UMEÅ UNIVERSITY

Interventions for increased physical activity among office workers

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*Det har jag aldrig provat förut,
så det klarar jag säkert!*

*Pippi Långstrump
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Abstract

The positive association between physical activity (PA) and health is well established. Technical developments in modern life have created major changes in our societies and working life, and a growing body of research has identified sedentary behavior (SB) as an independent risk factor for type 2 diabetes, cardiovascular disease, and cancer as well as for premature mortality. To promote health, it is important to find ways to decrease SB and incorporate PA in office settings, for example, by using new office designs and behavioral interventions.

The aim of this thesis was to evaluate two workplace interventions among office workers to determine if these led to increased PA and reduced SB, and to describe underlying factors behind these results.

The thesis is based on two workplace interventions. The first intervention was the Inphact treadmill study, a 13-month randomized controlled trial where treadmill workstations were installed and participants were instructed to use the treadmill for at least one hour per workday. The second intervention was the Active Office Design (AOD) study. This study included a multicomponent PA promoting program, implemented in parallel with an office relocation to either traditional cell offices or to a flex office with activity-based work (ABW). The two groups in the AOD study were followed from 6 months before relocation to 18 months after.

Objectively measured data for SB, PA, and body measurements were collected in both studies. In the Inphact treadmill study, body composition, metabolic outcomes, self-reported energy and stress, and depression and anxiety scores were also measured. In the AOD study, measurements of health and lifestyle, musculoskeletal disorders, workload, work tasks, utilization of possibilities to be active at work, and perceptions of the performed PA promoting program were assessed via questionnaires. In addition, interview data were collected via focus groups and individual interviews. Linear mixed models were used for the main statistical analyses of the quantitative data. To explore the factors that influence SB and PA at work we combined factor analysis of mixed data with multiple linear regression. Interview data were analyzed using qualitative content analysis and a deductive approach to a process evaluation model.

In both study populations, sitting time was low and standing time was high already at baseline, compared to other studies on office workers. In the Inphact treadmill study, the intervention group showed increased walking time during workdays compared to the control group for all follow-up measurements. At the same time, a decrease in moderate-to-vigorous PA (MVPA) was observed in both the intervention and control groups during leisure time. No intervention effects were seen on body measurements, body composition, metabolic outcomes, stress, or anxiety during the treadmill intervention.

In the AOD study, employees relocated to flex offices increased their walking time and MVPA during work hours to a greater extent than those relocated to cell offices, but neither group changed the amount of time spent sitting at work. Contrary to the Inphact treadmill study, no compensatory effects were seen during leisure time. The exploratory analysis resulted in six employee character-types, where the "harmonic and healthy" and "engaged with high workload" tended to sit more and to stand less, while the character type with "high BMI, creative and collaborative work" tended to sit less and stand more. The process evaluation of the intervention revealed a strong culture to encourage PA within the organization and that the intervention was supported by management. The timing of the program was questioned, and activities to support the relocation to the flex office with ABW were requested. Social acceptance for standing and walking at work increased, although the need for the intervention was debated due to the strong culture of facilitating PA at work already in place prior to the study.

In conclusion, we showed long-term increases in PA were achieved in office workers, but the changes did not lead to improvements in body measurements and metabolic balance during the follow-up period. The two studies showed conflicting results regarding compensatory effects during leisure. Participants in the Inphact treadmill study decreased their MVPA during leisure, while no compensatory effects were seen in the AOD-study. Our results suggest a possible ceiling effect for the amount sitting time can be reduced in office workers, and that SB and PA in offices is influenced by many factors, such as organizational culture, physical environment, work tasks, work load and physical comfort. Together, the studies in this thesis confirm the importance of carefully tailored worksite interventions for decreasing SB and increasing PA at work.

Abbreviations

ABW   Activity-Based Work

BMI   Body Mass Index

EE   Energy Expenditure

LPA   Light-intensity Physical Activity

MET   Metabolic Equivalent of Task

MVPA   Moderate to Vigorous Physical Activity

NEAT   Non-Exercise Activity Thermogenesis

OPA   Occupational Physical Activity

PA   Physical Activity

SB   Sedentary Behavior

WHO   World Health Organization

WHP   Worksite Health Promotion

Enkel sammanfattning på svenska

Det är välkänt att fysisk aktivitet är viktig för vår hälsa. Den tekniska utvecklingen i samhället och arbetslivet har inneburit stora förändringar, som gör att vi sitter mer och rör oss mindre. Forskning har visat att stillasittande utgör en oberoende riskfaktor för sjukdomar som typ 2-diabetes, hjärt-kärlsjukdomar och cancer samt förtida död. En stor andel av den arbetande befolkningen arbetar numera på kontor. För att främja hälsa är det viktigt att minska sittandet och öka den fysisk aktiviteten bland kontorsarbetare. Det kan till exempel göras genom ny utformning av kontor och aktiviteter som uppmuntrar till mer rörelse.

