LACK OF MUSCLE ACTIVITY IN LEG MUSCLES OF OFFICE WORKERS – EFFECT OF A DYNAMIC OFFICE CHAIR

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ABSTRACT

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The World Health Organization has named physical inactivity as a world-wide health risk. Physical inactivity has shown to induce harmful health responses, independently from physical activity. A great deal of daily physical inactivity is accumulated from prolonged sitting periods. Furthermore, daily sitting may accumulate at work. Office work, in particular, has been identified highly passive due to the high rates of sitting during working hours. Recent findings indicate that local muscular activation is the key factor signaling the metabolic responses to activity behavior. When interrupting prolonged inactivity period, the number of activity breaks has shown to be more significant for health parameters, than the intensity of the activity.

In the present study, we investigated local muscle activity in lower extremities during occupational sitting in Finnish office workers (n=4). We expected, that replacing a static office chair with a dynamic chair might induce enhanced muscle activity, and, thus, decrease the inactivity time in lower extremities during sitting. We compared two dynamic chairs (HG and HM) to a conventional static chair (SC) that were used by the office workers, each chair being used for one week in randomized order. Electromyographic (EMG) activity was recorded from quadriceps, hamstring, gastrocnemius and tibialis anterior muscles with textile electrodes embedded into clothing and averaged for quadriceps and hamstring muscles (QH) and lower leg muscles (LL). The average sitting time in the office was 5.16 h ± 1.04 h during the 12 days of measurements. The LL muscles were inactive for 82 ± 1.63 % and QH muscles for 90 ± 0.66 % of sitting time, LL muscles being proportionally more active during sitting than QH muscles. No marked difference between dynamic chairs and SC chair was observed in inactivity time. However, a positive trend was seen in LL muscle activity when dynamic chairs were compared to SC chair: greater than 10 % difference in average EMG, mean amplitude and burst rate was detected with dynamic chairs, when compared to SC chair. The results from the present study give slight support for the hypothesis that dynamic chairs would enhance muscle activity during sitting. Dynamic chairs might predispose leg muscles to more "active" sitting, yet further research is needed to determine if the intensity of the muscle activity induced by dynamic chairs is enough for significant health benefits.

Keywords: dynamic chair, electromyography, inactivity, muscle activity, office work, physical activity, sitting, static chair, textile electrodes

TIIVISTELMÄ

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Maailman terveysjärjestö WHO on nostanut fyysisen inaktiivisuuden lisääntymisen merkittäväksi terveysriskiksi maailmanlaajuisesti. Fyysisen inaktiivisuuden haittavaikutukset terveyteen ovat riippumattomia fyysisen aktiivisuuden terveyttä edistävistä vaikutuksista. Inaktiivisuusaika kertyy hereillä oloaikana muun muassa toistuvista istumisjaksoista. Toimistotyötä tekevillä päivittäinen istuen kulutettu aika voi olla huomattavan suuri. Lihasaktiivisuuden tuottamat paikalliset vasteet ovat avainasemassa fyysisen aktiivisuuden terveyshyötyjä tarkasteltaessa. Inaktiivisuusjakson keskeyttävien aktiivisuusjaksojen lukumäärällä on havaittu olevan terveysvaikutusten kannalta suurempi merkitys, kuin aktiivisuuden intensiteetillä.

Tässä tutkimuksessa tutkittiin istumisen aikaista lihasaktiivisuutta jalkojen lihaksissa suomalaisilla toimistotyöläisillä (n=4) työpäivän aikana. Vertasimme kahta dynaamista työtuolia (HG ja HM tuolit) perinteiseen staattiseen toimistotuoliin (SC tuoli) koehenkilöiden istuessa kolmen viikon aikana 5 peräkkäistä työpäivää kullakin tuolilla satunnaisessa järjestyksessä. Lihasaktiivisuutta rekisteröitiin vaatteeseen integroiduilla tekstiilielektrodeilla nelipäisen reisilihaksen, hamstring-, kaksoiskanta- sekä etummaisen säärilihaksen päältä. Elektromyografia (EMG) data keskiarvoistettiin etu- ja takareiden lihaksista (QH) sekä säärten (LL) lihaksista. Tuoleihin kiinnitettiin kiihtyvyysmittarit (ACC) rekisteröimään istuimen liikkeitä istumisen aikana. Koehenkilöt istuivat keskimäärin 5.16 ± 1.04 h työpäivän aikana omalla työpisteellään. LL-lihakset olivat inaktiiviset 82 ± 1.63 % ja QH-lihakset 92 ± 0.66 % ajasta istumisen aikana. Dynaamisilla tuoleilla istuttaessa LL-lihaksissa rekisteröitiin lievästi korkeampi aktiivisuustaso staattiseen tuoliin verrattuna (+10 % ero), kun tarkasteltiin aktiivisuuden keskiarvoa tai aktiivisuusburstien lukumäärää. QH-lihaksissa tuloksissa ei havaittu systemaattisia eroavaisuuksia. Inaktiivisuusjaksot LL-lihaksissa olivat lyhyempiä dynaamisella tuolilla istuttaessa, mutta inaktiivisuusajassa ei havaittu suurta eroa tuolien välillä. Tulokset tukevat oletusta, että dynaamiset työtuolit saattavat lisätä aktiivisuutta alaraajojen lihaksissa staattiseen tuoliin verrattuna. Lisätutkimuksia tarvitaan, jossa kyetään osoittamaan, onko istumisen aikana rekisteröity lihasaktiivisuus intensiteetiltään riittävää terveyshyötyjen saavuttamiseksi.

Asiasanat: Dynaaminen tuoli, elektromyografia, fyysinen aktiivisuus, inaktiivisuus, istuminen, lihasaktiivisuus, staattinen tuoli, tekstiilielektrodit, toimistotyö

ABBREVIATIONS

ACC	Accelerometry device
BMR	Basal metabolic rate
CPA	The Compendium of Physical Activities
EE	Energy expenditure
EMG	Electromyography
EMG_{MVC}	Electromyocraphic activity recorded during maximal voluntary contraction
HDL	High-density Lipoprotein
HG	Håg 05 -chair
HM	Herman Miller Aeron –chair
IPAQ	International physical activity questionnaire
LPL	Lipoprotein lipase
MVC	Maximal voluntary contraction
NEAT	Non-exercise activity induced thermogenesis
PA	Physical activity
REE	Resting energy expenditure
SC	Static chair
TG	Triglyceride
WHO	The World Health Organization

CONTENTS

1 INTRODUCTION

1.1 Low physical activity is a world-wide phenomenon - reason for action

In 2013, The World Health Organization (WHO 2013) listed physical inactivity one of the leading health risk for human society. The phenomenon of low physical activity level (e.g. Hamilton et al. 2007; Haskell et al. 2007) is seen worldwide, yet the severity might vary regionally (Figure 1). It was estimated by the WHO that 3.2 million deaths yearly were associated with people being insufficiently physically active (WHO 2013). The physical inactivity data from 76 countries was collected during years 2002 to 2004 by using The International Physical Activity Questionnaire (IPAQ) (Bauman 2009; Dumith 2011; Guthold 2008; Sjöström 2006). An average level of physical inactivity, when weighted for population, was 17.4 %, ranging from 2.6 % to 62.3 %. Inactivity was more prevalent among women than men, 23.7 % vs. 18.9 % respectively. (Dumith et al. 2011.)

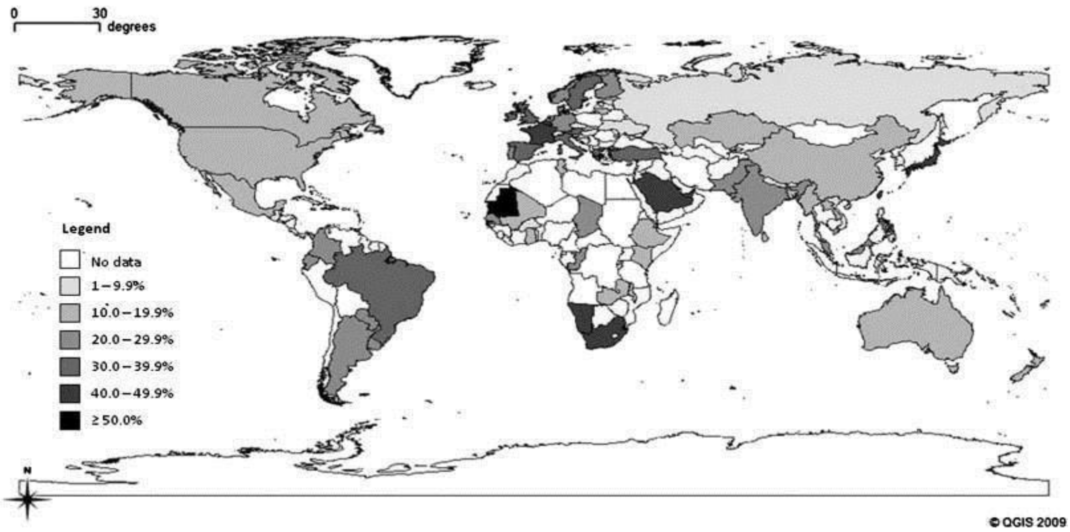

FIGURE 1. Physical inactivity among population based on data from 76 countries. Varying levels of physical inactivity may be seen on each continent world-wide. (Dumith et al. 2011.)

One out of five individuals was insufficiently physically active in global comparison (Dumith et al. 2011). In 1990, about one third of US adults met the CDC-ACSM's recommendations for moderate activity (Jones et al. 2008). The epidemiologic investigations suggest that the percentage of physically inactive population has decreased among U.S. adults (Jones et al. 1998; Haskell et al. 2007; WHO, 2013). Yet the level of physical activity is still not meeting the recommendations for health (Haskell et al. 2007). Sjöström and coworkers (2006) conducted the Eurobarometer study about physical activity across EU countries. Approximately 30 % of European adult population was sufficiently physically active for health, Netherlands and Sweden presenting the highest (44%) and the lowest (23%) prevalence for physically active citizens, respectively. The results suggest that moderate level of physical activity and recommendations are met in majority of the participating countries. Yet, the prevalence of physical inactivity varied from 7 to 43 % between countries. As much as two thirds of the European population was insufficiently active for optimal health benefits according to these results. (Sjöström et al. 2006.) The level of physical activity varies between regions, while demographic characteristics also seem to determine the activity behavior of population. (e.g. Bauman et al. 2009; Brownson et al. 2000) The statement of WHO (2013) that the high prevalence of physical inactivity should be regarded as a world-wide health risk, does not seem groundless.

1.2 Sitting exposures to sedentary behavior

In general, people are awake for 16 hours per day. The daily life consist of different domains of daily life; leisure, transportation and work for example. Daily hours spent in each domain might be relatively constant, yet individual. An individual might spend 8 hours at work and 2 hours commuting to work. This would leave 6 hours of leisure time for optional activities. Total amount of physical activity is accumulated from independent domains of daily life, which each involves individual types of activity. (Howley 2001; Shephard 2003.)

A great deal of physical inactivity is accumulated from sitting periods during waking hours. This is why inactivity time is usually detected by asking sitting time. TV-viewing time is often regarded as a marker of leisure time inactivity and sitting time, however this does not take into account total sitting time for which occupational and commuting also contribute (Marshall & Gyi, 2010; Van Uffelen et al. 2010). Categorizing the physical activity according to life domains, might help an individual to recall his/hers total sitting time, thus the daily inactivity time is summed up from sitting time occurring during leisure, transporting and work (Caspersen et al. 1985). The results of Sjöström et al. (2006) revealed that meeting health-enhancing activity level did not decrease the prevalence of high rates of sitting. For example, Finland showed one of the highest rates of physical activity (91 % of population meeting the recommendations) among European countries. Simultaneously 49 % of Finnish habitants sat over 6h /day, while the average among European countries was 41 %. (Sjöström et al. 2006.) The portion of the time spent seated from the waking hours has increased remarkably, as there is a global trend towards less active lifestyle (Hamilton et al. 2007) due to office work, automatization of house-hold chores and commuting (Hamilton et al. 2007; Healy et al. 2008; Van Uffelen et al. 2010).

A comparison between 20 countries revealed a median sitting time of 300 minutes per day. In 12 out of the 20 countries, median sitting time was more than 5 hours per day. On average, participants reported 3 to 8 hours of daily sitting. (Bauman et al. 2011.) A recent longitudinal study of Australian mid-age women revealed that 53 % of participants were sitting 6 hours per day and one third was sitting 6 to 9 hours per day (Peeters et al. 2013). Even more concerning results were achieved by Jans et al. (2007), when they investigated the physical activity behavior among Dutch working population within various occupational categories. The mean sedentary time for Dutch workers was 14 h / day and about one half of the sedentary time was accumulated by sitting. The evidence indicates that the great amount of sitting during daily life is a world-wide phenomenon. This has raised interest about the influence of prolonged sitting on metabolic health (Marshall & Gyi, 2010).

1.3 Work occupies a great deal of waking hours

Occupational physical activity contributes strongly to the total amount of physical activity (Levine 2007; Tigbe et al. 2011) and the cumulative energy expenditure (EE) (Shephard 2003) during waking hours. Time spent at work might contain various non-exercise activities and thereby increase the time spent physically active on daily basis (Levine, 2007). Activity at work contributed for one third of the daily physical activity in Dutch workers when averaged for various occupations (Jans et al. 2007; Proper & Hildebrandt 2006). The mirror image is that working hours might also significantly increase the inactivity time when the work requires passive operations at one's personal work station; e.g. work on computer (Tremblay et al. 2010). Epidemiological studies about the physical activity of working population reveal that over 60 % of participants engage regular physical activity during leisure time (Duncan et al. 2012; Proper & Hildebrandt 2006), yet only 27 % of British working population actually met the recommendations for sufficient daily physical activity (Duncan et al. 2012).

1.3.1 Occupation is a strong determinant for daily physical activity

Epidemiologic evidence from the studies conducted on working population (e.g. Duncan et al. 2012; Proper & Hildebrandt 2006; Schofield et al. 2005; Toomingas et al. 2012) indicate how the modern society places a great challenge for an individual to maintain the physical activity level optimal for health. The energy requirement of daily living and the time spent physically active has decreased substantially (Haskell et al. 2007). A great deal of static sitting is required in various occupations, e.g. among office workers (Oliver et al. 2010; Pesola et al. 2014) and administrative personnel (Duncan et al. 2010; Mummery et al. 2005).

In the cross-sectional study, conducted by Brownson et al. (2000), occupational activity increased the activity level among women living the U.S. compared to situation when only leisure time activity was considered. Physically demanding work may expand daily EE by 1500 kcal /day compared to sedentary work (Levine 2007). However, a great variation in total EE has been observed between different occupations, varying from 300 kcal/ day for seated workers compared to over 2000 kcal/day for vigorous intensity activity requiring occupations (Hamilton et al. 2007). Proper and Hildebrandt (2006) reported that among Dutch workers, the most active occupational sectors were agriculture, wood and furniture industry, construction industry, metal industry and service functions. Also Schofield et al. (2005) found that certain ambulatory-based occupations accumulated more physical activity during working time when measured objectively with pedometers. In their study, conducted on working population in New Zealand, blue-collar workers and nurses were the most active occupations compared to relatively inactive office and retail work, referred as desk-based jobs. Physically active and inactive occupations were compared within same service sector. Walking delivery postal workers were reported to spend daily 1.7 h longer in upright posture than their colleagues performing administrative, office-bound work. In contrast, the office staff spent 1.5 h / day longer in sedentary posture. (Tigbe et al. 2011.)

1.3.2 Work-related sitting time varies among occupations

Studies conducted on working population (Chau et al. 2012; Duncan et al. 2010; Mummery et al. 2005) have revealed that certain occupations involve sitting in greater extent compared to others; administrative and office workers, managers, scientific professionals are often reported to sit the majority of the working time (Duncan et al. 2010; Jans et al. 2007; Mummery et al. 2005) corresponding to 4 to 6 hours of sitting (Chau et a. 2012). Lowest engagement to sitting at work has been observed within laborers, production and transport workers and other industrial occupations, service workers and agricultural occupations (e.g. Jans et al. 2007) also referred as blue-collar workers (e,g, Mummery et al. 2005). Less than 2 hours of sitting at work was reported by Chau et al. (2012) for this occupation category.

From one third up to one half of daily sitting might be accumulated during working hours and commuting to and from work (Duncan et al. 2012; Jans et al. 2007). Occupational sitting time among Australian workers was over 3 h / day (Chau et al. 2012; Mummery et al. 2005) while 25 % of the participants reported over 6 h of daily occupational sitting (Mummery et al. 2005). Leisure time may accumulate daily sitting time for additional 3 hours (Chau et al. 2012; Van Uffelen et al. 2010). Also workers in the U.S. spend up to one half of their working time sitting on a chair, corresponding to 4.2 hours of sitting (Van Uffelen et al. 2010). However, for British working population the mean sitting time exceeded 9 hours on workdays (Duncan et al. 2012).

1.3.3 Passive nature of office work

Both self-reported and objective assessment of the physical activity give support for the passive nature of office work, as high percentage of sitting time, varying from 50 to 80 %, from total working time has been recorded in office workers (Pesola et al. 2014; Ryde et al. 2013; Tigbe et al. 2011; Toomingas et al. 2012). Call-center operators were reported to spend 75 % of their working time sitting, on average (Toomingas et al. 2012). By recordings of muscle activity during waking hours, lower limb muscles of Finnish office workers were found to be inactive for 78.6 % of working hours, on average. Leisure time inactivity time for these subjects was 61.6 % of measured hours, on average. (Pesola et al. 2014.) Tigbe et al. (2011) conducted a 24-h monitoring of physical activity with accelerometers in postal workers. Office staff was reported to spend half of their working time in sedentary posture. Oliver et al. (2010) also reported office workers to sit 69 % of waking hours when assessed with accelerometers. It is worth noticing, that among desk-based occupations, the inactivity periods are often prolonged as they usually involve concentration to tasks conducted while seated (Weber et al. 2009).

Some generalization is possible to make about the physical demands of different occupations. Similarly to occupation-related energy requirement, occupation is associated with the accumulation of inactivity time, in particular the amount of sitting time during working hours. There are certain occupations which require workers to remain seated for relatively great portion of the working time. Office work, among other occupations, exposures people to low physical activity because workers are required to remain seated for prolonged periods of time. Yet the individual variation among workers is great. (Miles-Chan et al. 2013.) A study conducted on call-center operators revealed how the working time spent seated ranged from as low as 6 % to as high as 95 % (Toomingas et al 2012). Similarly, Tikkanen et al. (2013) reported great individual variance within the duration of the longest continuous inactivity period, ranging from 3 to 40 min during waking hours.

