and leisure-time sitting, physical activity and obesity in working adults. *Prev Med*. 2012 Apr 30;54(3):195-200.
56. Morken T, Magerøy N, Moen BE. Physical activity is associated with a low prevalence of musculoskeletal disorders in the Royal Norwegian Navy: a cross sectional study. *BMC musculoskeletal disorders*. 2007 Jul 2;8(1):1.
57. Sluka KA, O'Donnell JM, Danielson J, Rasmussen LA. Regular physical activity prevents development of chronic pain and activation of central neurons. *J Appl Physiol*. 2013 Mar 15;114(6):725-33.