Syftet med denna avhandling var att utvärdera två arbetsplatsinterventioner bland kontorsanställda, och undersöka om de ledde till ökad fysisk aktivitet och minskat sittande, samt att beskriva underliggande orsaker till resultaten.

Avhandlingen bygger på två arbetsplatsinterventioner. Inphact-studien var en 13-månaders randomiserad kontrollerad studie, där kontorsarbetare lottades till antingen en interventionsgrupp eller kontrollgrupp. Deltagarna i interventionsgruppen fick ett gåband installerat vid sitt skrivbord, och de ombads att använda gåbandet minst en timme per arbetsdag. Personerna i kontrollgruppen fortsatte arbeta som vanligt. I AOD-studien följdes en organisation som genomförde en flytt av sina tjänstemän till två olika kontorstyper; antingen cellkontor eller ett flexkontor med aktivitetsbaserat arbetssätt. Parallellt med kontorsflytten genomfördes i båda kontoren ett hälsofrämjande program som syftade till att minska sittandet och öka den fysiska aktiviteten, både på arbetstid och fritid. Programmet innehöll föreläsningar, workshop med chefer och kommunikationskampanjer. De två grupperna följdes från 6 månader före flytt till 18 månader efter flytt. Tid i sittande, fysisk aktivitet och kroppsmått undersöktes i båda studierna. I Inphact-studien studerades också metabol funktion, stressnivå, depression och ångest. I AOD-studien fick de anställda svara på enkätfrågor om hälsa och livsstil, kroppsliga besvär, arbetsbelastning, arbetsuppgifter, i vilken grad de använde olika möjligheter att vara fysiskt aktiva på jobbet och vad man tyckte om det genomförda programmet. För att få ytterligare information om faktorer som påverkar rörelse på jobbet, och effekter av det genomförda programmet, genomfördes intervjuer bland de anställda.

Från början satt deltagarna i båda studierna ungefär 50% och stod 40% av arbetstiden, vilket är mindre sittande och mer stående jämfört med andra studier. I Inphact-studien ökade interventionsgruppen sin tid i gående på arbetet vid alla uppföljningar jämfört med kontrollgruppen. Samtidigt observerades en minskning av medel- och högintensiv fysisk aktivitet i båda grupperna under fritiden, framförallt på helger. Det blev inga förändringar av kroppsmått, metabol funktion, upplevd stress, depression eller ångest.

I AOD-studien ökade de som flyttade till flexkontor sin tid i gående och sin medel- och högintensiva aktivitet på arbetet, jämfört med gruppen som flyttade till cellkontor. Det blev inga kompensatoriska effekter utan snarare en tendens till ytterligare ökning av den fysiska aktiviteten under fritiden i båda grupperna. Analys av bakomliggande orsaker till olika rörelsebeteenden på arbetet visade ett komplext samspel mellan olika faktorer. Karaktärstyper som var "harmoniska och friska" och "engagerade med hög arbetsbelastning" tenderade att sitta mer och stå mindre, medan karaktärstypen med "högt BMI med arbetsuppgifter som innebär kreativitet och samarbete" tenderade att sitta mindre och stå mer. Utvärderingen av programmet för ökad fysisk aktivitet i AOD-studien visade att det inom organisationen redan vid studiens start fanns en hälsofrämjande kultur där fysisk aktivitet uppmuntrades. Det fanns också ett starkt stöd från ledningen för det nya programmet. Den sociala acceptansen för att stå och gå på jobbet ökade ytterligare under studiens gång, men behovet av interventionen ifrågasattes till viss del. Tidpunkten för programmet ansågs inte vara optimal för de som flyttade till flexkontor, eftersom det samtidigt fanns ett stort behov av att fokusera på det nya arbetssättet.