2 DAILY ENERGY EXPENDITURE AND THE ROLE OF PHYSICAL ACTIVITY IN METABOLIC HEALTH

Human health relies on metabolic health which is closely associated with the level of daily physical activity. However, physical activity has decreased in modern society as a great portion of waking hours is actually spent sedentary. Daily energy expenditure provides one aspect for the observation of daily physical activity level, but also local factors, insulin and lipoprotein lipase activity, reflect the metabolic health in human body via their important role in glucose and fat metabolism. The relationship between metabolic health and physical activity is discussed here briefly as it creates the base for understanding the novel aspect of inactivity physiology, introduced by Hamilton et al. (2004).

2.1 The basal metabolism at rest determines daily energy expenditure

Human daily energy expenditure at rest comprises of processes related to basal metabolism and the thermic effect of food ingested. Basal metabolic rate (BMR) describes the minimal energy cost of metabolic processes of the human body. (Miles-Chan et al. 2014.) Determining BMR requires standardized laboratory assessment. The resting metabolic rate (RMR), estimated to correspond to the oxygen consumption of 3.5 ml//kg/min (Howley, 2001; Tremblay et al. 2010), should be considered as a proxy for BMR. The two terms are often understood to be equivalent, but the assessment of RMR allows less controlled conditions regarding the metabolic state of the subject. (Miles-Chan et al. 2014.)

In supine position, resting energy expenditure (REE) is about 5.4 kJ/min (Levine et al. 2000), also expressed as 1.0 kcal/kg/h (Ainsworth et al. 2011). The resting metabolic rate (RMR) is dependent on age, gender, body weight and body composition (Frankenfield 2013; Pourhassan et al. 2014; Lam et al. 2014). REE accounts for the major part of daily EE for healthy adults. An estimated REE for a man with normal body-weight is about 1400 kcal / day yet individual variation results from the body composition related characteristics (Frankenfield 2013). Fat-free mass (FFM), skeletal muscle mass in particular, has been determined to be the strongest predictor of REE

(Pourhassan et al. 2014), explaining over 75 % of the variation between individuals (Lam et al. 2014). The thermal effect of ingested food has shown to contribute on daily EE by 10 % (Levine 2007).

2.2 Physical activity of daily life

The total daily energy requirement is a combination of RMR and physical activity level (Lam et al. 2014) as illustrated in Figure 2. Any physical activity, involving muscular contraction, increases the energy expenditure above resting value (Caspersen et al. 1985). This encompasses both non-exercise and physical exercise activities during waking hours and in different domains of life. The major part of daily EE is involved in basal metabolic processes and the thermal effect of food ingested, thus activity-induced energy expenditure has been evaluated to cover 20-30 % of the daily EE (Westerterp 2003). However lifestyle and behavioral characteristics strongly influence the level of daily physical activity, adopted by an individual.

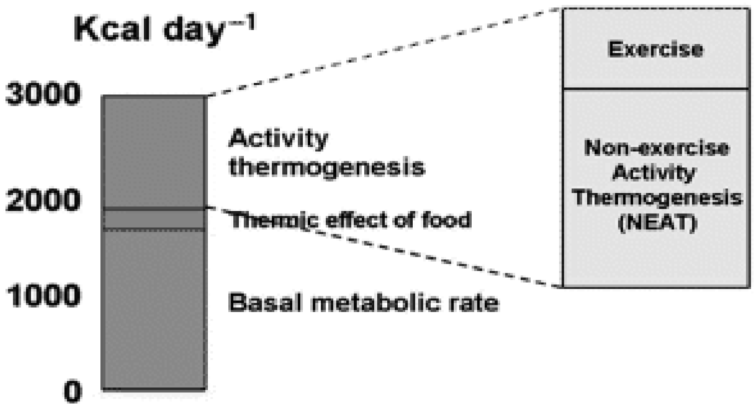

FIGURE 2. Daily energy expenditure (EE) is highly dependent on the energy cost of metabolic processes, leaving only fractional role for daily physical activity. Furthermore, the daily physical activity is mostly comprised of light-intensity physical activity conducted while non-exercise activities (Levine et al. 2007).

Physical activity should not be conceptualized interchangeable with physical exercise. Apart from daily routines at work or during leisure time at home, physical exercise is usually planned and structured activity. (Caspersen et al. 1985.) Thus, exercise is a sub-category, and a specific form, of physical activity, usually conducted to maintain or improve and physical fitness and health (Corbin et al. 2000, adapted from Bouchard et al. 1990). The routines of daily life consist of a wide range of non-exercise activities often with relatively light intensity level, yet increased EE with respect to rest (Hamilton et al. 2007). In a study conducted by Healy et al. (2008a) the physical activity time during waking hours was detected with accelerometers. About 40 % of the observed time could be considered as physical activity time out of which over 90 % was categorized to be light-intensity activity. (Healy et al. 2008a.) Tikkanen et al. (2013) observed averaged EMG amplitude from thigh muscles of 4 % EMG_{MVC}. EMG_{MVC} refers to muscle activity recorded during maximal voluntary contraction, serving as reference recording, of the muscle in question. Thus, very light intensity activity was required from the muscles of lower limbs during waking hours (11h). When activated, the average amplitude of activity burst was about 6 % EMG_{MVC}. The average amplitude in daily life activities can be regarded to remain relatively light, as for example, the EMG level required when walking (5 km/h) would be 10 % EMG_{MVC}. (Tikkanen et al. 2013.) Finni et al. (2014) reported that the time spent in moderate intensity level contributed only for about 8 % of the waking hours. Moreover, activity time in moderate-to-vigorous intensity covered only 4 % of the waking hours, corresponding to 0.61 h / day on average, according to Healy et al. (2008a).

The role of non-exercise activities in total energy expenditure is significant. An average individual spends 65 % of their active time at low-intensity activity (Westerterp 2003). The physical activity level is mainly determined by the amount of low-intensity activity, involving various non-exercise actions (Finni et al. 2014; Healy et al. 2008a). Energy expenditure induced by non-exercise activity (NEAT) is the most variable component of the activity-induced EE (Hamilton et al. 2007; Levine et al. 2000) as it may vary from 3 to 50 % in free-living conditions (Lam et al. 2014) or from 300 to 200 kcal / day (Levine 2007). For non-exercise activities it is characteristic that they occur frequently, often accumulating up to hundreds of bouts per day, and every day during a week. The intensity usually remains low which enables this type of activity to be repeated during the day. Frequent, yet relatively short, activity bouts throughout the day may accumulate the total activity time beyond 8 hours. (Hamilton et al. 2007.) Exercise for fitness was found to increase total daily energy expenditure for only 13 % (Finni et al. 2014). Moreover, for physical exercise the time frame is usually about 60-90 min but may vary between 30 min and 150 min. This is a relatively limited time window with respect to non-exercise activities conducted throughout the day. (Finni et al. 2014; Howley, 2001.)

There is no clear consensus in the field of physical activity, what is considered as sedentary action, nor sedentary lifestyle (Tremblay et al. 2010). Sedentary time typically comprises of activities not requiring physical activity thus associated with low EE. The duration, intensity, and frequency together define the energy requirements of physical activity. While the intensity of physical activity may vary along a continuum from high to low, the activity-induced energy expenditure and daily physical activity level depend all of these determinants. (Haskell et al. 2007.) Sitting increases the EE only slightly with respect to supine position (Miles-Chan et al. 2014). Sedentary behavior usually involves actions done while maintaining seated or reclined posture (Healy et al. 2011), such as reading, typing or watching a TV while seated or driving a car. The investigation of daily life activity patterns strives to identify the entire range of physical activities from sedentary to light and more vigorous activities (Pate et al. 2008; Shephard 2003.)

The development of the modern society has resulted in less time being spent at the lightest quartile on the continuum of physical activity, as in other words, physical inactivity time has replaced the time spent in light-intensity activities. Various daily routines involving light activity level have been replaced by inactivity; people tend to use elevator instead of walking stairs or drive to grocery store instead of walking (Hamilton et al. 2007). Finni et al. (2014) observed about 30 % of the waking hours to consist of some level of physical activity. Furthermore, physical exercise did not decrease the inactivity time during daily life, thus a significant part of the day is spent physically inactive (Finni et al. 2014).

2.3 Benefits of regular physical activity

Physical activity and health are closely associated. According to Blair et al. (2012), cardiovascular disease, diabetes and cancer explain 65 % of all deaths world-wide. Each of these conditions is considered to be related to physical activity at some level. The health benefits of regular physical activity are related to a lower risk of developing metabolic disorder, diabetes mellitus and obesity as, for example, a risk of diabetes is associated with deceased level of physical activity (Bauman 2004). The international recommendations for physical activity aim to describe guidelines about sufficient physical activity for maintaining or improving individuals’ health.

The Compendium of Physical Activities (CPA) was developed to enhance the evaluation of intensity of various physical activities and comparability between independent investigations within the research of physical activity. The purpose is to provide estimations for the energy expenditure, expressed as metabolic equivalent (MET) value, for various physical activities typically present in daily life. This should help investigators to convert the self-reported questionnaire-based physical activity into metabolic values without direct objective measurement. The CPA was originally completed in 1993 and has then been updated, most recently in 2011 by Ainsworth and her colleagues. (Ainsworth et al. 2011.) 1 MET is equivalent for resting metabolic rate RMR (1.0 kcal/kg/h), the caloric expenditure for a person at rest. The metabolic equivalent for specific activity expresses the energy cost as a multiple of 1 MET (e.g. Brownson et al. 2000; Howley, 2001; Martinez-Gonzalez et al. 2001; Weber et al. 2009). The CPA strives to encompass the entire range of physical activities with specific energy demands, from sleeping (equivalent for 0.9 METs) to light and moderate intensity activities up to very vigorous running at 14 mph speed (23 METs). Specifications exist for the intensity of activity, for example for home activities: cleaning with light effort is considered with lower MET value than sweeping with moderate effort (2.3 METs vs. 3.8 METs, respectively). (Ainsworth et al. 2011.) A wide range of daily activities falls between the sedentary actions and activities involving moderate-to-vigorous intensity, that is, between 1.5 and 3 METs (Haskell et al. 2007; Tremblay et al. 2010).

In 1995, The Centers for Disease Control and Prevention and the American College of Sports Medicine established a committee (CDCP-ACSM) in order to create recommendations for physical activity for the American population. An updated recommendation given for 18 to 65 year-old adults includes a minimum of 30 min of moderate-intensity aerobic physical activity on 5 days each week. The intensity level influences on the amount needed on weekly basis, thus conducting vigorous-intensity for a minimum of 20 min on three days each week is enough to meet the recommendations. In addition to aerobic endurance activity recommendations, also muscular conditioning is taken under consideration. (Haskell et al. 2007.)

2.3.1 Insulin and lipoprotein lipase are central metabolic biomarkers

Insulin and lipolysis lipase (LPL) are central biomarkers for the metabolism of skeletal muscle. Insulin is a key factor in the processes of energy substrate usage and storage. Insulin-resistance hinders the transportation of ingested glucose into glycogen stores of skeletal muscles. Instead, the excessive glucose is carried to liver to be processed in hepatic lipogenesis. The decreased muscle glycogen synthesis and increased hepatic lipogenesis change the energy storing pattern in human body. (Petersen et al. 2007.) Lipoprotein lipase (LPL) is an enzyme that regulates the lipid metabolism in human body by regulating the hydrolysis of plasma triglycerides. By binding to circulating lipoproteins it regulates and facilitates the uptake of lipoprotein derived fatty acids and triglycerides (TG) into skeletal muscle and adipose tissue (Hamilton et al. 2004), thus LPL contributes to HDL metabolism and regulates the supply of fatty acids for either storage or oxidation (Wang & Eckel 2009). LPL is produced in various tissues but skeletal muscle is a major site for LPL synthesis (Wang & Eckel 2009).

Changes in glucose uptake of skeletal muscles (Biensø et al. 2012; Stephens et al. 2011) and lipid metabolism reflect the metabolic health and physical activity behavior (Bey & Hamilton 2003; Hamilton 2004). The development of insulin-resistance has shown to play a role of in pathogenesis of metabolic syndrome, cardiovascular conditions and type 2 diabetes mellitus (Petersen et al. 2007). Insulin sensitivity and LPL activity have been widely investigated by researchers on the field of physical activity, because they respond readily to the changes in the physical activity status (Tremblay e al. 2010).

2.3.2 Physical activity level is associated with metabolic health

Paffenberger et al. (1993) reported that regular moderate-to-vigorous physical activity was associated with lower rates of death from all causes and from coronary heart disease among middle aged and older men, independently of other life style characteristics such as quitting cigarette smoking, maintaining normal blood pressure and avoiding obesity. The findings of Paffenberger have later been confirmed by several research groups. Low level of physical activity increases the risk of premature death substantially. When compared to sedentary individuals, the risk of death was 17 % lower in women who met the recommendations for physical activity and 39 % lower for those who were moderately fit (Blair et al. 2012). Regular physical activity at moderate intensity level, as recommended, protect from premature death, decreasing the risk of death with 30 % (Bauman 2004). Metabolic health is predisposed to risk factors such as high blood pressure, high blood glucose, obesity, and insufficient level of physical activity. In addition these contributors are associated with each other (Blair et al. 2012). The risk for developing cardiovascular disease (CVD) is considered to be related with the level of physical activity, even though controversial opinions exist due to the difficulties in proving the causality (Bauman 2004; Thorp et al. 2011). Levels of occupational and leisure-time physical activity are determined to be independently associated with the risk of abdominal obesity. High occupational activity contributes to lower risk of abdominal obesity. Respectively, individuals who are sedentary on leisure time predispose to higher risk of abdominal obesity if they have physically inactive occupation, compared to those whose work consists of physically active tasks. (Steeves et al. 2012.) Other conditions also, for example different types of cancers, osteoporosis, anxiety and depression might also be associated with insufficient physical activity (e.g. Haskell et al. 2007).

Evidence exists for the preventive role of physical activity against diabetes and metabolic syndrome, and all-cause cancers (Bauman 2004). Already a slight increase in contractile activity already can result in notable benefits in glucose tolerance in previously sedentary individuals (Tremblay et al. 2010). Even low contractile activity also enhances the sensitivity of LPL activity in skeletal muscles. In result, the active muscle tissue clears the surrounding extracellular fluid from lipids. (Zderic & Hamilton 2006.) Interrupting inactivity with two minutes of light-intensity activity has shown to be enough to trigger the advantageous effects, and even stronger response was achieved with moderate-intensity activity (Bailey & Locke 2014; Dunstan et al. 2012a).

3 INACTIVITY PHYSIOLOGY

3.1 Association of sedentary behavior with metabolic health

Nowadays, physical inactivity is one of the leading health problems world-wide (Blair et al. 2012; WHO, 2013). A novel perspective towards the metabolic health is the concept of 'inactivity physiology'. Lack of daily non-exercise physical activity, outside the domain of leisure time sports, places a new challenge for metabolic health. (Hamilton et al. 2004). Physical inactivity has both direct and indirect effects on metabolic health and the development of chronic health conditions (Blair et al. 2012). Each of these conditions might be related to other lifestyle characteristics as well, and are simultaneously influenced by various factors (e.g. Stephens et al. 2011). Sedentary behavior induces the risk of various metabolism-related conditions such as obesity, cardiovascular disease (Hamilton et al. 2007; Thorp et al. 2011), hypertension, type 2 diabetes (Van Uffelen et al. 2010), but also all-cause mortality (Thorp et al. 2011; Van Uffelen et al. 2010). Peeters et al. (2013) found that women sitting more than 6 hours per day had increased odds of having problems with breathing, tiredness and other health related responses. The risk seemed to increase for women sitting over 9 hours per day (Peeters et al. 2013). According to the meta-analysis by Edwardson et al (2012), the time spent sedentary was related to the prospects of developing a metabolic syndrome. Whereas Healy et al. (2008b) concluded that sedentary time may have a stronger influence on waist circumference than the time spent in moderate-to-vigorous intensity activities. Similarly, sedentary behavior is thought to increase the risk of CVD independently from the time spent physically active.

Not only does physical inactivity decrease the daily EE in total, and thus increase the risk of metabolic disorders, obesity and mortality (Thorp et al. 2011), but recent findings about the changes in local biomarkers support the independent role of inactivity in metabolic health (i.e. Bey & Hamilton 2003; Hamilton et al. 2004). The cellular responses to physical inactivity are shown to differ from those of physical exercise, despite the equivalent biomarkers reflecting the responses. The LPL activity, for example, is influenced by both inactivity and physical activity but, the mechanisms seem to differ. (Hamilton et al. 2007; Tremblay et al 2011.) Oxidative, posture supporting, muscles show higher LPL activity compared to glycolytic muscles (Bey &

Hamilton 2003), indicating that non-exercise activities are supposed to activate the oxidative sections of skeletal muscles frequently in normal daily life (Hamilton 2004). The benefits of physical exercise are particularly seen in the least oxidative regions of the muscles, whereas the changes in LPL activity associated with physical inactivity are seen in oxidative regions of the muscle tissue (Hamilton et al. 2004). The causal relationship between physical inactivity and specific metabolic biomarkers requires further investigations about daily activities with objective measures of sedentary time and behavior (Hamilton et al. 2007), for example with using accelerometers (Healy et al. 2008b) and electromyographic (EMG) recordings (Finni et al. 2014). While still waiting for evidence achieved with objective measures, researchers are consistent about the role of sedentary behavior in metabolic health independently from physical activity (Edwardson et al. 2012; Hamilton et al. 2007; Thorp et al. 2011; Tremblay et al. 2010).

3.2 Inactivity-induced lack of local muscular activity

Investigators have been able to localize some of the effects of inactivity to be mediated in skeletal muscle (Bey & Hamilton 2003; Stephens et al. 2011; Hamilton et al. 2004). Stephens et al. (2011) examined the specific metabolic effects of minimizing low-intensity muscle activity; one day of prolonged sitting reduced whole-body insulin action but the insulin mediated glucose uptake was disturbed in skeletal muscle stronger than in liver. Even when the energy intake was reduced and matched to lowered energy expenditure during prolonged sitting, the decline in insulin action was attenuated but not prevented completely (Stephens et al. 2011). The decrease of LPL activity and fatty acid uptake was only existent in unloaded muscles (Bey and Hamilton 2003) indicating the site-specificity of the effects of inactivity on lipid metabolism (Hamilton et al. 2004). It can be speculated that there are other factors, beside the energy surplus, involved in the detrimental impact of inactivity (Stephens et al. 2011).

3.2.1 Local biomarkers reflect the inactivity-induced changes in skeletal muscle

Results from bed rest studies reveal inactivity-induced changes in the regulation of glucose uptake and storage in skeletal muscle. Lower content of the key proteins of glucose transport and storage was observed after 7 days of bed rest (Biensø et al. 2010).

Alibegovic et al. (2009) observed increased insulin resistance after 9 days of bed rest at whole-body level. The insulin sensitivity in skeletal muscle is impaired by prolonged physical inactivity due to decreased insulin-stimulated glycogen synthase (Alibegovic et al. 2009; Biensø et al. 2012).

Skeletal muscle LPL activity is sensitive to changes in physical inactivity level (Hamilton et al. 2004). Reduced LPL activity is associated with unfavorable increase in circulating TG levels, decreased HDL cholesterol and also with increased risk of cardiovascular disease (Hamilton et al. 2007) due to impaired uptake of fatty acids and triglyserides (Hamilton et al. 2004). The rate of whole-body lipolysis and basal fat oxidation was decreased in response to 9 days of bed rest (Alibegovic et al. 2009). It is the lack of local activation in postural muscles that is assumed to influence on lipoprotein metabolism (Bey & Hamilton 2003; Hamilton et al. 2007). The decrease of skeletal muscle LPL activity finally impairs the lipid storing hence the inactivity-induced changes in whole-body insulin action are associated with a turnover of substrate utilization in basal metabolic processes (Wang & Eckel 2009) indicating also the close relationship between insulin and LPL activity. Increased plasma insulin levels, increased basal glucose oxidation and decreased fat oxidation promote hepatic synthesis of triglyserides and accumulation of plasma lipids. Insulin-stimulated non-oxidative glucose metabolism is simultaneously decreased. (Alibegovic et al. 2009.)

3.2.2 Sitting predisposes to local muscular inactivity

Changes in metabolic biomarkers can be seen already after relatively short period of sedentariness. Physical inactivity of 4 hours was enough to reduce LPL activity in unloaded muscles in rodents. Both muscle TG uptake and plasma HDL-Cholesterol were decreased after only 1 day of inactivity. The acute responses to one day of inactivity were similar to chronic inactivity lasting 11 days, when compared to ambulatory controls. (Bey & Hamilton 2003.) Peddie et al. (2013) observed cardio-metabolic effects following only 1 day of prolonged sitting in young healthy adults. Similarly, only 1 day of sitting was enough to result in impaired insulin action in humans (Stephens et al. 2011).

Bed rest can be seen as a relatively severe case of physical inactivity, when no contractile activity is required from weight bearing muscles at all. Sitting is also largely static for skeletal muscles throughout the body (Ellegast et al. 2012). Moreover, sitting is often executed during normal daily life. Prolonged sitting is suggested to induce similar physiological responses on skeletal muscles than bed rest because the weight-bearing skeletal muscles are lacking contractile activity (Van Uffelen et al. 2010.) Prolonged sitting might be an independent risk factor for symptoms associated with metabolic syndrome or other conditions, like glucose metabolism malfunction or alterations in lipid metabolism (Hamilton et al. 2007).

Metabolic biomarkers respond independently on inactivity, light activity and physical exercise. Daily physical exercise alone does not prevent the negative consequences of otherwise sedentary lifestyle (Mummery et al. 2005; Pate et al. 2008), as a 1-hour exercise bout does not compensate the deleterious health outcomes of prolonged sitting (Duvivier et al. 2013). An increase in LPL activity was seen in glycolytic muscle fibers after a physical exercise bout. Physical exercise did not change LPL activity in the oxidative areas, which should be activated by regular ambulatory activation. (Hamilton et al. 2004.) Biensø et al. (2012) compared the changes in insulin-induced glucose extraction when an acute exercise bout was performed before and after bed rest. Acute exercise increases glucose extraction in skeletal muscle via enhanced insulin activity. Physical exercise performed after bed rest did not, however, return the glucose extraction to similar level when compared to changes seen before bed rest. (Biensø et al. 2012). Replacing one hour out of 14 hours of sitting, with physical exercise did not attain similar beneficial response in blood glucose and insulin levels or in plasma lipids as seen with replacing six hours of sitting with light-intensity activity, even when the energy expenditure of both activity regimens were kept similar (Duvivier et al. 2013).

3.3 Sedentary lifestyle is a strong contributor to daily inactivity time

3.3.1 Daily routines play a significant role in individuals' physical activity behavior

A physically active person is defined as someone who regularly meets the recommendations for physical activity (Jones et al. 1998; Tremblay et al. 2010), that is, practices moderate-to-vigorous intensity activities three times a week, or corresponding amount of aerobic exercise with varying intensity levels, and regularly executes exercises for the muscular strength and endurance (Haskell et al. 2007). Performing regular physical exercise does not guarantee the level of total physical activity to be sufficient for health (Pate et al. 2008) as the sedentary behavior can occur together with recommended levels of moderate-to-vigorous physical activity (Tremblay et al. 2010). A great deal of daily light-intensity activities is replaced by automatized functions resulting in more passive lifestyle, independently from the time spent with physical exercise (Hamilton e al. 2007). Sedentariness has become an independent determinant of daily activity behavior beside physical activity itself.

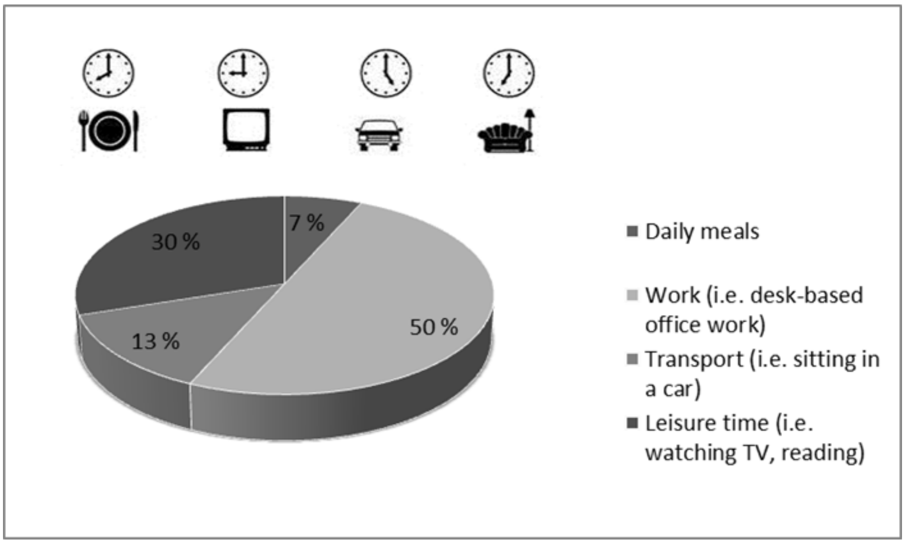

FIGURE 3. Daily life encompass various opportunities to adopt sedentary behavior hence accumulate daily sitting time as high as 15.5 hours daily (Tremblay et al. 2010).

Population-based surveys show the independent role of sedentary behavior within daily life. The accumulation of sedentary time is highly influenced by the routines of daily life throughout waking hours (Figure 3). The problem exists also on individual level; as an individual might commit regular physical exercise at moderate-to-vigorous intensity, yet also adopt otherwise sedentary lifestyle during the rest of the waking hours (Tremblay et al. 2010). According to Healy et al. (2008b) sedentary time covers 57 % of waking hours, when recorded with accelerometer. Similar results are attained with EMG recordings, as the muscles of lower limbs were regarded to be inactive for almost 70 % of the waking hours, corresponding to 7.5 hours per day (Pesola et al. 2014; Tikkanen et al. 2013). From the waking hours, only as little as 4-9 % might be classified as moderate-to-vigorous intensity activity, whereas 20-39 % may be classified as low-intensity activity. The rest, thus over half of the waking hours, encompasses physical inactivity. (Finni et al. 2014; Healy et al. 2008b.)

3.3.2 Sufficient physical activity level is not attained with physical exercises alone

Daily inactivity time is not altered by physical exercise bout. Finni et al. (2014) investigated whether the time spent sedentary is affected by the amount of physical exercise done during the same day. The research group hypothesized that exercise would increase the time spent in moderate-to-vigorous intensity and decrease the muscle inactivity time. The mean sedentary time detected was 70 % of waking hours. Exercise for fitness increased the total time spent at an intensity level of moderate-to-vigorous intensity during waking hours. However, significant difference in mean sedentary time was not seen between days when the subject did or did not perform exercise for fitness. (Finni et al. 2014.) Even when being active, the activity time is mostly spent at light intensity levels as only 25 % and 9 % of physical activity is performed at moderate- and high-intensity levels, respectively. Thus high-intensity activity does not have a significant impact on the level of physical activity on daily basis. (Westerterp 2003.)

Daily energy expenditure is more likely to alter with light-intensity activity than physical exercise. Daily life offers opportunities for non-exercise activities to be executed throughout much of the day, but time spent on physical exercise is limited compared to that. Daily physical exercise bouts do not significantly increase the daily energy expenditure. Instead, the total EE of everyday life is strongly affected by non-exercise activities (Hamilton et al. 2007; Westerterp 2003), if the daily routines encompass various light-intensity activities or, in contrast, is spent sedentary (Tremblay et al. 2010). A 13-h observation of two individuals revealed differing caloric expenditure with different activity behaviors. Greater energy expenditure during daily actions was accumulated for an individual who did not execute any moderate-to-vigorous intensity activity but spent 75 % of the time observed at light intensity range. Whereas for an individual who took part in moderate-to-vigorous intensity activity for 1 hour, 70 % of the time was categorized as sedentary and only 23 % as light intensity activity. Moreover, the estimated energy expenditure for total of 13-h observation remained lower for this subject. (Pate et al. 2008.) Levine et al. (2000) reported a systematic increase in energy consumption along the continuum of daily actions at different intensities, when compared to resting state. Sitting motionless increased energy consumption by 4 %, whereas when standing still the increase was 13 % with respect to resting level (Levine et al. 2000). Standing usually induces greater energy expenditure compared to sitting, yet it does not remarkably alter the daily EE (Miles-Chan et al. 2014). Replacing static sitting or standing with performing fidgeting-like movements and postural changes, should increase the metabolic cost with respect to total sedentariness (Levine et al. 2000), in particular when performed over prolonged portion of waking hours (Miles-Chan et al. 2013).

It is worth noting, that the recommendations for physical activity should be regarded as an additional part of weekly routines in addition to non-exercise activities occurring in other domains of daily life (e.g. household work, self-care, walking around home or office) (Haskell et al. 2007). The energy expenditure produced by exercise bouts does not correspond to the energy expenditure of daily non-exercise physical activity. Neither do they produce similar metabolic responses in terms of glucose and lipid metabolism. Furthermore, because the non-exercise activities might be executed repeatedly, even every day, they have a potential to frequently interrupt the inactivity periods and thus increase the total activity time more efficiently than physical exercise bouts alone. (Hamilton et al. 2007.) Health recommendations for physical activity are not worthless, yet consideration should be given also to non-exercise time during waking hours as this might reveal the volume of light-intensity activity (Finni et al. 2014). Health promoters should pay attention on how to encourage people to decrease their sedentary time through increasing the engagement to daily light-intensity and non-exercise activities (Dunstan et al. 2012a; Healy et al. 2008b).

4 DECREASING PHYSICAL INACTIVITY BY INCREASING LOCAL MUSCLE ACTIVITY DURING DESK-BASED OFFICE WORK

4.1 Sedentary occupation exposes to unbeneficial health outcomes

Various occupations require workers to sit relatively large portion of working time, as discussed earlier. Moreover, work encompasses consecutive days on weekly basis. This results in frequent bouts of prolonged sitting during working time. The independent role of physical inactivity on metabolic health increases the concern that desk-based occupations might have severe implications on individual's health. Thus, detecting physical inactivity during office days might reveal useful information about the passive nature of office work. Occupational sitting, in particular, has shown to promote unfavorable metabolic health responses, including overweight and increased BMI (Duncan et al. 2012; Mummery et al. 2005), cardiovascular disease, diabetes mellitus and even mortality (Hamilton et al. 2007; Peeters et al. 2013; Van Uffelen et al. 2010). In Australian men, sitting over 6h / day was associated with BMI over 25 (Mummery et al 2005). The risk of abdominal obesity was increased especially in sedentary workers who did not compensate for work-time sedentariness by increasing their physical activity during leisure-time (Steeves et al. 2012). Mummery et al. (2005) also reported that meeting the recommended minimal amount of physical activity (30min/day) was not enough to prevent obesity if working time involved a lot of sitting time.

It is suggested, that occupational physical activity may contribute stronger to health than leisure time pursuits (Schofield et al. 2005; Tigbe et al. 2011) as the time frame for occupational activity is longer compared to leisure time on daily basis. Chau et al. (2012) stated that leisure-time sitting would be a stronger predictor of obesity than occupational sitting. However, occupation influences physical activity level at work independently of leisure time, as no occupational influence is seen in leisure time sitting behavior (Chau et al. 2012). Not forgetting the health benefits of leisure time PA for workers with strenuous work, when the occupation does not involve physical activity, the leisure time physical activity contributes strongly on health outcomes (Steeves et al. 2012). Differing perspectives complicate the interpreting of the results from individual studies. Nevertheless, a consensus exists that total accumulation of occupational and non-occupational sitting time is an independent predictor of the risk of obesity beyond physical activity (Chau et al 2012; Healy et al. 2008b; Steeves et al. 2012). Thus sedentary occupation exposures people to physical inactivity along with other domains of life; passive commuting and leisure time habits without physical activity.

4.2 Local contractile activity inhibits the deleterious influence of muscular inactivity

The causal relationship between prolonged sitting and impaired metabolic health has gained support from recent findings. The insulin action was reduced after only 1 day of sitting, even if energy intake was matched to low expenditure (Stephens et al 2011). Even though no significant difference is seen in EE between seated and supine position, the activity-induced changes in heart rate and determinants of respiratory gas exchange indicate greater activation of postural muscles during sitting (Miles-Chan et al. 2014). Light intensity activity, conducted by walking, induced beneficial changes in postprandial lipaemia in healthy men when compared to sitting. However, within this subject group, standing did not change postprandial responses in lipid metabolism. (Miyashita et al. 2013.) The initial metabolic health status might influence on the intensity required to see changes in metabolic parameters. Thorp et al (2014) reported that standing periods interrupting prolonged sitting showed beneficial effects on postprandial blood glucose response in overweight subjects. Healy et al. (2008a) reported a positive association between number of breaks in the sedentary time and the metabolic biomarkers, even though the average intensity of the breaks remained light.

Activation of postural muscles with light intensity is enough to trigger advantageous changes in local biomarkers (Bey & Hamilton 2003; Dunstan et al. 2012a; Duvivier et al. 2013). The postural switch from seated position to standing activates the posture supporting skeletal muscles (Miles-Chan et al. 2014), provoking the local contractility associated with LPL regulation and insulin action (Tremblay et al. 2010; Zderic & Hamilton 2006). The responses on skeletal muscle glucose and fat metabolism, point out the role of local muscular activity in interrupting inactivity periods. Interchanging between sitting and standing resulted in lower blood glucose response in overweight, previously sedentary subjects (Thorp et al. 2014). Two minutes of walking between 20-min sitting periods was enough to induce lower postprandial blood glucose response when compared to uninterrupted sitting (Bailey & Locke 2014). Nygaard et al. (2009)

concluded that the beneficial influences of light-intensity activity appear regardless of the intensity, as slow walking induced similar response than more vigorous walking. The deleterious effects of sedentary behavior are presupposed to be preventable by ordinary light-intensity contractile activity occurring during non-exercise activities (Zderic & Hamilton 2006). Standing time was recently reported to be negatively correlated with all-cause mortality, even though it can be regarded as very light-intensity activity (Katzmarzyk et al. 2013).

4.3 Breaking up prolonged inactivity periods during office work

Physical activity deficiency cannot be replaced just by adding recommended, relatively short bouts of physical exercise on the week schedule if the rest of daily life comprises of sedentary behavior (Finni et al. 2014; Pate et al. 2008; Tremblay et al. 2010.) Interrupting the sedentary time is associated with metabolic risk variables independently from physical activity. The research of physical activity has woken up to identify the characteristics of activity and inactivity periods independently. Findings from experimental studies indicate that other factors than impaired energy status explains the deleterious effects of physical inactivity on metabolic health. Not only does the sedentary time in total count for the metabolic outcomes discussed, but also the manner in which the sedentary time is accumulated during daily life (Healy et al. 2008a; Tikkanen et al. 2013; Toomingas et al. 2012). The positive effect of acute physical activity bout on glucose metabolism and insulin action has been observed in both healthy, normal-weight adults (Nygaard et al. 2009; Peddie et al. 2013) and obese and overweight subjects (Altenburg et al. 2013). Biensø et al. (2012) observed that the physical exercise performed after bed rest did not fully normalize the deleterious effects of prolonged inactivity. Instead, a short physical activity bout breaking up sedentary time stimulated insulin action in skeletal muscles (Dunstan et al. 2012a) resulting in enhanced skeletal muscle glycogen synthesis (Biensø et al. 2012; Peddie et al. 2013) increased insulin sensitivity and reduced insulin secretion (Altenburg et al. 2013; Dunstan et al. 2012a).

In order to facilitate physical activity during occupational sitting, manufacturers have developed dynamic chairs to replace conventional office chairs which are often regarded to be relatively static (Ellegast et al. 2012, Herman Miller 2007; Håg 2013).

Standing desks have been adopted into work places to enable workers to stand instead of sitting. However, the findings from recent investigations are inconsistent about the efficiency of standing instead of sitting, in terms of metabolic health responses. In previously sedentary office workers, postural interchanging between sitting and standing resulted in beneficial changes in blood glucose responses (Thorp et al. 2014). However, Bailey and Locke (2014) recently reported that light activity breaks between sitting periods resulted in reduced blood glucose response but no effect was seen in lipid parameters, or when sitting was interrupted with only standing. Miyashita et al. (2013) reported reduced postprandial lipaemia during brisk walking, yet neither did they observe any response with standing. Conclusions should be made with caution due to the variation in subject characteristics. The total number of activity breaks had stronger beneficial relationship with metabolic variables than total time spent sedentary, time spent at moderate-to-vigorous intensity or mean intensity of the breaks between sedentary periods. (Healy et al. 2008a.) Frequent activity breaks were found to lower the postprandial insulin response more effectively than continuous physical activity (Peddie et al. 2013).

Rising up from a chair gives the body a stimulus wanted to prevent deleterious effects of prolonged inactivity (Hamilton et al. 2007.) It is noteworthy that each non-exercise activity bout, regardless of its intensity or duration, interrupts the sedentary period. However, it is not clear, if any muscular activation, regardless of the intensity, is enough to prevent the deleterious health responses of prolonged inactivity and lack of muscular activation. Long term observation and objective detection of physical inactivity behavior are still required, yet suggestive evidence already exists. (Dunstan et al. 2012b; Marshall & Gyi, 2010.) While waiting for general recommendations for limiting occupational sitting, one should activate muscles regularly during working day. There is growing interest if increasing physical activity during sedentary office work could hinder the unbeneficial metabolic responses. Researchers have applied light activity bouts in order to interrupt prolonged inactivity periods. However if leaving the work station is not possible for an individual, we would want to increase physical activity without involving spatial moving. In the office, sitting by the desk is often replaced by standing when pursuing greater physical activity level. Thus, it is necessary to determine, if we are able to induce muscular activation during passive office work, despite of the static posture.