Sammanfattningsvis visar studierna att det är möjligt att öka den fysiska aktiviteten bland anställda i kontorsmiljö, men det blev inga förbättringar av kroppsmått eller metabol balans. De två studierna visade olika resultat vad gäller kompensatoriska effekter på fritiden. Interventionsgruppen i Inphact-studien minskade sin medel- och högintensiva aktivitet på fritiden, medan deltagarna i AOD-studien ökade sin aktivitet även på fritiden. Våra resultat tyder på att det kan finnas en takeffekt för minskad tid i sittande bland kontorsarbetare. Studierna visar vidare att fysisk aktivitet bland kontorsarbetare påverkas av många faktorer, såsom organisationskultur, fysisk miljö, arbetsuppgifter och arbetsbelastning. Resultaten visar också på betydelsen av att skräddarsy åtgärdsprogram för att minska sittande och öka fysisk aktivitet på kontorsarbetsplatser.

Original papers

This thesis is based on the following papers:

I. Bergman F, Wahlström V, Stomby A, Otten J, Lanthén E, Renklint R, Waling M, Sörlin A, Boraxxbekk CJ, Wennberg P, Öhberg F, Levine JA, Olsson T. Treadmill workstations in office workers who are overweight or obese: a randomised controlled trial. Lancet Public health. 2018;3(11)e523-e535.

II. Wahlström V, Bergman F, Öhberg F, Eskolsson T, Olsson T, Järvholm LS. Scand J Work Environ health Effects of a multicomponent physical activity promoting program on sedentary behavior, physical activity and body measures: a longitudinal study in different office types. Scand J Work Environ Health. 2019;45(5)493-504.

III. Wahlström V, Olsson D, Öhberg F, Olsson T, Slunga Järvholm L. Underlying factors for sedentary behavior and physical activity among office workers – an exploratory analysis. Manuscript.

IV. Wahlström V, Fjellman-Wiklund A, Harder M, Slunga Järvholm L, Eskilsson T. Implementing a Physical Activity Promoting Program in a flex-office - a process evaluation with a mixed methods design. Submitted.

Preface

Physical activity has enriched my life in many ways. When I was small, my parents often found me standing upside down, or jumping in the door openings. This was probably highly irritating. Nowadays I am less upside down, and I seldom jump in door openings, but physical activity is still important for me to find balance and to feel good.

Becoming a physiotherapist gave me understanding about physical activity as a powerful tool to promote health and treat various illnesses in my clinical work. Spending five years working with occupational safety and health issues in industry gave me experiences of the workplace as an important arena for prevention and health promotion among employees. During these years, the individual perspective, which often dominates practical work in healthcare, was expanded by the organizational perspective. These experiences led to a curiosity and a longing for knowledge.

My clinical practice also gave me insights that individuals with no previous habits for regular exercise could find it difficult to join and follow treatments or worksite interventions focusing on exercise. However, if replacing sitting with light physical activity in everyday life could be enough to affect health, and if this could be incorporated during working hours, this might be a therapeutic window for individuals who are otherwise difficult to reach. The curiosity about this putative opportunity for improved health has been a driver for me when working on this thesis. It has been stimulating to combine my previous work experiences with my PhD studies, and hopefully I can contribute with a small piece of the puzzle to the big picture of knowledge in the field.

Introduction

Human bodies are made for movement, and the positive association between physical activity (PA) and health is well established (1,2). Jeremy Morris (1910-2009) was a British epidemiologist and a pioneer in PA research. He found that the conductors on the London double-decker buses had fewer heart attacks compared to their sedentary driving colleagues. He published his results in the fifties, and since then research on PA has mainly focused on PA on a moderate to vigorous intensity level (3,4). Over the past decade, "the drivers of the buses" have been more in focus, and a growing body of research has identified sedentary behavior (SB) as an independent risk factor for diseases like type 2 diabetes, cardiovascular disease and cancer as well for increased mortality (5–8). Over the last decades the technical developments have led to major changes and challenges in our society and in working life. The service sector has grown bigger, sedentary work in office environments has become more common, and lifestyle related illnesses characterized by overweight and obesity are increasing. To promote health, it is important to find ways to decrease SB and incorporate PA in office settings, for example, by new office designs and by different types of behavioral interventions.

Definitions of physical activity and sedentary behavior

Physical activity is a complex behavior defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (9,10). The term metabolic equivalent of task (MET) is used to quantify the energy expenditure (EE) of an activity. MET is the ratio of a person's working metabolic rate relative to their resting metabolic rate, and 1 MET corresponds to the EE when sitting down resting (1 MET = resting EE 3.5 ml O_2/kg/min) and the MET value increases with increasing PA intensity (Figure 1) (11).