5 DETECTING SKELETAL MUSCLE ACTIVITY WITH TEXTILE ELECTRODESS EMBEDDED INTO CLOTHING

The need for objective method for detecting muscle activity and inactivity is obvious. The accelerometers, used for detect inactivity time, (Healy et al. 2008b; Weber et al. 2009) offer a feasible tool for detecting the onset and categorizing the intensity of physical activity. The limitation of accelerometers is that they do not always distinguish standing from sitting, or the lowest activity levels where postural changes are not present. Electromyographic (EMG) recording detects electrical signals of skeletal muscles and thus provides important information about the function of the neuromuscular system, but also about the activation and inactivity of the muscle (Enoka 2008, 197).

5.1 Electromyography

The EMG recording is based on the measurement of the difference between detecting electrodes (Stegeman & Hermens 2000). There is as wide range of applications for EMG measurement. Some of them are more research oriented than others, aiming to identify the function and behavioral strategies of motor units and the neuromuscular system. (Farina et al. 2004.) In ergonomics, EMG is widely used to detect the activity patterns and relative stress of specific muscles during work when sustaining a posture for a prolonged period of time is required. (e.g. Zhang et al. 2011.)

Surface EMG (sEMG) detects the electrical activity of superficial muscle or muscle groups as a summation of motor unit action potentials (Farina et al. 2004; Mathiassen et al 1996; Merletti et al. 2009) and thus provides a global measure of action potential activity in the muscles of interest. The level of electromyographic activity is usually expressed in voltages (μV) (Merletti et al. 2009). The conventional, practically valued method, for surface electromyography is so called bipolar electrode recording, which is also considered as a standard method (Marozas et al. 2011; Finni et al. 2007). Bipolar electrode comprises typically of two metal electrodes attached firmly on the skin above the muscle. (Stegeman & Hermens 2000; Enoka 2008, 197.)

5.2 EMG recording in the assessment of physical activity of daily life

There has been growing interest towards the utilization of EMG in long-term recordings. The traditional sEMG recording involves laboratory assessment, thus it is not a feasible method for large study groups, and for investigations of physical activity during daily life. The conventional metal electrodes, attached firmly on the skin are not the most comfortable method from the subject's point of view. (Marozas et al. 2011.) The skin preparation might cause irritation in long-term recordings, whereas the connection between the electrodes and the skin might undergo changes due to drying of the electrodes. Also the detection system; consisting of electrodes, wires and signal capturing system; is rather difficult to apply in field conditions. (Finni et al. 2007.)

Textile electrodes enable long-term recordings. Textile electrodes embedded into clothing have been developed to provide a method for capturing biopotentials from human muscle with electrodes that are more feasible for long-term recording than conventional metal electrodes (Finni et al. 2007; Marozas et al. 2011). Similarly to traditional metal electrodes, textile electrodes are applied on the surface of the skin, above the muscles of interest. Textile electrodes provide a novel method for detecting muscle activity from muscle groups thus textile electrodes provide a global measure of synergist and antagonist muscles activity instead of monitoring the activation pattern of specific muscle. (Finni et al. 2007).

The detecting of daily muscle activity patterns does not require muscle or muscle fiber specific detection of activation, but a global measure of the duration and intensity of skeletal muscle activity (Finni et al. 2007). The advantages of textile electrodes include elastic and flexible properties of the textile (Rattfalt et al. 2007). They are also washable and reusable. The greater surface area of textile electrodes might contribute to lower dependency on electrode placement (Finni et al. 2007). In long-term recordings, it might not be necessary to use electrode gel due to the moisture provided by the skin itself during physical activity, reducing the risk of irritating reactions on the skin (Marozas et al. 2011). So far, textile embedded electrodes have shown to serve well in field conditions and long-term recordings when applied in to electrocardiographic recordings (Marozas et al. 2011) and in recordings of EMG activity of groups of antagonist and synergist muscles (Finni et al. 2007).

6 RESEARCH QUESTIONS AND HYPOTHESES

The present study investigated local muscle activities in lower extremities during occupational sitting in Finnish office workers. The aim of the study was to determine whether or not replacing a traditional office chair with a dynamic chair would show difference in muscle activity patterns during sitting in the lower extremities. No structured consultation regarding '*active sitting'* was given for the subjects, but they were instructed to perform their habitual sitting behavior in the office. We consider the activity pattern as a construct of several features which interfere with the level or intensity of local muscular activation. These features include the amplitude and the frequency of the activity bursts.

The back muscles and upper extremities have been traditionally investigated in the field of ergonomics related to office work (Ellegast et al. 2012). However in the light of inactivity physiology, the leg muscles are relatively large, weight-bearing muscles that play a role in metabolic health with their contribution to energy expenditure and metabolism. Both upper and lower limb muscles can be easily activated during office work performed while sitting. In dynamic chairs, the seat is tilting horizontally and allows greater inclination for forward and backward lean. Thus, when dynamic chairs are used, they can provide propulsion for the chair movement, and presumably for muscle recruitment as well, during sitting.

Ellegast et al. (2012) conducted a study to compare four dynamic chairs with a conventional static office chair. EMG was recorded only from back muscles, whereas the activity in lower extremities was assessed with accelerometer and specialized movement sensor data. They reported greater peak intensities of the activity level for lower extremities than for the back muscles. (Ellegast et al. 2012.) It seems reasonable to investigate the possible influence of the dynamic chair on the muscle activity of lower extremities during prolonged sitting. In the present study we investigated occupational sitting during office work. We recorded muscle activity from thigh and lower leg muscles with three different office chairs, with each chair being used for five office days each. We also applied a novel method for detecting EMG activity with textile embedded electrodes. The EMG shorts were shown feasible method in the long-term recording of muscle activity during daily activities by Finni et al. (2007). No previous work has been conducted using the long version of the EMG garment; recording muscular activation from the shank muscles in addition to the thigh muscles.

1) Does a dynamic office chair decrease muscle inactivity time with respect to a static chair

Not only the lack of physical activity, but increased daily sedentary time itself, has deleterious effects on health. Epidemiological evidence of the relationship between sitting and metabolic health exists (e.g. Edwardson et al. 2012; Hamilton et al. 2007). Physical inactivity, resulting from prolonged sitting periods, is occupying a great portion of the working time, especially in desk-based occupations (e.g. Jans et al. 2007; Ryde et al. 2013). This raises a question if it would be possible to induce muscle activity while sitting, and thus decrease daily inactivity time and hinder the harmful effects of prolonged inactivity. We expected that sitting with a dynamic chair would differ from the activity time recorded with a static office chair.

2) Does a dynamic office chair induce more frequent activity bursts to break up prolonged inactivity periods during sitting when compared to a static chair

Controversial results have been attained about the required intensity of physical activity to prevent unfavorable health implications. However, evidence exists that interrupting inactivity with physical activity should hinder the deleterious effects of prolonged inactivity (Healy et al. 2008a). Moreover, it is the local activation that is thought to trigger the metabolic changes in the skeletal muscle (Bey & Hamilton 2003; Dunstan et al. 2012). Dynamic chairs are assumed to involve skeletal muscles in controlling the seat movement. We deduced that having shorter individual inactivity periods or increased frequency of activity burst in skeletal muscles while sitting would indicate more frequent breaks to interrupt the inactivity periods. We expected to see changes in the length of inactivity periods or in the frequency of activity burst when a static office chair was replaced with a dynamic chair.

3) Does dynamic chair induce greater muscle activity in lower extremities during sitting with respect to a static chair

Dynamic chairs are designed to follow the movements of the sitter freely. The change in the body posture shifts the center of the gravity, and thus, develops a momentum. For example, the seat of dynamic chair is expected to tilt along when the sitter is leaning forward of backwards. (Herman Miller 2007; Håg 2013.) In contrast, conventional office chairs are regarded to be static as they are designed to support the body in various postures that may occur while sitting. The dynamic chairs might enable more fidgeting during sitting and the changes in posture should involve muscular activation. On the other hand, when the seat is tilting, skeletal muscles are recruited in order to stabilize the seat. Thus, greater level of muscle activity during sitting might occur with a dynamic chair with respect to a static office chair.

7 METHODS

7.1 Recruitment procedure

The subjects were recruited among the personnel of The University of Jyväskylä by a public email. The inclusion criteria were that one was committed to office work on a regular basis and did usually work on a personal workstation. In addition, the ability to commit in the study period for three weeks was checked when the individuals contacted the researcher. As a total, eight individuals indicated their interest to attend the study.

Five participants (n_{female} = 4, n_{male} = 1) met the inclusion criteria and were selected according to their availability and suitability (the location of the office close enough to the laboratory to ease the delivery of the chairs). Technical issues occurred during electromyographic recording, causing an interruption in the measurements for the fifth participant. Finally, four female participants completed the 3-week study periods. The characteristics of the subjects are presented in Table 1. The study was approved by the ethics committee of the University of Jyväskylä. The subjects signed an informed consent and permission for photographs to be taken and published for the purposes of presenting the study settings.

	Mean	*SD*
Age (yrs)	33.3	*9.7*
Height (cm)	166.8	*10.8*
BW (kg)	67.5	*12.4*
BMI (kg/m2)	24.1	*2.6*

TABLE 1. Characteristics for the participants (n = 4) of the present study.

7.2 The study protocol

The study period took up to three weeks for each subject (Figure 4). The subjects were asked to sit with three different office chairs while working in the office. Each chair was used for five office days, corresponding to one work week, and the order of the chairs was randomized by a draw.

Before the study period, the subjects were asked to describe their current office chair and to fill out a baseline questionnaire concerning their sitting habits and general information of the level of their daily physical activity (see Appendix 1).

On the first morning of each 5-day period, an office chair, equipped with an accelerometer (ACC) was brought into the subject's office. Oral and written instructions to adjust the dynamic chairs were given in the office. The instructions covered the adjustment of the height of the seat and the arm rests, and the tilt function for the dynamic chairs. The current chair of the subject was serving as a static chair. The subject was assumed to be well accustomed with their current chair and no specific instructions were provided. During the week the subject was asked to perform regular office work and to follow his/hers normal habitual behavior. Each week included one day of electromyographic recordings (EMG day) conducted with specific EMG garments with textile electrodes embedded into clothing. The subject was asked to fill out a questionnaire after each week, asking about their sensations during the week and about the chair at issue (see Appendix 2 for static chair; Appendix 3 for dynamic chairs).

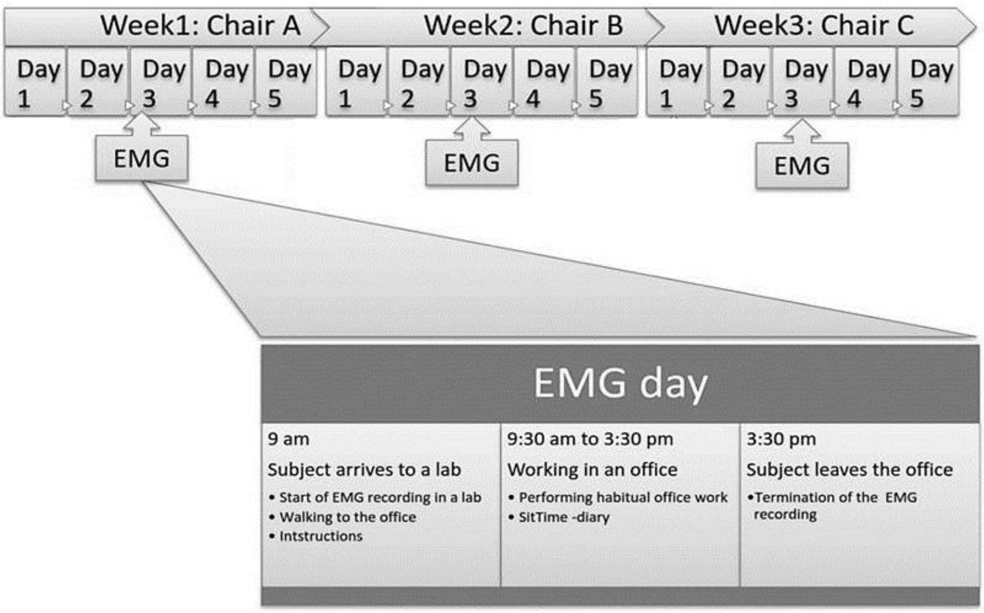

FIGURE 4. The protocol of the present study with a day of EMG recording emphasized. Each subject underwent a study period of 3 equivalent weeks. Subjects sat with 3 different office chairs, one work week with each. In order to detect chair movements during office work, accelerometer (ACC) attached to the chair was recording continuously for the 5-day period. EMG recordings were applied for one office day during each week to detect muscle activity during sitting.

The protocol for the EMG day. The EMG recording was conducted once during each week, resulting with three EMG days for each participant. Prior to the EMG day the subject had sat for at least one day with the chair at issue, and the timing for EMG day was same during the 3-week period for the given subject. The subjects were asked to wear tights embedded with textile electrodes (Figure 5), while working in their office. The subject signed in in the laboratory on the morning of the EMG day, where she was presented with the EMG garment. The recording was set on after the signal was visually checked in online mode. The subject then walked to her office under supervision. The walk went through a straight hallway which was determined to be long enough for 10 strides during gait. The EMG data collected during this walk on a hallway provided a reference measurement for the EMG activity for that day.

In the office, the subject was asked to perform their work as usual. The subject was asked to mark down the times when she rose up and sat back down on the chair at issue in the sitting time -diary (Appendix 4). The subject was also instructed to press a button on the recording module of the EMG tights each time she rose up or sat down. This was done to ease the processing of the EMG signal, as the sitting time would be readily identified from the collected data. Both actions were only to be done when the subject was working at her personal work station and with the chair at issue. Thus when the subject was sitting somewhere else than in her office (i.e. in a meeting, eating lunch), no sitting time was included in the analysis. When leaving the office in the end of the day, the subject returned the tights and the sitting time diary to the researcher.

7.3 The office chairs

In the present study, we asked the participants to use three different chairs during their normal workdays. Two dynamic chairs (Figure 5) were chosen beforehand by the research group: Herman Miller Aeron (HM) and Håg H05 (HG). The third chair, serving as a reference chair for static office chair, was the original chair of the subject (SC). The chairs were labelled with a tag to minimize inappropriate chair movements to be included in the ACC data (i.e. colleagues or cleaning personnel moving the chair in the office) and thus to interfere the results. When a new chair was brought to a subject for the first time, personal guidance and written instructions were given about the mechanisms and adjustments for given chair. The instructions were repeated on the

EMG day to ensure proper invocation of the available adjustments. (Appendix 5) The subjects were asked to maintain their regular sitting habits but encouraged to utilize the dynamic functions of the dynamic chairs. However, with their current chair (SC), they were asked to lock off the tilting function, if there was one. This was made to diminish the variation within the mechanisms of the SC chairs. A more detailed description about the dynamic chairs is represented in the chair instructions which were given to the participants (Appendix 5).

FIGURE 5. Muscular activation during sitting with dynamic office chairs was compared to sitting with a conventional office chair. Two dynamic chairs were applied in this study: a) Herman Miller Aeron® chair (HM): *"The patented Kinemat ® tilt mechanism lets your neck, shoulders, hips, knees, and ankles pivot naturally. The Aeron chair moves effortlessly with your whole body, as if your body were telling the chair what to do."* (Herman Miller 2007.) b) Håg H05 office chair: *"An ergonomic chair is one that follows you naturally into your next seating position. It should heed the body's movements, both small and large, and stay still when the body wants it to. -- HÅG H05 was designed around the theory of balanced rocking."* (Håg 2013.)

7.3.1 Herman Miller Aeron® -office chair

Herman Miller Aeron® chair (Figure 5a), manufactured by Herman Miller (Herman Miller, Inc., Zeeland, Michigan) was designed to support the natural sacral-pelvic curvature and tilt action of the human body. The mechanism of the HM chair is referred as *"kinematic coherence model,"* as it responds to the movement of the body throughout the continuum from reclined position to forward tilt. Tension for the tilt can be adjusted and the seat can be locked to take the tilt mechanism out of use. The height of the seat can be adjusted stepless. For the armrests, the height and the width can be adjusted and additional sacral support, *PostureFit*®, is applied on the backrest. The chair is equipped with wheels enabling spatial movements during sitting. (Herman Miller 2007.)

7.3.2 Håg H05 office chair

The design of the Håg H05 chair (Figure 5b), manufactured by Håg is based on *"dynamic ergonomy"*. The HG chair is designed to follow the balance point of the body and movement of the sitter. The backrest of the chair is fixed to the seat so that the torque is transmitted to the seat when the sitter is leaning backwards. The patented tilt mechanism, *BalancedMovementMechanism*™, allows the seat to tilt back- and forwards freely. The freedom of the forward and backward tilt is 11^{o} and 15^{o}, respectively. The seat cannot be locked but the resistance for the tilt can be adjusted. The footrests ease backward tilting. Other adjustments in the Håg H05 chair include the height of the seat, the height and position of the armrests and the depth of the seat, (that is the distance of the seat from the backrest). Wheels allow the sitter to move around at the office. (Håg 2013.)

7.4 Detecting activity in the office

7.4.1 Assessment and analysis of electromyographic data

EMG garment with textile embedded electrodes were utilized. Textile embedded electrodes (Myontec Ltd, Kuopio, Finland) were utilized to record electromyographic activity from lower limb muscles during an office day. The garment were sportswear alike tights (Figure 6) measuring global muscle activity from superficial muscles of the lower limbs.

EMG shorts manufactured by the same company were tested for validity and shown to be a valid method for long-term physical activity recordings (Finni et al. 2007). The tights contained eight pairs of bipolar textile electrodes, made of conductive yams with silver fibers over the following muscle groups of left and right legs: quadriceps (52.5 cm^2) hamstrings (24 cm^2), calf muscles (51 cm^2) and tibialis anterior muscle (24 cm^2). Additional ground electrodes (58.5 cm^2) were located on the lateral sides of the tights over the iliotibial band. The EMG tights were equipped with portable recording device to store the recorded signals. The module was located on the waistline and the wires connecting the module to electrodes were embedded into the garment (Figure 6).

FIGURE 6. The EMG garments (Myontec LTd, Kupio, Finland) measure surface EMG on four muscle groups of lower extremities. A) The front side of the tights and the textile electrodes shown inside out. B) The portable module collecting the data is attached in the front.

Electrode gel (Redux Electrolyte Creme, Parker Laboratories Inc, Fairfield, NJ, USA) was applied on the electrodes to enhance the contact between the electrodes and the skin. No other skin preparation was done. As the subject dressed the tights, proper placement of the electrodes was confirmed by the researcher visually and by palpating the muscles. The location of the electrodes was determined by the manufacturer of the garment and could not be altered so the electrodes measuring quadriceps and hamstring muscles laid on the distal portion of the muscle (Finni et al. 2007), whereas for calf and tibialis anterior muscles the electrodes were placed on the thickest part of the muscle. In long-term recordings, it might be necessary to momentarily undress the tights e.g. when going to toilet, which might result with a replacement of the electrodes. Slight variation in electrode location should not alter the detected data due to the relatively large detection surface (Finni et al. 2007). The tights were washed by hand with detergent after each measurement day to avoid any traces from the electrolyte gel and subjects' skin from previous measurements.

7.4.2 Analyses of the EMG data

Detection of sitting periods. Pressing a button on the module during recording adds a marker on the EMG signal which can be seen when analyzing the data. Sitting periods were detected from the signal by comparing the sitting time -diary and markers on the signal. All other activity signal was excluded from the data, resulting in a data with only time periods when the subject was sitting at his/her personal working station to be left for further analyzes.

Signal processing and data analyzing. Recording frequency of 1000 Hz was used. Averaging with 0.04 s timeframe was applied to a rectified EMG signal, and this rectified averaged EMG signal (25 Hz) was then stored into a portable module from which it was afterwards imported into a PC. MegaWin- software was used to visually assess the quality of the signal and to synchronize the data with the sitting time -diary.
To provide representative activity data for thigh muscles during sitting, the activity data detected from the quadriceps and hamstring muscles of the left and the right thigh (QH) was averaged in MegaWin -software. This was also performed for the EMG signal of lower leg muscles (LL) of the left and the right shank, tibialis anterior and calf muscles. Finally, the processed data included averaged EMG activity for upper (QH) muscles and lower (LL) leg muscles separately.

MatLab -software was used to calculate the level of EMG activity. Due to the small number of subjects, no statistical analysis was conducted on the data. The data was imported from MegaWin to MatLab-software in ASCII format and a custom algorithm was used for processing the data (Tikkanen et al. 2013). The descriptive EMG variables are represented and explained in Table 2.

TABLE 2. In the present study the EMG variables were classified as temporal variables, describing activity time, and variables that express the level of EMG activity. Variables are presented in the left column. Short explanations are given in the right column of the table.

Temporal EMGvariables (units)	**Description**
Activity time-% (% sit.time) **Activity** (min)	Muscular activity time during sitting Datapoints above inactivity threshold (3μV) Normalized to recording time and the absolute time
Inact-% (% sit.time) **Inacitivity** (min)	Muscular inactivity time during sitting Datapoints below inactivity threshold (3μV) Normalized to sitting time and the absolute time
Activity categories: **Low act** (% sit.time) **Mod act** (% sit.time) **High act** (% sit.time)	The intensity of the activation, in comparison to EMG activity during walking. Normalized to recording time (% sit.time). 3μV≤ **Low activity** ≤ walking intensity Walking ≤ **Moderate activity** ≤ 2*walking 2*walking ≤ **High Activity**
SUM_Inact.period_SUM (% sit.time) and (min)	Summed duration of the 5 longest inactivity periods during single recording. Normalized to recording time and the absolute time
The level of EMG activity	**Description**
averEMG (% of walking)	Average level of EMG activity during sitting (including also inactivity). Normalized to activity during walking.
Mean ampl (% of walking)	The mean amplitude of activation bursts. Normalized to reference gait.
Burst rate (bursts/min)	Rate of the activation bursts
Burst duration (s)	Average duration of activity bursts

Intensity categories were applied to determine the level of muscle activity. Muscle inactivity threshold was set above the signal baseline (3μV). Based on our previous experience, this threshold has been found to be high enough to classify random baseline noise as inactivity, but sensitive enough to incorporate very light muscular contractions, like those occurring during standing, to activity category. To further separate muscle activity intensities, two additional thresholds were used: light-to-moderate (individual average EMG amplitude of normal walking) and moderate-to-high muscle activity threshold (2 x individual EMG amplitude of normal walking) (Figure 7). The threshold value of walking was measured on each EMG day (described in Ch 7.2). From this walking period, average EMG amplitude was analyzed and entered in a template, which was automatically read by the MatLab analysis program.

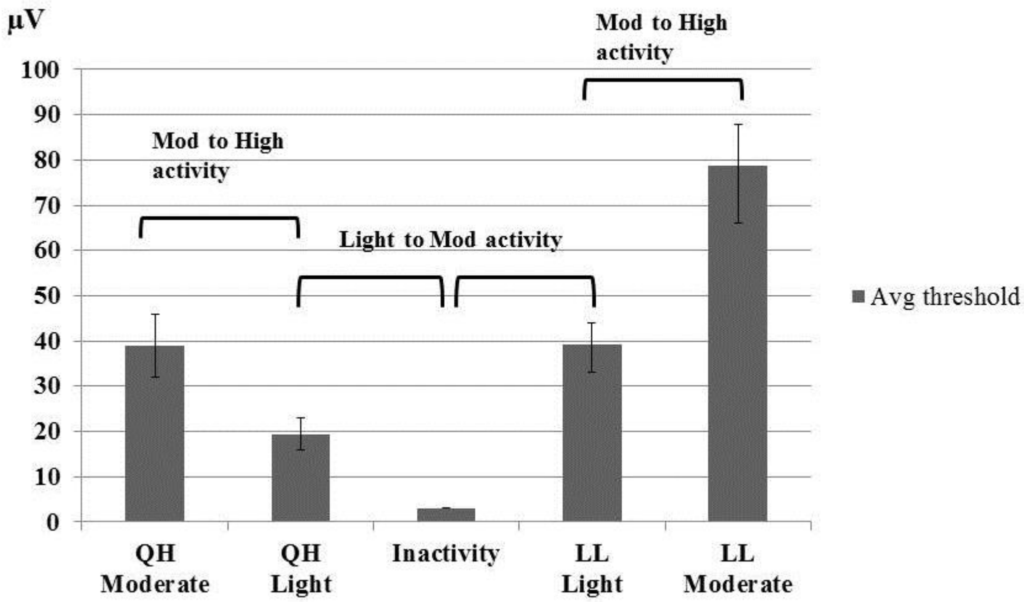

FIGURE 7. Averaged thresholds for each activity category for thigh (QH) and lower leg (LL) muscles. The inactivity threshold was set above the signal baseline (3µV). Light (3µV - walking), moderate (walking - 2x walking) and high (≥ 2x walking) activities were categorized based on a reference walk at laboratory conditions. Reference walk was performed individually on each EMG day to determine day-specific thresholds.

EMG normalization. The absolute level of the muscle activity is expressed in voltages (µV). To enable individual comparison between days, the EMG signal was normalized. The EMG variables describing the level of EMG activity were normalized by using the EMG activity recorded during gait (see Ch 7.2 *The Protocol for the EMG day*) as a reference level. The total sitting time varied between days for the subjects. Therefore the temporal variables of muscle activity were normalized to recording time in order to standardize this variation in daily sitting time in the office. Hence, the results concerning activity time are represented as a percentage of recording time (% rec.time) and the level of activation as a percentage of the EMG activity during gait (% of walking), respectively.

The effect size was evaluated by comparing the dynamic chairs with the SC chair. To evaluate the leg muscle activity when sitting with dynamic chairs (HG and HM chairs), the results were compared to the current chair of the subjects (SC chair). The differences between two dynamic chairs and the SC chair are expressed as percentages of the SC chair value (% of SC). When interpreting the temporal variables a 15 % difference to SC chair was chosen as a threshold value for noticeable effect. For the EMG variables, a 10 % difference with respect to SC chair was highlighted. No comparison between subjects was performed due to the limited amount of data.

7.5 Kinematics of the seat during sitting

Accelerometers (ACC) were utilized for detecting the movements of the seat during sitting. 3D-accelerometer (Gulf Coast Data Concepts Inc, Waveland, MS, USA) detecting g-force impacts within a range of ±6 g, was attached to the chair horizontally, underneath the seat (Figure 8), using equivalent position with each chair. We expected to detect any fidgeting-like movements that might occur during office work: moving around in the office with the chair, backward and forward tilting or rotating around the center. The ACC recording started on the first morning when the subject sat on the chair at issue and was finished after the 5-day measurement period.

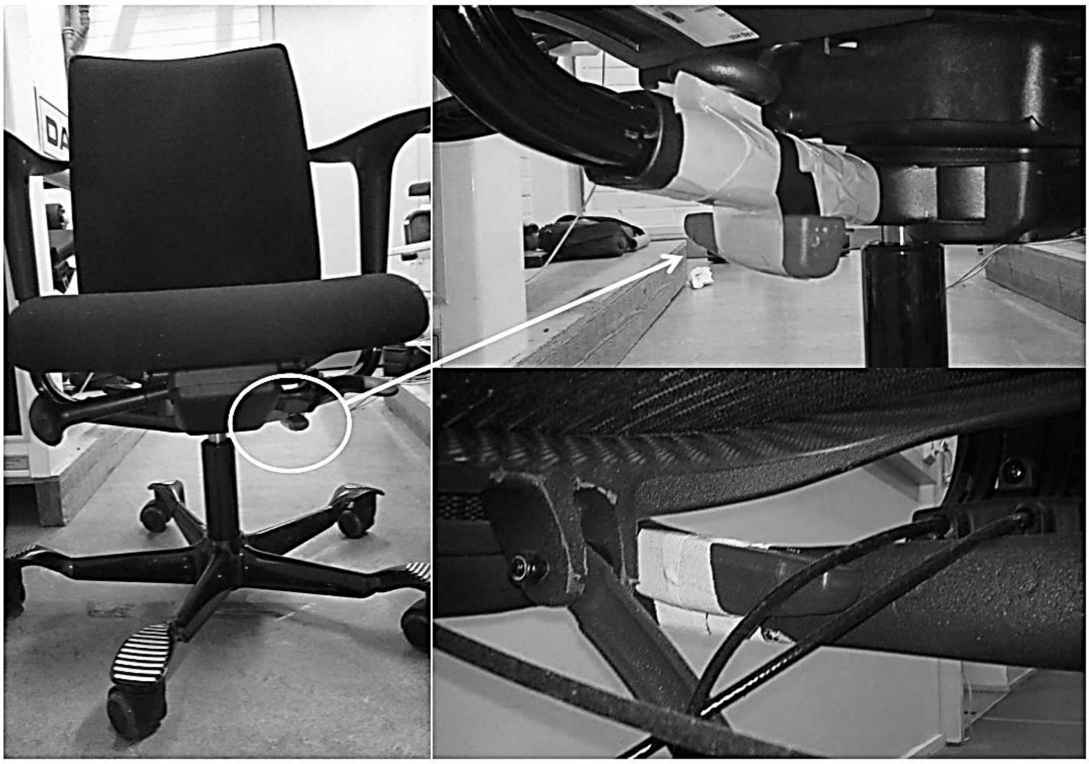

FIGURE 8. 3D-accelerometer (Gulf Coast Data Concepts Inc, Waveland, MS, USA) was attached to record the movements of the chair during sitting. Positioning of the ACC device was on the horizontal plane underneath the seat.

Accelerometry data analysis. Collected ACC data was exported to a PC and processed with custom software. The program composes a resultant vector for the detected 3D data. Data is then band-pass filtered (11-25 Hz) and a threshold filter (0.05g) was applied. The ACC data from the day of EMG measurement was included into further analysis by synchronizing the data with sitting time-diary. At the time of the present study, the analysis process and parameters had not been tested. To analyze the present data we used an existing parameters which has been used to analyze the ACC data during daily activities, such as while at sedentary, walking or running (Laukkanen et al. 2014). During the analyzing process we discovered that this analyzing protocol was not sensitive enough for the present data. Epoc times of 5, 15 and 60 s were tested for the present data. However no difference was observed between the results with these analyses. The used parameters categorized the intensity to sedentary (< 373), light (373-585), moderate (585-881) and vigorous (>881).

7.6 Questionnaires

The participants were presented with four questionnaires in total during the 3-week study period (Appendix 1-3).

7.6.1 Baseline questionnaire

The baseline questionnaire was filled prior to study period. Subjects were asked about their habitual sitting behavior. Daily sitting time was examined by asking the subject to estimate the occupational sitting time apart from working time and apart from leisure-time sitting. The subject was asked if she was consciously performing fidgeting-like movement while sitting in the office and also asked to evaluate their level of physical activity in daily life by asking about their weekly exercise habits. (Appendix 1.)

7.6.2 Post-week questionnaire

After each study week, the subject was asked to recall the past five days when she had been sitting in the office with a chair at issue. Thus the post week questionnaire was filled three times. The subject was asked about how often she adjusted the chair and which features did she usually adjust. The feeling of comfort was examined by asking subject's sensations in different body parts during the 5-day period. When a dynamic chair (HG or HM chair) was at stake, the subject was asked to rate the chair with respect to her regular office chair (SC chair) according to various features of the chairs. (Appendix 2; Appendix 3.)

8 RESULTS

The processed and analyzed EMG data included the office time when the subject sat at his/her personal work station. The results are averaged between the four participants. The effect of the dynamic chairs (HG and HM) is expressed as a percentage with respect to the static chair (SC). The protocol of ACC-data analysis did not produce meaningful results or serve the purposes of the present study, thus no results for seat movement are reported in this section.

8.1 Sitting time during office work

For total, 61.9 hours of sitting was analyzed (Table 3). On average, subjects spent sitting at their personal workstation for about 5 hours and 10 minutes per day, varying from 3.8 hours up to 6.6 hours for per day. Total sitting times recorded for each subject with different chairs are presented in table 3. According to the baseline questionnaires, the subjects estimated their daily sitting time to cover 80 to 95 % of their working time, out of which, about 89 % was spent at the personal work station. Subjects estimated that they usually sit 3 to 4 hours continuously during work.

TABLE 3 Total sitting time at the personal work station accumulated during the day with EMG recording, presented individually. [1)]HG =Hååg, HM =Herman Miller, SC =Static chair

				Chair[(1] Total sitting time [h]		
Subject	**HG [h]**	**HM [h]**	**SC [h]**	**Total [h]**	**Average [h]**	***SD***
1	3,81	5,14	6,11	15,06	5,02	*1,16*
2	5,30	3,82	4,29	13,42	4,47	*0,75*
3	6,63	6,45	4,64	17,72	5,91	*1,10*
4	5,61	3,98	6,08	15,67	5,22	*1,11*
Total [h]	21,35	19,39	21,13	**61,87**		
Average [h]	5,34	4,85	5,28		**5,16**	***1,04***
SD	*1,17*	*1,22*	*0,95*			

8.2 Muscle activity time and inactivity during sitting

Temporal variables of muscle activity during sitting are expressed as percentages of the total sitting time in Table 4. Results are averaged between subjects for each chair; HG, HM indicating the dynamic chairs and SC indicating the static chair. Percentage difference between dynamic chairs and the SC chair is also presented.

In absolute time, the average activity time during sitting for thigh (QH) muscles was 21.8 min ±1.33 min (21.6 min, 20.5 min and 23.2 min with HG, HM chair and SC chair, respectively). Average activity time for LL muscles was 52.4 ± 5.44 min, (52.7 min, 57.7 min and 46.9. min with HG, HM and SC chair, respectively) On average, the thigh muscles (QH) were inactive for 4.8 ± 0.25 h of the time spent sitting whereas the lower leg muscles (LL) were inactive for about 4.3 ± 0.34 h from the total of 5.2 ± 1.04 hours of sitting (Table 4).

The majority of muscle activity during sitting was categorized to be low activity in both muscle groups, corresponding to the intensity below the intensity of walking. Low-intensity activity in QH muscles covered 90 % of overall activity time, whereas for LL muscles corresponding value was 98.8 % of activity time. The percentages of higher intensities remained below 1.0 % of total sitting time (Table 4). The averaged and summed duration of the five longest inactivity periods (SUM_Inact.period) for QH muscles was 24.5 ± 3.17 min and for LL muscles 17.7 ± 3.48 min. With temporal variables, a 15 % difference between chairs was considered as notable change. In shank muscles, dynamic chairs had lower sum of inactivity periods with respect to SC chair (Figure 9).