Sedentary behavior (from the Latin word sedere, 'to sit') is defined as any waking behavior in a sitting, reclining or lying posture, characterized by an EE ≤1,5 METs (12). The "SB pattern" is the manner in which SB is accumulated throughout the day or week, i.e. the timing, duration and frequency of sedentary bouts and breaks. "Sedentary time" describes the total amount of SB, e.g. minutes per day or week, while "sedentary bouts" describe periods of uninterrupted sedentary time. "Light-intensity PA" (LPA) is performed at MET levels between 1.50 and 2.99 METs, for example slow walking or light household chores (13). Moderate- intensity PA is performed at approximately 3-6 METs (for example brisk walking), and vigorous-intensity PA is performed at >6 METs, for example running, aerobics, heavy shoveling, or digging. Moderate PA (MPA) and vigorous PA (VPA) are usually presented together as "moderate-to-vigorous PA" (MVPA) (11,13).

Physical activity and energy expenditure

EE has three components; 1) basal metabolic rate, 2) thermic effect of food, and 3) PA. Basal metabolic rate represents approximately 60% of EE and is correlated to body weight. The thermic effect of food, which is "the cost" for digestion, absorption and transportation of nutrients, contributes with about 10% to the total EE (14). PA results in further increased EE and the increase is closely linked to the intensity of the activity. PA has the possibility to increase EE to a great extent, and for extremely physically demanding tasks the EE can increase 10-20 times compared to the resting EE. The variations of human EE are mostly related to the degree of PA (13). Non-exercise activity thermogenesis (NEAT) is the energy expended during non-exercise physical activities. Most NEAT activities, like standing, walking or household chores, are performed at light intensities (14), but there are also NEAT activities that could be performed at more intense levels, like climbing the stairs or cycling to work.
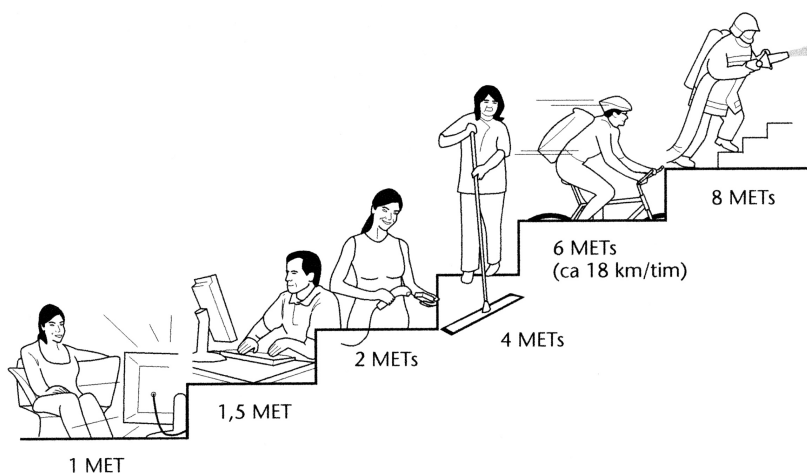
Figure 1. Energy expenditure at rest and for different types of work tasks, described in METs. One MET corresponds to the energy expenditure when sitting down resting. (Data from Ainsworth et.al 1993 (15). Illustrated by Niklas Hofvander.

Physical activity, sedentary behavior, and health

Relations between physical activity, sedentary behavior and health

Physical inactivity is defined as an insufficient PA level to meet present recommendations for PA, for example, adults (≥18 years) not achieving 150 minutes of MVPA per week (12,16). Individuals not reaching the recommended guidelines for MVPA are commonly defined as being physically inactive. Physical inactivity is related to increased risks of several non-communicable diseases, and is considered to be the fourth leading factor for global mortality (1). Adults who are physically inactive have a 20-30% increased risk of all-cause mortality, compared to those meeting the PA guidelines. PA is also important for EE and is critical for maintaining energy balance and weight control and for preventing obesity (16).