TABLE 4 Muscle activity time during sitting (% of recording time) averaged between subjects. a) Results being averaged between chairs. b) Chair specific results for temporal variables.

a) TEMPORAL VARIABLES OF MUSCLE ACTIVITY

Thigh Muscles (QH[1])	**Average**	***sd***
Activity-% [% sit time]	7.95	*0.66*
Low act [% sit time]	7.16	*0.75*
Mod act [% sit time]	0.61	*0.09*
High act [% sit time]	0.18	*0.05*
Inact-% [% sit.time]	92.05	*0.66*
SUM_Inact.period [% sit.time][3]	7.89	*0.57*
Lower Leg Muscles (LL[2])		
Activity-% [% sit time]	18.4	*1.63*
Low act [% sit time]	18.18	*1.55*
Mod act [% sit time]	0.19	*0.06*
High act [% sit time]	0.03	*0.02*
Inact-% [% sit.time]	81.6	*1.63*
SUM_Inact.period [% sit.time][3]	5.8	*1.03*

b) CHAIR SPECIFIC RESULTS FOR TEMPORAL VARIABLES

			Chair[4]					
Thigh Muscles (QH(2)	**HG**	***sd***	**% SC**	**HM**	***sd***	**% SC**	**SC**	***sd***
Activity-% [% sit time]	8.67	*6.38*	**10.78**	7.37	*1.52*	**-5.84**	7.82	*2.41*
Low act [% sit time]	7.92	*5.77*	**10.74**	6.41	*1.05*	**-10.37**	7.15	*1.96*
Mod act [% sit time]	0.58	*0.53*	**6.08**	0.72	*0.44*	**32.63**	0.54	*0.38*
High act [% sit time]	0.17	*0.16*	**32.61**	0.24	*0.26*	**81.72**	0.13	*0.11*
Inact-% [% sit.time]	91.33	*6.38*	**-0.91**	92.63	*1.52*	**0.5**	92.18	*2.41*
SUM_Inact.period [% sit.time][3]	8.35	*2.18*	**3.33**	7.25	*1.06*	**-10.25**	8.08	*3.75*
Lower Leg Muscles (LL(3)								
Activity-% [% sit time]	19.36	*3.84*	**17.20***	19.32	*11.07*	**16.95***	16.52	*4.27*
Low act [% sit time]	19.09	*3.68*	**16.52***	19.05	*10.86*	**16.23***	16.39	*4.16*
Mod act [% sit time]	0.23	*0.19*	**93.65**	0.22	*0.20*	**8959**	0.12	*0.11*
High act [% sit time]	0.04	*0.05*	**173.88**	0.05	*0.03*	**254.47**	0.01	*0.02*
Inact-% [% sit.time]	80.64	*3.84*	**-3.4**	80.68	*11.07*	**-3.35**	83.48	*4.27*
SUM_Inact.period [% sit.time][3]	5.37	*2.52*	**-22.93***	5.05	*1.44*	**-27.46***	6.97	*4.31*

[1)] QH = averaged EMG for superficial thigh muscles (Quadriceps and Hamstring muscles)
[2)] LL = averaged EMG for superficial shank muscles (Tibialis anterior and Gastrocnemius muscles)
[3)] The sum of the 5 longest inactivity period
[4)] Chairs HG = Håg05, HM = HermanMiller Aeron and SC = Static chair
[*)] ≥15 % difference to SC chair

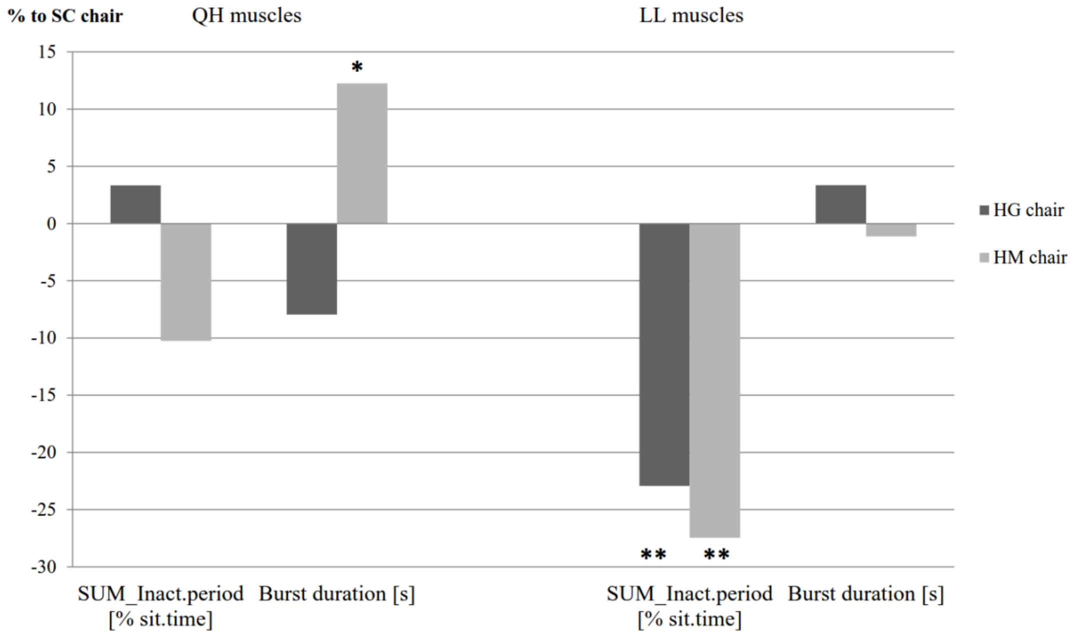

FIGURE 9. The sum of inactivity periods and average duration of activity bursts in upper (QH) and lower (LL) leg muscles. *) For EMG variables (Table 5) > 10 % difference to SC chair was regarded notable. **) > 15 % difference to SC in temporal variables (Table 4).

The level of muscle activity. The results for EMG variables describing the level of muscle activity are represented as a percentage of the activity recorded during the reference walk (% of walking). Increased mean amplitude of muscle activity bursts (Mean ampl) was recorded in leg muscles with both dynamic chairs, when compared to the SC chair. The significance of the change varied between muscle groups and chairs. The increase was most significant in thigh muscles with the HM chair (+23.7 % to SC) and in shank muscles with the HG chair (+15.51 % to SC). Table 5 represents both averaged and chair specific results for EMG variables.

TABLE 5. Thigh muscle and shank muscle EMG activity (normalized to walking) averaged between subjects. a) Results being averaged between chairs. b) Chair specific results for temporal variables.

a) EMG VARIABLES

Thigh Muscles (QH[1])	**Average**	***sd***
averEMG (% of walking)	6.3	*0.43*
Mean ampl [% of walking]	52.62	*5.84*
Burst rate [bursts/min]	19.51	*2.98*
Burst duration [s]	0.23	*0.03*
Lower Leg Muscles (LL[2])		
averEMG (% of walking)	5.17	*0.55*
Mean ampl [% of walking]	21.83	*1.62*
Burst rate [bursts/min]	43.85	*3.33*
Burst duration [s]	0.22	*0.01*

b) CHAIR SPECIFIC RESULTS FOR EMG VARIABLES

				Chair[3]				
Thigh Muscles (QH[1])	**HG**	***sd***	**% SC**	**HM**	***sd***	**% SC**	**SC**	***sd***
averEMG (% of walking)	6.12	*3.17*	**2.16**	6.79	*3.10*	**13.34***	5.99	*2.44*
Mean ampl [% of walking]	50.96	*12.58*	**6.62**	59.11	*19.42*	**23.68***	47.80	*10.50*
Burst rate [bursts/min]	22.56	*15.06*	**16.44***	16.60	*4.64*	**-14.34***	19.37	*5.85*
Burst duration [s]	0.21	*0.04*	**-7.95**	0.26	*0.07*	**4.07**	0.23	*0.07*
Lower Leg Muscles (LL[2])								
averEMG (% of walking)	5.38	*1.32*	**18.27***	5.58	*2.77*	**22.6***	4.55	*1.91*
Mean ampl [% of walking]	23.11	*6.19*	**15.51***	22.38	*3.40*	**11.83***	20.01	*5.03*
Burst rate [bursts/min]	44.61	*12.36*	**10.93***	46.74	*17.17*	**16.23***	40.21	*7.70*
Burst duration [s]	0.23	*0.06*	**3.36**	0.22	*0.05*	**-1.12**	0.22	*0.08*

[1)] QH = averaged EMG for superficial thigh muscles (Quadriceps and Hamstring muscles)
[2)] LL = averaged EMG for superficial shank muscles (Tibialis anterior and Gastrocnemius muscles)
[3)] Chairs HG = Håg05, HM = HermanMiller Aeron and SC = Static chair
[*)] ≥10 % difference to SC chair

In terms of the EMG variables, inconsistent results were seen in QH muscles. In LL muscles, increase was seen in average EMG, mean amplitude and burst rate with both dynamic chairs with respect to SC chair. No notable changes were seen in the duration of individual activity bursts (s), as the differences between chairs remained small and there was no consistency (Table 5). Figure 10 illustrates the difference for both dynamic chairs (HG and HM chairs) with respect to the SC chair for the EMG variables describing the level of muscle activity.

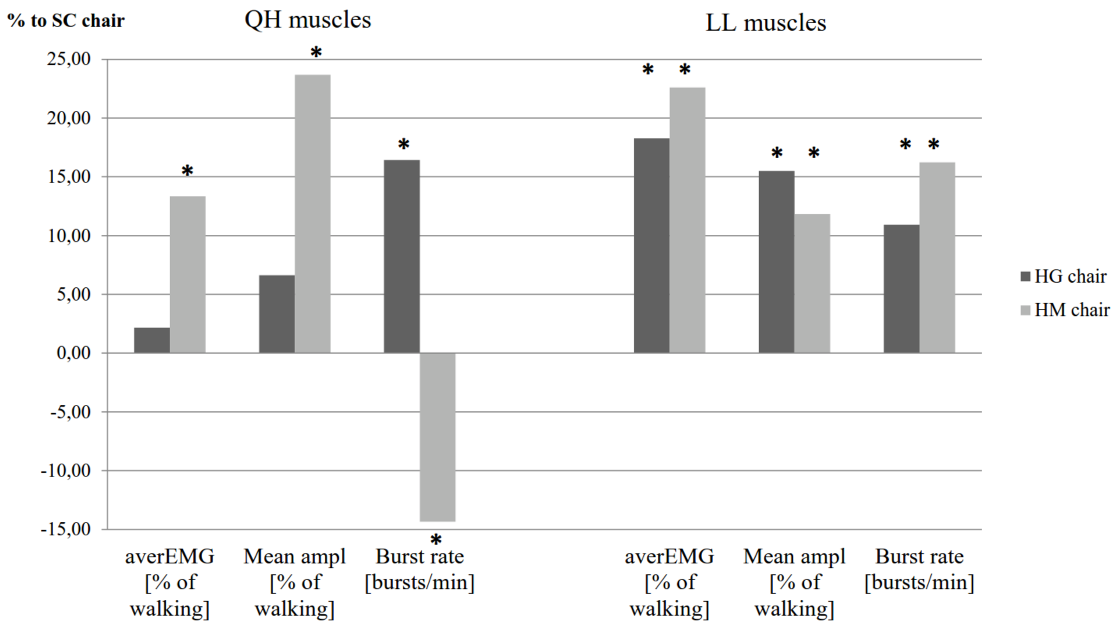

FIGURE 10. Overview of EMG variables for dynamic chairs presented as a %-change to SC chair. Results for thigh muscles (QH) are illustrated on the left side of the figure, whereas the right side of the graph illustrates lower leg muscle (LL) activity. *) a ±10% difference to SC chair is emphasized, being regarded as notable change for EMG variables.

In general, when muscle activity during sitting was individually averaged between chairs, higher amplitude was recorded from thigh muscles with respect to LL muscles for each participant. On the other hand, higher burst rates were observed in shank muscles when compared to thigh muscle activity. (Figure 11.)

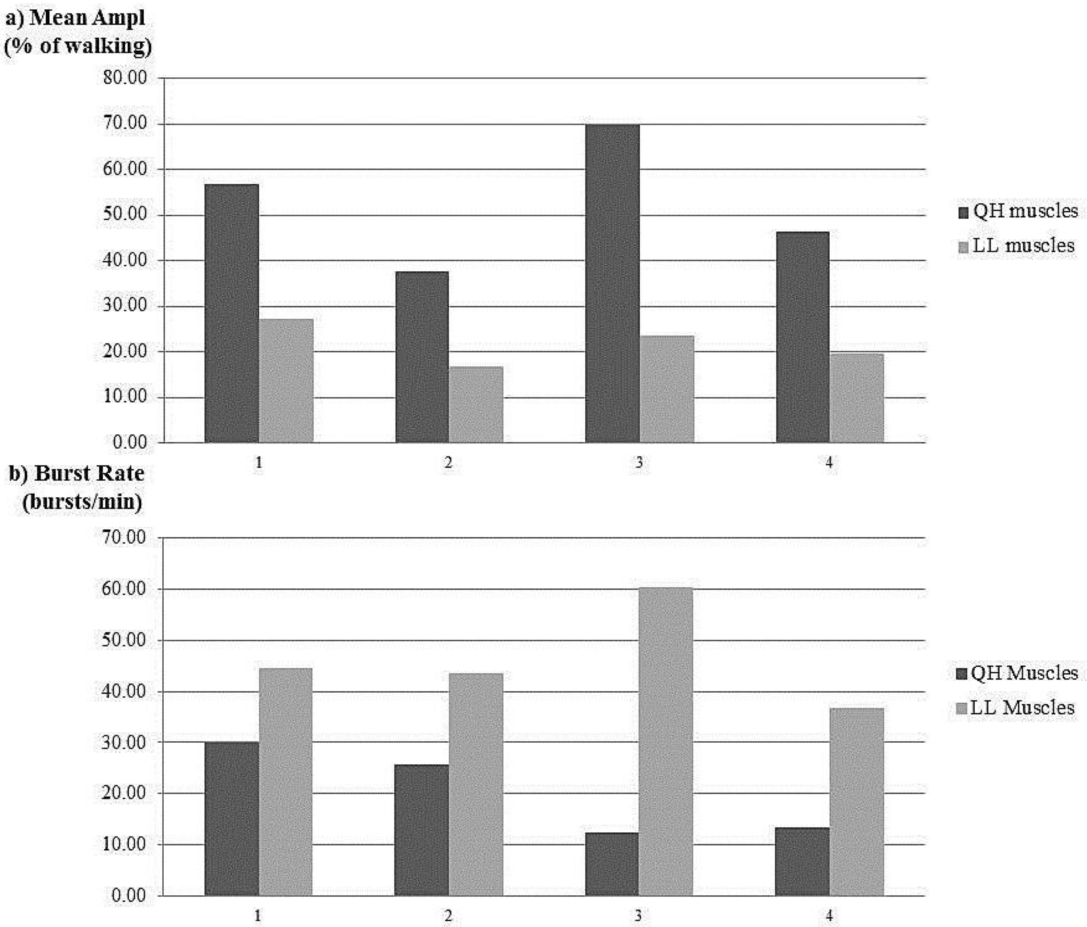

FIGURE 11. EMG activity in lower extremities during occupational sitting in the four subjects (1-4) comprises of various features: a) Mean amplitude of muscle activation normalized to amplitude during walking (% of walking) b) The averaged burst rate (number of bursts per minute). Dark grey illustrates the activity in thigh muscles (QH) whereas the light dark illustrates activity in lower leg muscles (LL). The individual results are averaged between the three chairs (HG, HM and SC) at issue

8.3 Chair characteristics and feeling of comfort during office work

The participants filled a questionnaire and rate the chair at issue after sitting 5 days with each chair. They were asked to recall their feeling of comfort after a day in the office, generalized over past days. This was done in the baseline questionnaire but also after each study week. Combined answers are illustrated in Figure 12.

Three participants out of four rated the dynamic chairs higher than their regular office chair, whereas one did not report any difference between chairs. The most common features valued were the comfort, adjustability and a foot rest, if this was available. When evaluating the feeling of comfort, the subjects divided their body into five regions: the shoulder region, the upper limbs, the back, the thighs and buttocks and the shins and calves (Figure 12).

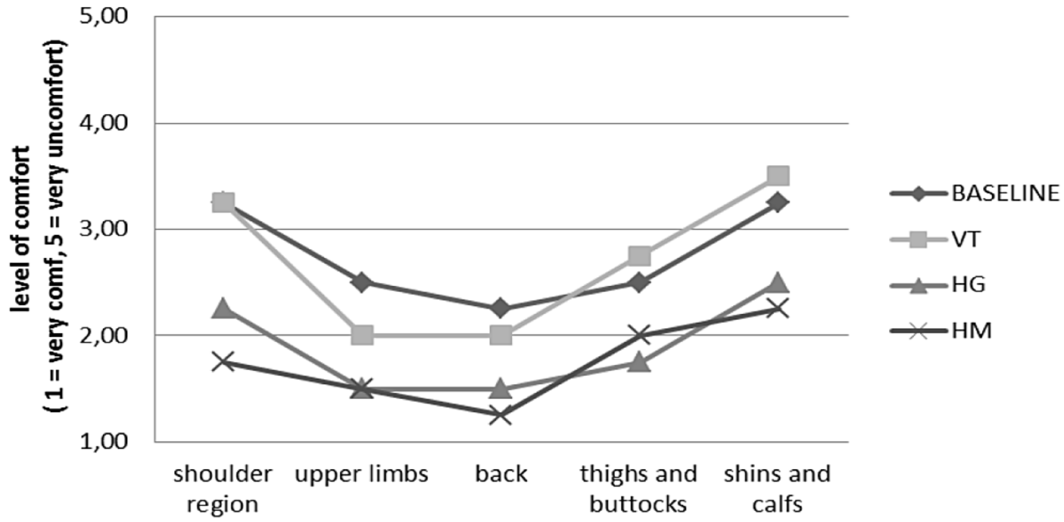

FIGURE 12. The sensations in different body regions after office days were examined with a questionnaire. The subject was asked to recall the past five office days when having sat with a chair at issue and evaluate the feeling of comfort on a scale from 1 to 5, in which level 1 corresponded to very comfortable sensation and 5 to very uncomfortable sensation in a specified region of the body.

9 DISCUSSION

9.1 Muscle activity in lower extremities during sitting in an office

The main finding of the present study was that sitting was highly passive for the weight-bearing muscles. The muscles of lower extremities were inactive for 80 to 90 % of the sitting time depending on the muscle group. When activated, the intensity of muscle activation remained low.

Preliminary evidence from human studies suggests that it is reasonable to encourage office workers to frequently interrupt the prolonged sitting periods with some light-intensity activity during a work day. Pesola et al. (2014) achieved improvements in muscle activity time with counselling office workers to be more active during a work day. This requires changes in subjects' behavior and attitudes. These achievements are to be efficient as long as individuals keep on performing the newly adapted behavior. Metabolic health is related to the local muscular activation, which is hindered by the daily sitting and other prolonged sedentary activities. Metabolic cost of postural maintenance during sitting and standing seems to be highly individual (Miles-Chan et al. 2013) and the metabolic response to acute physical activity bout is subject to initial health status of an individual Miyashita et al. 2013; Thorp et al. 2014).So far, research has not been able to express the initial intensity of physical activity and muscular activation required to achieve health benefits.

Another perspective is to change the environment more encouraging for physical activity. Pursuing more active work environment, standing work desks and dynamic chairs have been applied in offices. It was in our interests to investigate if dynamic chair induce grater muscle activity during seated office work. Due to the great amount of muscle inactivity in thigh muscles, and a low number of subjects, no marked change was seen in terms of muscle activity time during sitting between two dynamic chairs and a static office chair. Yet, a positive trend was seen in lower leg muscle activity when the subjects sat on a dynamic chair, with respect to a static chair. Additionally, according to the sensations in the body after an office day, the participants found sitting with a dynamic chair more comfortable when compared to their current static office chair.

9.2 Activity time in lower extremities during sitting

Great deal of daily inactivity time is accumulated during working hours, especially for individuals working in desk-based occupation (Duncan et al. 2012; Jans et al. 2007: Mummery et al. 2005). In the present study the average daily sitting time in the office was 5.16 hours (± 1.04 h). When averaged between subjects and between the chairs, thigh muscles were inactive for 92 % of the time spent sitting whereas shank muscles were inactive for about 82 % of the sitting time, on average. This corresponded well with the self-evaluation by the subjects. The results seem reasonable according to previous literature. In the office, work is often performed at the personal work station. Office workers are sitting by their desks the majority of the work day. (e.g. Duncan et al. 2012; Jans et al. 2007: Mummery et al. 2005).

No clear evidence of decreased inactivity time was seen in thigh muscles with dynamic chairs (HG, HM) when compared to a static chair (SC). However, a positive trend in muscle activity time was seen in both muscle groups with HG chair and in lower leg muscles with HM chair. Proportional changes remained small due to great percentage of inactivity time (% of recording time). Somewhat systematic change in EMG activity was seen in lower leg muscles (LL) with dynamic chairs with respect to SC chair. In lower leg muscles, the sum value for the 5 longest inactivity periods was lower with the dynamic chairs when compared to SC chair. In thigh muscles, the results were more confusing.

During sitting, body posture is highly supported and no activation is required from the weight-bearing muscles. When not performing any fidgeting-like movements, sitting is almost equivalent for resting in terms of metabolic cost. Similarly, the metabolic requirements of standing still can be regarded equivalent to sitting in spite of the upward posture. (Levine 2000; Miles-Chan et al. 2014.) This illustrates the highly passive nature of office work, and sitting in particular. Workers may sit prolonged periods of time concentrating on their work and spend a considerable portion of their work day sitting at their personal work station. Muscle activity in lower leg muscles was slightly attenuated in the light of temporal variables and EMG variables with dynamic chairs, with respect to a static chair, yet high individual variability existed. Inconsistent results from thigh muscles were left open to interpretations. The lower leg muscles were proportionally more active during sitting and the individual inactivity periods remained shorter. Even though no significant change was seen in inactivity time, this might indicate that the dynamic chairs induced more frequent interruptions between inactivity periods than the conventional static office chairs. Some association might exist between the mechanical features of the chair and the muscle activity induced during sitting. Further research with prolonged observation is required to indicate the possible cause-effect relationship between seat dynamics-related muscle activation during sitting and possible metabolic effects.

9.3 Level of EMG activity during sitting

In terms of intensity categories, the intensity of muscle activity, detected during sitting, remained below walking intensity. Increased mean amplitude of muscle activity bursts (Mean ampl) was recorded in leg muscles with both dynamic chairs, when compared to the SC chair, but the significance of the change varied between muscle groups and chairs being most notable in thigh muscles with HM chair. In lower leg muscles, both dynamic chairs increased the burst rate (number of activation bursts per minute) with respect to SC chair, as hypothesized. Confusing results were attained in thigh muscles. Burst rate increased 18 % with HG chair but slight decrease was seen with HM chair.

The interpretations from the present results have to be made with caution but some speculation can be made leaning on other research conducted on the field of physical activity. Low-intensity activation in skeletal muscles might prevent deleterious metabolic effects resulting from prolonged inactivity periods. The light-intensity activities have shown to be more significant in decreasing sedentary time on daily basis when compared to physical exercise bouts in terms of daily inactivity time (Finni et al. 2014), daily energy expenditure (Pate et al. 2008) and local effects on skeletal muscle metabolism (Duvivier et al. 2013). In previously sedentary office workers, postural interchanging between sitting and standing resulted in beneficial changes in blood glucose responses (Thorp et al. 2014). Whereas some evidence state that the intensity of standing is not enough but at least intensity corresponding to slow walking should be applied in activity bouts (Miyashita et al. 2013; Nygaard et al. 2009). Recent findings indicate that local muscular activation is the key factor signaling the metabolic responses to activity behavior (Miles-Chan et al. 2014; Thorp et al. 2014). The results from the present study give slight support for the hypothesis that dynamic chairs would enhance local muscular activation by increasing the burst rate and thus breaking up the inactivity periods to be shorter, and that way, induce "healthier" sitting. Not only does the sedentary time in total, but also the manner in which the sedentary time is accumulated during daily life (Healy et al. 2008a; Peddie et al. 2013). Yet the proof is limited as no clear statement has been presented at this point about the required intensity of physical activity.

9.4 Distribution of muscle activity between thigh and lower leg muscles during sitting

Physical activity during sitting appears to be greater in lower leg muscles than for thigh muscles. Greater portion of activity time was recorded with each chair for shank muscles. In addition, the shank muscles showed greater activity time and shorter inactivity periods, with respect to thigh muscle activity. Similarly to the present study, Ellegast et al. (2012) also reported higher physical activity during sitting for lower legs with respect to thigh muscles. The tilt-functions of the dynamic chairs used in the present study were designed to follow the body movement, thus the shift in the center of the mass in seated posture. Shifting the posture might not require notable muscular effort from thigh muscles as they are being well supported against the seat. Instead, it can be speculated if the slightly increased activity seen in shank muscles indicates the role of these smaller muscles in fidgeting movements. These have shown to slightly increase the metabolic cost of sitting (Levine et al. 2000). If this was the case, by facilitating fidgeting-like movements to occur during sitting, the dynamic chairs might enable increased muscular activation at some level. In the present study, the mean amplitude of muscle activation was relatively higher in thigh muscles than in shank muscles. Compared to thigh muscles, lower leg muscles are a relatively small muscle group, thus the influence on daily energy expenditure can be assumed to be small. Muscle activation should induce positive responses in local biomarkers in skeletal muscles (Zderic & Hamilton, 2006). The present study did not consider physiological biomarkers or energy expenditure; hence only theoretical speculation can be made.

9.5 Methodological reflection of the present study

The noteworthy limitations of the present study were the small number of subject, limited recording time for EMG activity, inappropriate method for detecting chair movements and lack of observation of the workers while sitting in the office.

No metabolic biomarkers, nor energy expenditure during sitting, were investigated in the present study. Assumptions about the metabolic responses for the changes in muscular activity level can only be made in the light of previous literature. At this point, detecting physical activity on muscular level was determined to produce enough information about the association between chair type and metabolic health. However, if stronger evidence appears about the influence of seat dynamics on muscular activation, future investigations should include metabolic biomarkers to reveal the possible metabolic responses. The assessment of health outcomes would require more subjects, long term observing and more controlled study design.

9.5.1 The course of the present study

Participants enrolled in a 3-week period, during which they sat for 5 office days with 3 different chairs. However, the weeks were not always identical for a subject as the subject might have to leave the office for an extended period of time. In this case, the week was adjusted to include five office days. During these days, it was controlled that the subject had sat at least for one day with each chair before EMG recording. However, as only one day of EMG recording was conducted with each chair, it can be questioned if it was purposeless to include 5 days of sitting with each chair. EMG measurements were always started under supervision to ensure a proper function of the detecting system. Recording was conducted on only one day with each chair. It may be questioned, if this time period was long enough. Averaging activity data for few days might have moderated daily variation in muscle activation, like in different sitting behavior as well.

The number of the subjects remained low. Finally, only four subjects were measured for the whole 3-week study period. It was not purposeful to do statistical analysis and the averaged results should be considered with caution. The reason for the small number of participants partially resulted from scheduling problems. Measurements were started for the fifth subject when technical issues occurred in the detecting system. We did not continue the measurements after the garments were repaired. Due to the small number of subjects, high variation existed in individuals’ sitting behavior, EMG activity characteristics. This might be associated with the inconsistence among the EMG data, in thigh muscles in particular.

9.5.2 Examining sitting in the office

Sitting in the office was not monitored. On the day of EMG recording, the subject was accompanied to the office in the morning, where it was possible to revise the functions of the chair and instruct the use of sitting time -diary. After this, the subjects were left to their office for the day to work. Observation would be time demanding and would need strict protocol, but it would have provided useful information about individual sitting behavior and possible errors in sitting diary.

The activity data should include only sitting but some instant bouts of standing might be included. The subjects were instructed to report each time point when they rose up from the chair and walked away from their personal work station. The possible errors in breaking up the sitting periods from complete EMG data are supposed to be systematical for each subject. The evaluation of EMG data and the analyses were conducted by the same person. The data was visually evaluated by the researcher, thus significant exceptions were excluded. On the other hand, instant bout of standing should not cause misinterpretation to temporal variables in long-term recording and it can be regarded to be common for office work.

Subjects’ own office chair served as a reference chair. Thus, subjects were well accustomed with their own chair. Oral and written instructions were provided for the dynamic chairs, and subjects reported having received similar instructions for their own chair earlier. Each subject had at least one day to become accustomed to a new chair before EMG was recorded but the number of days before EMG days varied between subjects. However, with this small number of subjects the habituation could have been more controlled and constant between subjects. In addition, longer habituation might ensure better utilization of dynamic features.

9.5.3 Textile electrodes served as a novel method for EMG recording

Traditional methods for recording daily activity time (sitting time diaries, accelerometers) do not distinguish local activation on skeletal muscles within passive actions which do not involve movement. Thus these methods do not describe the whole spectrum of physical activity, the lowest quartile of the continuum in particular. The evaluation of the absolute level of EMG activity is difficult as it would require sensitive laboratory methods. Whereas, the method we utilized in the present study, is feasible for estimating the activity level during daily life in real life environment. Novel textile embedded electrodes are showing good validity for long-term recordings thus they provide a feasible tool for detecting muscle activation during daily life (Finni et al. 2007). The present study can be considered as a piloting study for future research. Textile electrodes served well in field conditions and in the long-term recording. The analyzing protocol for the 8-channel EMG data was developed during this study. Thus, useful information about the detecting system and analyzing procedure was achieved during the investigations. As mentioned earlier, wearing off of the electrodes occurred during study period which interrupted the measurements on the first week for the fifth subject. These were traced to result from an abrasion of the electrodes. Textile electrodes are not supposed to wear out in normal use with proper care. However, in this case the electrodes suffered damage because of the detergent used to wash the garments was not suitable.

At the present study, only one size of garments was available. The varying body dimensions appeared to cause problems for electrode placement resulting in interference in the EMG signal. EMG garments seemed to fit for each subject around the thighs but remained loose from the lower leg. This might have resulted in moving of the fabric if the electrodes dried and lost the skin contact. Due to signal interference, data of m. tibialis anterior activity was excluded from the analysis for two individuals. To enable the comparison for shank muscle activity, the data was excluded from all of the measurement for these subjects. If several pieces of garments were available for future studies, this would enable better fit of the garments for each subject, and furthermore, to temper the wearing off of the electrodes due to frequent washing.

9.5.4 Accelerometry data did not show notable results

We were not able to report results concerning the accelerometry data during sitting, neither in absolute g-force impact values or time spent in different intensity categories. The device detects g-force impact within the range of ±6 g that covers the activity intensities of habitual physical activity in children (Laukkanen et al. 2014). In the present study, we did not observe g-force impacts greater than 1 g during sitting. During the analyzing process, we discovered that the level of detected g-force impacts remained minor (<1g). Furthermore, the time spent above the level of 0 g remained below 1 min each day as this short period of light activity was recorded for two subjects, during one office day for each. We concluded that either the ACC device was not sensitive enough to detect the seat movements, the device was placed too close to the center of the chair, in a position where no big movements occur and the parameters used for analyzing the data were not serving the purposes of the present study. The previous might be due to improper positioning of the device. The accelerometers were attached under the seats in order to detect chair movements during sitting. Further piloting might have had revealed both problems but, in order to keep up with the limited time resources, we had to apply existing analyzing template, which might have not been suitable to detect very low levels of g force-impacts. The lack of reportable results should not lead to questioning of the validity of accelerometers for detecting PA. Ellegast et al. (2012) utilized pressure sensors integrated in the seats in addition to accelerometers. It seems that detecting low levels of accelerations requires sensitive methods and benefits from integration of more than one detecting system.

9.6 Conclusions

In the present study we expected to observe that replacing a standard office chair with a chair equipped with dynamic seat characteristics might induce enhanced muscular activation in lower limb muscles and thus decrease the inactivity time in lower extremities during sitting. It was expected that sitting with a dynamic chair would produce different muscle activation in terms of EMG variables with respect to a static chair. We were expecting to record more activity time, and greater amplitude for muscle activation with dynamic chairs. In addition we assumed that the individual activity bursts would encompass longer duration and greater frequency. Alternatively the increased burst rate should results with shorter individual inactivity periods.

No remarkable difference was observed between dynamic chairs and conventional static office chair. Similar conclusion was made by Ellegast et al. (2012). Sitting is highly passive for lower limb muscles, as the lower leg muscles were inactive for 80 %, and thigh muscles even greater proportion, of the sitting time. Our results, however, indicate a slight upturn in the level of shank muscle activity during sitting on a dynamic chair with respect to a static chair. It remains to be solved if the intensity of activity in associated muscles during sitting is high enough to induce metabolic health benefits.

Sitting for prolonged periods of time has unfavorable health implications, but it is inevitable for large portion of working population. While waiting for general recommendations for healthy amount of sitting on a daily basis, we should concentrate on providing bouts of local light-intensity muscular activation regularly during a day. In particular, this should be carried out in occupations that demand workers to remain seated for prolonged periods of time. The design of dynamic office chairs is often stated to encourage movement, thus one might connect this to healthy way of sitting. However, in the light of the present study we should not rely on the seat dynamics alone.

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APPENDIX I Baseline questionnaire

TUOLITUTKIMUS2013_ALKUKYSELY Pvm __/__/2013 ID___

Taustatiedot /Personal information

Ikä/Age _____ v./y.

Sukupuoli

1 mies / male

2 nainen / female

Pituus / Height _____ cm

Paino / Bodyweight _____ kg

Tutkija täyttää:

Säären pituus ____ cm

Reiden pituus ____ cm

1 Työtilat ja työpiste / The current workstation

Arvioi työtiloja ja työpistettä, joissa olet työskennellyt viimeisen 1 kk(30pv) aikana.
Please, evaluate your working environment and your work station for the last 30 days.

1.1 Työskenteletkö suurimman osan ajasta...
For the most of my working time, I am...

1 Yksin, omassa huoneessa / working alone, in a private office
2 Useamman henkilön työhuoneessa / sharing an office with others
3 Laboratoriotiloissa / working in a laboratory
4 Liikuntatiloissa / working in a sport hall etc.
5 Yleisöpalvelutiloissa / working in a public
6 Kotona / working at home
7 Muualla, missä / somewhere else ________________________

1.2 Millaista työtuolia olet pääasiassa käyttänyt viimeisen 1 kk aikana?
What kind of a chair have you been using for last 30 days?

1 Säädettävä työtuoli / an adjustable office chair
2 Työtuoli ilman säätöjä →**siirry kysymykseen 2 /**
an office chair without adjustability → **move to question 2**
3 Satulatuoli / a saddle chair
3 Muu työtuoli, millainen / some other type ___________

1.3 Arvioi kuinka hyvin työtuolisi on säädetty tarpeittesi mukaan.
Evaluate, how well your current working chair is adjusted to meet your needs.

1 Erittäin hyvin / very well
2 Hyvin / well
3 Keskinkertaisesti / fairly
4 Huonosti / poorly
5 Työtuoliani ei ole säädetty / my current chair is not adjusted

1.4 Miten usein säädät työtuoliasi?
How often do you adjust your working chair?

1 Monta kertaa päivässä / several times in a day
2 Kerran päivässä / once in a day
3 Kerran viikossa / once in a week
4 Kerran kuukaudessa tai harvemmin / once in a month
5 En koskaan / I do not adjust my chair

1.5 Oletko käyttänyt tuolisi mahdollista keinuominaisuutta viimeisen 1 kk aikana?
Have you utilized tilting -function of your chair?

1 Kyllä / Yes, I have
2 En / no

1.6 Kuinka usein olet käyttänyt työtuolisi keinuominaisuutta viimeisen 1 kk aikana?
How many times have you utilized the tilting -function

1 Monta kertaa päivässä /several times in a day
2 Kerran päivässä /once in a day
3 Kerran viikossa / once in a week
4 Kerran kuukaudessa tai harvemmin / once in month
5 En koskaan / I have not utilized the tilting function

2 Istumisen määrä / the amount of sitting during office work

Arvioi istumisen määrää viimeisten 1kk (30pv) ajalta. Evaluate the time spent sitting when working during last 30 days

2.1 Kuinka pitkän ajan yleensä työskentelet istuen yhtäjaksoisesti?
In average, for how long are you sitting continuously at work?

1 alle 30 min / less than 30 min
2 30-60 min / 30 to 60 min
3 1-2 tuntia / 1 to 2 h
4 yli 2 tuntia / more than 2 h
5 vaihtelevasti lyhyitä ja pitkiä jaksoja / the duration varies between short and long periods

2.2 a Kuinka paljon viimeisen 1 kk aikana olet keskimäärin istunut koko työajastasi?
In the last 1 month, how much on average have you been sitting of your total working time?

_________% työajasta (0-100%) / % of worktime (0-100%)

2.2 b Kuvaa lyhyesti, millaista työskentelysi on silloin kun en istu / Describe briefly your actions when you are not sitting at work

____

____

2.3 Työaikaisesta istumisajastasi, kuinka paljon viimeisen 1 kk aikana olet keskimäärin istunut omassa työpisteessäsi? In the last 1 month, how much, on average, have you sat at your personal workstation of your accumulated sitting time at work?

_______________% työn aikaisesta istumisesta (0-100%) / % of time spent sitting at work(0-100%)

2.4 Kuinka paljon istut keskimäärin päivässä vapaa-aikana (poislukien työaika)? (ruutu-aika, ruokailu, autolla ajaminen jne.) Kirjoita vastaus kokonaisina tunteina. / For how many hours do you usually sit on your leisure time (h/day)?

__________________ (0-24 h)

3 Istumisen tauottaminen

3.1 Oletko tietoisesti tauottanut pitkiä istumisjaksoja viimeisen 1 kk aikana? Have you deliberately interrupted your sitting during last 30 days?

1 Useita kertoja päivässä
2 Kerran päivässä
3 Harvemmin kuin kerran päivässä
4 En lainkaan → **siirry kysymykseen 3.3** / I have not → **go to question 3.3**
5 En osaa sanoa

3.2 Jos olet tietoisesti tauottanut pitkiä istumisjaksoja, mitä olet pääasiassa tauoilla tehnyt? When deliberately stopping your sitting, what do you usually do?

1 Seisonut istumisen sijaan / stand
2 Kävellyt omassa huoneessa tai käytävillä / walk around
3 Venytellyt tai tehnyt voimisteluliikkeitä / do some stretching
4 Käynyt liikkumassa (esim. kävely, pyöräily, kuntosali) työpäivän aikana / do some physical activity
5 Rentoutunut / relax
6 Muuten, miten?_______________________________________

3.3 Jos et ole pitänyt taukoja, niin mikä siihen on tärkein syy?
What is the principal reason for not having breaks from sitting?