MVPA is strongly associated with decreased risks of diabetes, ischemic heart disease, stroke, breast cancer, colon cancer and depression (2,8,16). Several epidemiological studies, both cross-sectional and prospective, have shown SB to be an independent risk factor for premature mortality and diseases like type 2 diabetes, cardiovascular disease, and some types of cancer (6,7,17). The associated risks have shown to be strongest for type 2 diabetes. For example, in a meta-analysis by Biswas et. al., the pooled HR was 1.910 for diabetes type 2 among those with the longest sitting time. This study also showed that the increased risk associated with sedentary time was generally of lower magnitude in persons also participating in PA at higher activity levels compared with persons with lower activity levels (6). Objective measurements of SB and PA have made it possible to quantify the time spent at different activity levels. PA behaviors of different intensity levels are interdependent, and research indicates that replacing sedentary time with LPA could be important in preventing obesity (14). Studies have estimated the health impacts of replacing sedentary time with either LPA or MVPA, by using isotemporal statistical models (18-20). This modeling makes it possible to estimate the theoretical consequences of replacing one behavior with another for a given amount of time (18). In summary, a recurring finding in these studies, is that replacing sedentary time with either LPA or MVPA is beneficial, but greater benefits are gained from MVPA (18-20). As an example, Matthew et al. found that replacing one hour of SB with LPA per day decreased mortality risk by 18%, but replacing one hour of SB with MVPA decreased the mortality risk by 42% (20). Even though isotemporal analyses only provide estimates of potential benefits from reduced SB, they give insights about disease outcomes that are difficult to evaluate in intervention trials. Figure 2. shows the distribution of time during waking hours from an Australian study (5).
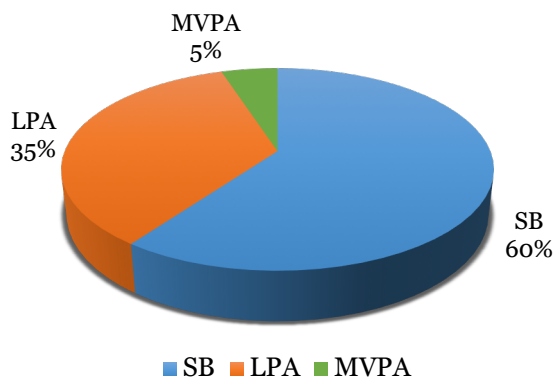

Figure 2. The distribution of time at different activity levels per day during waking hours measured by using accelerometers. SB=Sedentary Behavior, LPA=light physical activity MVPA=moderate-to-vigorous physical activity.

In contrast to the studies identifying SB as an independent risk factor, a meta-analysis from 2016 showed that high levels of MVPA, 60-75 minutes per day,

compared to low levels of MVPA, seemed to eliminate the increased mortality risk associated with high sitting time (21). Thus, even though SB and PA can be described as separate behaviours, there is still not enough evidence to conclude whether they are independent or not in relation to health effects, and more research is needed to understand the interactions between SB and PA (22,23). Epidemiological studies that have examined the health effects of SB have mostly been based on questionnaires, and the levels of activity have mainly focused on questions related to exercise. Some of the studies have also used television-watching time as a surrogate measure of SB. Television-watching time as a measure of SB has, however, been suggested to be associated with confounding due to related snacking behavior (22,24).

Except for the total accumulation of SB, evidence suggests that the way that sitting time is accumulated might be of importance for metabolic function and health (7,25,26). Experimental studies have shown that regularly interrupting sitting with light- or moderate intensity PA resulted in a acute reductions in postprandial glucose and insulin levels in overweight and obese adults (27,28). The suggested explanation for this response is the "inactivity physiology theory", hypothesizing that frequent muscular contractions could prevent the harmful effects that occur from muscular inactivity when sitting (24,29). The effects of breaking up sitting with active breaks seem to be more effective among individuals with lower cardio-respiratory fitness (27,30). Even though the evidence for breaking up SB is inconsistent, it might be of great importance for promoting health. More research is needed to understand how interrupted sitting affects health, both acutely and in the long-term (19,22,24). An epidemiological study, using compositional data analysis found, in agreement with the experimental studies, that replacing SB with LPA could have long-term benefits for glycemic control, and thereby contribute to preventing and managing diabetes (26).

It has proven to be challenging to induce people to embrace physical exercise, and a possible therapeutic option could be to focus more on decreasing SB and increasing LPA for individuals not at all interested in exercise. Increased LPA could thus be of great clinical importance to public health. Despite research progress in the field of SB, the evidence base is insufficient, and more research, preferably based on objectively measurements, is needed to support public health guidelines for sitting time (22,23). Time spent sleeping, sitting, standing, or moving are all interdependent, and to get a complete picture, the contribution of objective measurements will be of high importance in future research.

Overweight, obesity and health
Weight increase is a result of an imbalance between calories consumed and expended, and the energy surplus results in weight gain. In recent decades the prevalence of overweight and obesity has increased steadily, and is described as a pandemic development (1,31). According to the Global Burden of Disease Study, 37% of men and 38% of women have a BMI of 25 or higher (32). In North America, 61% of the adult population are overweight or obese, and in

Europe about 50% are overweight, whereof half of the overweight women are obese (1). Since 2006, the increase in obesity among adults seems to have leveled off in high-income countries, but the increase seems to be continuing in low- and middle-income countries (32,33). In Sweden, the prevalence of obesity has tripled since the 1980s, and 51% of the adult population are reported to be overweight or obese (34). Data from the Västerbotten Intervention Program show that 70% of men and 55% of women between 30 and 60 years in Västerbotten were overweight or obese in 2018. The prevalence of overweight for men and women together between 30 and 60 years has increased from 36% to 38% from 1990 to 2018, while obesity increased from 10% in 1990 to 24% in 2018 (35).

Overweight and obesity are associated with increased risks for diseases like type 2 diabetes, cardiovascular diseases, some types of cancer, Alzheimer's disease, vascular dementia, musculoskeletal disorders, depression and reduced life expectancy. Obesity might also lead to decreased mental health and lower quality of life (33,36). The economic burden of obesity is also extensive. In the US, 21% of total health care costs are related to obesity and obesity-related conditions. In Europe, approximately 23% of medication costs are related to overweight or obesity. A study on "healthy obese" adults showed that obese persons, even if metabolically healthy, showed a four-times greater risk to becoming disabled with declines in functional ability and decreased independence in older ages, compared to normal weight adults with similar health (37). Employers also suffer economic consequenses from obesity-related costs, due to an increase in total absent days and decreased productivity among obese workers (33,38). It is therefore of great importance to reduce and reverse the obesity-related burden globally (1,39).

The increase in overweight and obesity is driven by a complex combination of interacting factors related to diet, personal finances, sociocultural aspects, metabolism, genetics, physical environment, and individual lifestyle behaviors (36). Factors in the global food supply system are considered to lead to overconsumption and a subsequent weight increase. Over time, the availability of energy-dense and more processed food has increased, and such products are often inexpensive and effectively marketed (36,40). There are individual differences in genotypes in relation to metabolism and obesity, but even though these factors play a role, they cannot explain the global increase of obesity prevalence during the last decades (33,36). Socioeconomic factors are also related to the prevalence of obesity. A recent study within the OECD countries showed that educational level was inversely related to overweight and obesity, particularly among women. The McKinsey Global Institute suggests that different sectors (i.e. governments, retailers, consumer-goods companies, restaurants, employers, educators and healthcare providers) all must work together to achieve success (41). In line with this, the World Health Organization (WHO) also claims that different sectors simultaneously should address and contribute to the production, distribution, and marketing of food and shape environments that facilitate possibilities to be physically active (1). Due to the complex interplay between different factors, there is a need to rely less on interventions on the individual level, such as education and personal

responsibility, and instead focus more on environments and norms in society (32), and to combine individual interventions with environmental and societal changes (36).

Due to technological developments in society, PA demands have decreased in different domains, during transportation, leisure, and household chores, as well as at work (5,14,42). Variability in NEAT could be one explanation for different levels of EE in humans, and is dependent on the total activity in all domains. Due to societal developments, the levels of NEAT have decreased. By reassigning time spent sitting to more NEAT activities, daily EE would increase, which would facilitate weight stability and thus imply great benefits to public health (13). Regardless of weight, PA is important for counteracting weight gain and for stabilizing and slowing down health deterioration (37). PA has positive health effects among overweight or obese individuals, and may play a more important role in preventing ill health than previously believed (43,44).

Physical Activity guidelines
PA is recommended to promote health, reduce the risk of chronic diseases, prevent early death, and preserve or improve physical capacity such as fitness and strength (16,45). Guidelines are developed by experts under the Office of Disease Prevention and Health Promotion in the US, and are based on the current scientific evidence (46). The PA guidelines for American adults are presented below:

1. Adults should move more and sit less throughout the day. Some PA is better than none. Adults who sit less and do any amount of MVPA gain some health benefits.
2. For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) a week of vigorous-intensity aerobic PA, or an equivalent combination of MPA- and VPA aerobic activity. Preferably, aerobic activity should be spread throughout the week.
3. Additional health benefits are gained by engaging in PA beyond the equivalent of 300 minutes (5 hours) of MPA activity a week.
4. Adults should also do muscle-strengthening activities of moderate or greater intensity that involve all major muscle groups on 2 or more days a week, because these activities provide additional health benefits.