1 Unohdan pitää taukoja / I forget
2 Työ ei salli taukojen pitämistä (esim. kiire)
3 Työyhteisö paheksuisi taukojen pitämistä
4 En tarvitse palautumistaukoja
5 Muu syy, mikä____

4 Arvioi, millainen istuja koet olevasi istuessasi työpisteelläsi.

Ympyröi sinua parhaiten kuvaava vaihtoehto. (1 = vahvasti samaa mieltä, 5 = vahvasti erimieltä) **Yleisesti ottaen, istuessani työpisteelläni, jalkojen heiluttelu, käsien ojentelu tai muuten asennon vaihtelu, on sellaista…**

Evaluate your sitting profile. Choose the alternative best describing you when sitting at your work station. (1 = I strongly agree, 5= I do not agree) **In general, swinging my legs, stretching my arms, changing my position, are functions which…**

1 …I engage automatically	1	2	3	4	5
2 I realize only after I've already engaged to them	1	2	3	4	5
3 …have a conscious role in my daily routines	1	2	3	4	5
4 …I engage often and regularly	1	2	3	4	5

5 Mukavuustuntemukset / Comfortability

Arvioi tuntemuksiasi kehon eri osissa työpäivien lopussa viimeisen 1 kk aikana Evaluate your sensations in different body parts at the end of work days during last 30 days

(1=erittäin mukava, very comf, 5= erittäin epämukava, very uncomf)

Niska-hartiaseutu/ neck, shoulders	1	2	3	4	5
Yläraajat/ upper limbs	1	2	3	4	5
Selkä/ the back	1	2	3	4	5
Reidet, pakarat/ thighs, puttocks	1	2	3	4	5
Sääret, pohkeet/ Shins, calfs	1	2	3	4	5

6 Terveys / Health in general

Miten arvioisit terveydentilaasi ikäisiisi verrattuna? How would you evaluate your health comparing to other people at your age?

1 Erittäin hyvä / very good
2 Melko hyvä
3 Keskinkertainen
4 Melko huono
5 Erittäin huono / very poor

7 Työkyky / Working ability

Oletetaan, että työkykysi on parhaimmillaan saanut 10 pistettä. Minkä pistemäärän antaisit nykyiselle työkyvyllesi?
How would you rate your current working ability?

0 = Täysin työkyvytön/ poor work ability 10 = Työkyky parhaimmillaan/ personal best

0 1 2 3 4 5 6 7 8 9 10

8 Liikunta-aktiivisuus /Physical activity

8.1 Kuinka monena päivänä viikossa olet vapaa-aikanasi fyysisesti aktiivinen yhteensä 30 minuutin ajan päivässä (vähintään 10 min jaksoissa) siten, että sydämen syke kohoaa ainakin jonkin verran (esim. ripeä kävely, pyöräily, puutarhatyöt)**? Laske tähän mukaan myös liikunta työmatkoilla.** Mieti keskimääräistä tilannettasi viimeisen 3 kk (90pv)ajalta.

How many days in a week do you regularly do some physical activity for at least 30min per day? The physical activity bout should last 10min minimum and should raise your heart rate. Evaluate your situation for last 3 months.

1 Harvemmin kuin yhtenä päivänä viikossa / less than 1 day per week
2 1 päivänä viikossa
3 2 päivänä viikossa
4 3 päivänä viikossa
5 4 päivänä viikossa
6 5 päivänä viikossa
7 6 päivänä viikossa
8 7 päivänä viikossa / 7 days in a week

8.2 Kuinka monena päivä viikossa harrastat vapaa-aikanasi raskasta, kestävyystyyppistä liikuntaa vähintään 20 minuuttia kerralla niin että hengitys kiihtyy ja sydämen syke nousee selvästi (esim. hölkkä, pyöräily, hiihto, uinti)**? Laske tähän mukaan myös raskas liikunta työmatkoilla.** Arvioi keskimääräistä tilannettasi viimeisen 3 kk (90pv) ajalta**.**

How many days in a week do you regularly do vigorous physical activity? The exercise bout should last 20min minimum and should raise your heart rate obviously. Evaluate your situation for last 3 months.

1 Harvemmin kuin yhtenä päivänä viikossa / less than 1 day in a week
2 1 päivänä viikossa
3 2 päivänä viikossa
4 3 päivänä viikossa
5 4 päivänä viikossa
6 5 päivänä viikossa
7 6 päivänä viikossa
8 7 päivänä viikossa / 7 days in a week

8.3 Kuinka monena päivänä viikossa teet lihaskuntoharjoittelua
(esim.voimaharjoittelu, kuntopiiri, lihaskuntoliikkeet, joissa kuormitetaan päälihasryhmiä)**?**
Mieti keskimääräistä tilannettasi viimeisen 3 kuukauden ajalta**.**

How many days in a week do you regularly do vigorous physical activity? The exercise bout should last 20min minimum and should raise your heart rate obviously. Evaluate your situation for last 3 months**.**

1 Harvemmin kuin yhtenä päivänä viikossa / less than 1 day in a week
2 1 päivänä viikossa
3 2 päivänä viikossa
4 3-4 päivänä viikossa
5 5 päivänä viikossa tai useammin / 5 days in a week or more

APPENDIX II Post-week questionnaire (static chair)

TUOLITUTKIMUS2013_KYSELY 2 oma tuoli Pvm__/__/2012 ID__

Arvioi työpäiviäsi siltä ajalta, jonka olet viettänyt työpisteelläsi kuluneen viikon aikana.
Evaluate the current week according to the time you have spent working at your personal workstation

1 Miten usein säädit työtuoliasi tämän viikon aikana? / How often, on average, did you adjust your office chair during this week?

1 Monta kertaa päivässä / Many times in a day
2 Kerran päivässä / once in a day
3 Pari kertaa tällä viikolla / few times during this week
4 Kerran tämän viikon aikana / once
5 En koskaan / i did not adjsut the chair → Siirry kysymykseen **3** / go to question **3**

2 Mitä ominaisuuksia säädit työtuolistasi tämän viikon aikana? / What were the functions you adjusted on your chair?

1 Korkeus / the height of the seat
2 Selkänoja / the position of the back rest
3 Käsinojat / the arm rests
4 Muu, mikä? / something else, what? ______________________

3 Onko nykyisessä työtuolissasi keinuominaisuus, joka lukittiin tämän mittausviikon ajaksi?

Your current office chair has a tilt-function, but it was locked during this week.

1 Kyllä / Yes
2 Ei / No

4 Arvioi tuntemuksiasi kehon eri osissa tämän viikon työpäivien lopussa

Evaluate your sensations in different body parts at the end of work days during this week

(1=erittäin mukava, very comf, 5= erittäin epämukava, very uncomf)

Niska-hartiaseutu/ neck, shoulders	1	2	3	4	5
Yläraajat/ upper limbs	1	2	3	4	5
Selkä/ the back	1	2	3	4	5
Reidet, pakarat/ thighs, puttocks	1	2	3	4	5
Sääret, pohkeet/ Shins, calfs	1	2	3	4	5

5 Arvioi kuluvaa viikkoa työtehtäviesi ja työpisteellä viettämäsi ajan perusteella. Evaluate the curret week according to the time you spent at your personal workstation and the task you managed during this week

Kulunut viikko vastasi minulle tavallista työviikkoa. This week was similar to my regular weeks at work

(1 = erittäin hyvin, very much 5=erittäin heikosti, not very similar)

1 2 3 4 5

Mikäli valitsit edellisessä kysymyksessä vaihtoehdot 4 tai 5, valitse seuraavista paras vaihtoehto: Vietin kuluneen viikon aikana tavallista… **/ If you chose 4 or 5, answer the following:** During this week …

1 enemmän aikaa työpisteelläni seisten / I spent more time standing than I usually do

2 enemmän aikaa työpisteelläni istuen / I spent more time sitting than I usually do

3 tavallista vähemmän aikaa omalla työpisteelläni / I spent less time at my personal workstation than I usually do

6 Arvioi fyysistä aktiivisuuttasi kuluneen viikon aikana suhteessa viimeisen 1kk keskimääräiseen aktiivisuuteesi**.** Kuluneen viikon aikana fyysinen aktiivisuuteni vastasi minulle ominaista määrää… / **Evaluate your physical activity during this week according to your monthly physical activity regimens.** The current week was similar to my regular life…

(1= erittäin hyvin, very similar 5=erittäin heikosti, not very similar)

1 2 3 4 5

Mikäli valitsit edellisessä kysymyksessä vaihtoehdot 4 tai 5, miten kulunut viikko poikkesi tavanomaisesta fyysisen aktiivisuutesi suhteen? / If you chose 4 or 5, explain here how did this week differ from your regular physical activity regimens:

____

____

Muuta palautetta tutkimuksesta. / feedback from the study:

____

____

KIITOS vastauksistasi!

APPENDIX III Post-week questionnaire (dynamic chairs)

TUOLITUTKIMUS2012_KYSELY 2 HM/HÅG Pvm__/__/2012 ID__

Arvioi työpäiviäsi siltä ajalta, jonka olet viettänyt työpisteelläsi kuluneen viikon aikana.

Evaluate the current week according to the time you have spent working at your personal workstation

1 Miten usein säädit työtuoliasi tämän viikon aikana? / How often, on average, did you adjust your office chair during this week?

1 Monta kertaa päivässä / Many times in a day
2 Kerran päivässä / once in a day
3 Pari kertaa tällä viikolla / few times during this week
4 Kerran tämän viikon aikana / once
5 En koskaan / i did not adjsut the chair → Siirry kysymykseen **3** / go to question **3**

2 Mitä ominaisuuksia säädit työtuolistasi tämän viikon aikana? / What were the functions you adjusted on your chair?

1 Korkeus / the height of the seat
2 Selkänoja / the position of the back rest
3 Käsinojat / the arm rests
4 Muu, mikä? / something else, what? ______________________

3 Miten paljon käytit tuolin keinu-ominaisuutta kuluneen viikon aikana? (Siirry kysymykseen 5 jos tuolissasi ei ole keinuominaisuutta)/ **How much did you utilize the tilt- function of your chair ?** (If there is not a tilt-function on your chair, go to question 5)

1 Useita kertoja päivässä / several times in a day
2 Kerran päivässä / once in a day
3 Harvemmin kuin kerran päivässä / few times during the week
4 Kerran tämän viikon aikana
5 En lainkaan → **siirry kysymykseen 5** /I did not utilize the function → go to question **5**

4 Miten luonnolliselta tuolin keinu-ominaisuuksien käyttö tuntui? How natural was it for you to utilize the tilt-function?

(1 = Erittäin luonnolliselta / very natural 5 = Ei yhtään luonnolliselta / not at all)

1 2 3 4 5

5 Piditkö tätä tuolia… / Did you consider this chair …

1 Parempana kuin oma nykyinen työtuolisi → **vastaa kysymykseen 5a** / better than your original office chair → **answer question 5a**

2 Huonompana kuin oma nykyinen työtuolisi → **vastaa kysymykseen 5b** / worse than your original office chair → **answer question 5b**

3 Samankaltaisena kuin oma nykyinen työtuolisi → **siirry kysymykseen 6** / similar to your original office chair → **go to question 6**

5a Mitkä ominaisuudet tekivät tuolista paremman kuin nykyinen tuolisi?

Which features made you to prefer this chair

(1 = Erittäin paljon, very much 5= Erittäin vähän, only little)

Väri / the color	1	2	3	4	5
Muotoilu/ the visual look	1	2	3	4	5
Mukavuustuntemus / the comfort	1	2	3	4	5
Tuolin mahdollistama liike / the mobility of the seat	1	2	3	4	5
Säädettävyys/ the adjustability	1	2	3	4	5
Jalkatuki/ foot rest	1	2	3	4	5
Muu, mikä?/ Something else, what?_____________	1	2	3	4	5

5b Mitkä ominaisuudet tekivät tuolista huonomman kuin nykyinen tuolisi?

Which features did you <u>not</u> like in this chair?

(1 = Erittäin paljon, very much 5= Erittäin vähän, only little)

Väri / the color	1	2	3	4	5
Muotoilu/ the visual look	1	2	3	4	5
Mukavuustuntemus / the comfort	1	2	3	4	5
Tuolin mahdollistama liike / the mobility of the seat	1	2	3	4	5
Säädettävyys/ the adjustability	1	2	3	4	5
Jalkatuki/ foot rest	1	2	3	4	5
Muu, mikä?/ Something else, what?_____________	1	2	3	4	5

6 Arvioi tuntemuksiasi kehon eri osissa tämän viikon työpäivien lopussa

Evaluate your sensations in different body parts at the end of work days during this week

(1=erittäin mukava, very comf, 5= erittäin epämukava, very uncomf)

Niska-hartiaseutu/ neck, shoulders	1	2	3	4	5
Yläraajat/ upper limbs	1	2	3	4	5
Selkä/ the back	1	2	3	4	5
Reidet, pakarat/ thighs, puttocks	1	2	3	4	5
Sääret, pohkeet/ Shins, calfs	1	2	3	4	5

7 Arvioi kuluvaa viikkoa työtehtäviesi ja työpisteellä viettämäsi ajan perusteella. Evaluate the curret week according to the time you spent at your personal workstation and the task you managed during this week

Kulunut viikko vastasi minulle tavallista työviikkoa. This week was similar to my regular weeks at work

(1 = erittäin hyvin, very much 5=erittäin heikosti, not very similar)

1 2 3 4 5

Mikäli valitsit edellisessä kysymyksessä vaihtoehdot 4 tai 5, valitse seuraavista paras vaihtoehto: **Vietin kuluneen viikon aikana tavallista… /If you chose 4 or 5, answer the following:** During this week …

1 enemmän aikaa työpisteelläni seisten / I spent more time standing than I usually do

2 enemmän aikaa työpisteelläni istuen / I spent more time sitting than I usually do

3 tavallista vähemmän aikaa omalla työpisteelläni / I spent less time at my personal workstation than I usually do

8 Arvioi fyysistä aktiivisuuttasi kuluneen viikon aikana suhteessa viimeisen 1kk keskimääräiseen aktiivisuuteesi**.** Kuluneen viikon aikana fyysinen aktiivisuuteni vastasi minulle ominaista määrää… **/ Evaluate your physical activity during this week according to your monthly physical activity regimens.** The current week was similar to my regular life…

(1= erittäin hyvin, very similar 5=erittäin heikosti, not very similar)

1 2 3 4 5

Mikäli valitsit edellisessä kysymyksessä vaihtoehdot 4 tai 5, miten kulunut viikko poikkesi tavanomaisesta fyysisen aktiivisuutesi suhteen? / If you chose 4 or 5, explain here how did this week differ from your regular physical activity regimens:

____

____

Muuta palautetta tutkimuksesta. / feedback from the study:

____

____

KIITOS vastauksistasi!

APPENDIX IV Sitting Time -diary

1 Kirjaa päiväkirjaan tietokonetyöpisteeseen tuloaikasi sekä standarditehtävien suoritusaika.

2 Paina moduulin harmaata nappia lyhyesti ja kirjoita ylös kellonaika (sivu 2), kun työskentelyasentosi työpisteesi ääressä muuttuu merkittävästi (istuutuminen, nousu seisomaan) sekä merkittävimmät tekijät, jotka vaikuttivat työskentelyasentoosi ja mahdollisesti EMG-housujen asentoon. (esim. WC-käynti).

3 Kirjaa vielä työpäivän päätteeksi mukavuustuntemukset eri kehonosissa (sivu 1 alaosa).

1 Write down the time when you arrived to your workstation and when you performed the standard tasks

2 Press shortly the button of the module and write down the time (page 2) each time you change your position remarkably (i.e. rising up, sitting down) Write down the most remarkable things that might be relevant (i.e. visiting the toilet might change the position of EMG-electrodes)

3 After the day, answer the questioner about your sensations (on page 1)

Saavuin työpisteelle/ The time when arrived to workstation (klo h : min) _____:_____

Standarditehtävät suoritettiin / The standard tasks (h:min) _____:_____ to _____:_____

1 istuminen, kirjoittaminen / sitting, typing

2 lukeminen, reading

3 nojautuminen taaksepäin, leaning backward

4 eteenpäin kurottaminen / reaching forward

5 keskusteleminen, keinuminen / discussing, rocking

Täytä tämä osio päivän lopuksi / Fill this questionary at the end of the day

Arvioi työpäivän päätteeksi mukavuustuntemuksia eri kehonosissa **asteikolla 1-5** / Evaluate your sensations in different body parts . (1=erittäin mukava, very comf, 5= erittäin epämukava, very uncomf)

Niska-hartiaseutu/ neck, shoulders	1	2	3	4	5
Yläraajat/ upper limbs	1	2	3	4	5
Selkä/ the back	1	2	3	4	5
Reidet, pakarat/ thighs, puttocks	1	2	3	4	5
Sääret, pohkeet/ Shins, calfs	1	2	3	4	5

Changing the posture, press the marker and write down the time (hh:mm HUOM.(ie.WC)

istuutuminen _______ nousu seisomaan_________

sitting down _______ rising up _________

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

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istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

istuutuminen _______ nousu seisomaan _____

APPENDIX V Chair instructions (in Finnish)

HÅG05 (HG) Chair

Istuimen korkeus

- säätö istuimen vasemmalta puolelta
- kevennä istuntaasi säätäessäsi korkeutta
- jalat ylettyvät hyvin jalkatuille sekä lattiaan

Selkänoja

- selkänojan korkeus ja istuinosan etäisyys selkänojasta säädetään samanaikaisesti istuimen oikealta puolelta
- kevennä istuntaasi säätäessäsi tätä ominaisuutta

Käsinojat

- korkeussäätö löytyy käsinojan sisäsyrjältä
- kyynärvarsien tulisi nojata käsinojiin ja hartioiden säilyä rentoina
- voit halutessasi siirtää käsinojat syrjään selkänojan taakse

Jalkatuet

- Jalkatukien otelevyt tarjoavat hyvän tuen jaloille ja
- avustavat sinua nojautumaan taaksepäin

Keinutoiminto eteen- ja taaksepäin

- voit säätää vastuksen voimakkuutta eteen- ja taaksepäin tapahtuvassa keinunnassa
- säätö istuimen alta, oikealta puolelta **+ / -** -vivulla

HermanMiller Aeron (HM) Chair

Istuimen korkeus

- korkeussäätö istuimen oikealta puolelta
- jalkapohjat tukevasti lattiaa vasten

Selkänoja

- alaselälle kohdistuva tuki säädetään istuimen oikealta puolelta

Käsinojat

- korkeussäätö mahdollistuu vapauttamalla käsinojan takana sijaitseva vipu
- kyynärvarret tulisi saada 90^{o} -kulmaan hartiat rentoina

Keinu-toiminto

- Keinumisasteen säätö tapahtuu 2-osaisesta vivusta istuimen vasemmalta puolelta. Säätö on helpointa toteuttaa kun istuimella ei ole painoa. Jos säädät toimintoa istuessasi, keinuttele istuinta samalla kun vaihdat vipujen asentoa.
- Halutessasi vapauttaa istuimen kallistumaan eteenpäin, nosta etummainen vipu ylä-asentoon
- Takimmaisesta vivusta saat säädettyä istuinosan kallistumisen taaksepäin. Istuimen keinuminen vapautuu painamalla vipu ala-asentoon.
- Keinutoiminto lukittuu vaihtamalla etummainen vipu ala-asentoon, ja takimmainen yläasentoon

Vipujen asento, kun keinutoiminto halutaan vapauttaa:
etummainen vipu (vas.) yläasennossa, takimmainen vipu (oik.) ala-asennossa