Because the guidelines mainly focus of PA on a moderate to vigorous level, it is thus possible to be both "physically active" according to guidelines and still accumulate many hours of SB per day. One example could be an office worker who predominantly sits at work, commutes by car, and watches TV each evening, but who jogs for 30 minutes five times per week (47).

The Swedish guidelines for PA are developed by YFA (Yrkesföreningar för fysisk Aktivitet). In addition to the guidelines above, the Swedish guidelines recommend that prolonged sedentary time should be avoided. For those in

sedentary occupations or if sitting a lot during leisure, regular short breaks with some muscle activity for a few minutes are recommended, even if guidelines for PA are met (48).

Measurements of physical activity and sedentary behavior

When measuring PA, there are many aspects to consider. Information about the mode, frequency, duration and intensity of the activity should be captured (11). It could also be of importance to cover the PA in the domains of occupation, domestic work, transportation, and leisure time (11). Over the years PA has mostly been measured subjectively, by using questionnaires, diaries, observations, or interviews (49). However, over the past decade, objective assessments have become more common. Subjective and objective measurements have different strengths and limitations, and depending on the purpose and available resources, different methods can be applied (20,49).

Subjective measurements
Most data that have shown favorable effects from PA have been subjectively reported through questionnaires or diaries. Subjective measurements are suitable when evaluating results on a group level. Questionnaires are mostly used for large populations because they are cheap and quick and easy to use, for both participants and researchers (49). Even though diaries take more time than questionnaires, they are quite easy to complete and useful when measuring small groups. Diaries could cover PA in different domains like, occupational, household chores, transportation, and leisure (11). PA of different intensities might occur in any of these domains, which makes the assessment of total PA important. As an increase in one domain (e.g. occupation) might be compensated for by a decrease in another (e.g. leisure), the assessment of total PA is important in order to see the complete effect (11). Questionnaires might not be not suitable to use among the elderly and children, due to cognitive limitations (49). A drawback of questionnaires is that they need to be population and culture specific, and the likelihood of capturing incidental or lifestyle PA activites in questionnaires is low (11). Another disadvantage for questionnaires and diaries is the risk of low accuracy related to recall and social desirability bias. Social desirability is the tendency of some respondents to report in a way they deem to be more socially accepted than the "true" answer (51). Questionnaires have acceptable validity to capture structured PA, but are less sensitive for detecting small changes in everyday activity (11). Studies have shown self-reported sedentary time to be imprecise and biased compared to objective measurements (52,53). To get a deeper knowledge of the health effects of PA at different intensity levels, the use of objective measurements of SB and PA are key (22,49,50).

Objective measurements
During the last decade the availability and quality of devices for objective measurements of SB and PA have increased rapidly. This is reflected in the proportion of studies using objective measurements, which has increased from

4% in 2006 to 71% in 2016 (54). The choice of devices is driven by the purpose of the study. PA can be assessed by different methods, two of which are briefly described below.

1. Measurements of energy expenditure

Indirect calorimetry, performed in laboratories, is considered as the gold standard when measuring EE (11,55,56). This entails measurements of the oxygen consumed, the carbon dioxide produced and the ventilatory volume.

In combination with measurements of EE in a resting state and the thermic effect of food, the doubly labeled water method can be used to assess PA EE. It is usually performed in free-living conditions for 1-3 weeks (11,56). The method relies on ingestion of two stable isotopes (oxygen-18 and deuterium). The difference in elimination rate between these isotopes is used to calculate the CO_2 production and thereby the total EE over the measurement period. This method is also used in validation studies of accelerometers (57).

2. Movement sensors

Different sensors can be used to assess PA. Motion sensors measure either the number of steps or the changes in speed of movement.

Pedometers count the number of steps, but because they do not capture the intensity, frequency, type, duration, or context of the steps, they give only a crude measure of total PA. However, pedometers are cheap, small, and are preferable used for large groups or in interventions, as a motivator or when participants are supposed to track their own activities (58). Pedometers do not capture non-ambulatory movement like cycling and cannot be used during water sports. Limitations in storage are another drawback for pedometers (59).

Accelerometers give more accurate and reliable data than self-reported assessments (59,60). They provide information about the intensity, frequency and duration of an activity and thereby describe the patterns of activity, and make it possible to measure SB and PA in an accurate way in different domains (58). An accelerometer measures the acceleration of body movement in different directions, and accelerations in three axes can be assessed, namely the vertical (y), the mediolateral (x), and the anterior-posterior (z) axes. Accelerometers can be worn on the hip, thigh, arm, wrist or the back and the different placements provide different kinds of data. Different epoch lengths can be chosen for data collection. An epoch is a pre-determined time frame, within which the raw data are averaged as a mean value. Due to the frequency of variability in movements, the epoch length is age-dependent. For adults, one minute epochs are mostly used, but for children the epoch lengths are shorter (11). The acceleration signals from the different axes are filtered and pre-processed by the monitor, and then "translated" into activity counts. The greater the intensity of the PA, the greater is the acceleration, which is mirrored in activity counts. The activity counts are then classified in different intensity levels, using specific cut-points. The choice of cut-points to determine the activity levels for SB, LPA, and MVPA is dependent on the study population.

However, there is yet no consensus on what cut-points that should be used for different populations, i.e. preschoolers, adults or older adults, and this complicates the comparison between studies (57,61). The choice of epoch length and cut-points could influence the possibility to detect changes within a study (11,60). The disadvantage of accelerometers is that it is labour intensive to administer the measurements, and to process and interpret the data. Other limitations of accelerometers are their inability to measure cycling when worn on the wrist or hip and that most of them cannot be used during water sports. ActiGraph, which is a commonly used accelerometer, has a somewhat limited capacity to capture high-intensity PA, and the intensity patterns "flattens out" due to the pre-filtered data processing (58,62). By using absolute cut-points, individual variations in fitness are not considered in the classification of the intensity levels (63).

To achieve high specificity and sensitivity during data collection with accelerometers, aspects besides the measurement technology also need to be considered. Due to between-days variability, the number of days to measure as well as the valid measurement hours per day are important to consider when planning a study. In large population studies, 1 or 2 days of data per person might be enough, while more days are needed to evaluate the effects of intervention studies. In many studies among office workers, measurements for one week are performed and ≥10 hours of daily wear time is used as a criterion for being eligible for analysis (11,60). For measurements of SB and posture variation, thigh-worn accelerometers are suggested (22,50,58). As the first thigh-worn accelerometer used, ActivPAL has been described as the gold standard for measurements of SB, but in recent studies thigh-worn ActiGraph or Axivity have also been used (64,65). There have been rapid developments of devices as well as software, and artificial intelligence is increasingly used to recognize different activity patterns (66–68).

Body measurements
Anthropometry is the study of measures of the human body, for example weight and height. The most currently used term to define overweight and obesity is body mass index (BMI; body weight in kilograms, divided by height in meters squared) (1,33). Normal weight is defined as a BMI of 18.50-24.99, overweight as 25.00-29.99 and obesity as BMI ≥30.00. BMI as a measure is easy to use and gives a good estimation on a population level. On the individual level, it has its drawbacks because it does not distinguish the type of fat accumulation or body composition (69). Not only weight or BMI, but also the pattern of fat accumulation has been shown to be associated with metabolic risks, and fat distribution around the waist increases the risks of developing high blood pressure, type 2 diabetes and cardiovascular disease (70). Waist circumference and waist-hip ratio are recommended as a complement to measurement of BMI (69), and they are used in both clinical settings and research.

Sedentary behavior and physical activity at work

The technological developments in society have led to decreased physical demands when commuting, during leisure time, in the household, and at work (13,42). Working life has changed, and since the middle of the 20th century, work has been organized and performed in new ways. The service sector has grown bigger and increased from 20% of the US working population in the early 1960s to 43% in 2008. This change is estimated to correspond to a decrease in daily occupational-related EE of 100 calories per day, which accounts for a significant proportion of the mean body weight increase in the U.S. working population (42). Prevention in the work place has previoulsy mostly focused on reducing heavy physical workload, but now there is also a need and challenge to reduce SB and increase PA at work (71).

Sedentary behavior among office workers

Bernardo Ramazzini (1633-1714) was an Italian medical doctor, and he is called "the father of occupational medicine", because he was the first to focus on workers' health in a systematic way. In 1713 he wrote, "The maladies that afflict the clerks…arise from three causes: First constant sitting, secondly the incessant movement of the hand and always in the same direction, thirdly the strain on the mind from the effort not to disfigure the books by errors or cause loss to their employers when they add, subtract, or do other sums in arithmetic" (72). Ramazzini's observations of the constant sitting among office workers have received new attention in recent decades, and international studies show that office workers spend the majority of their time in the office seated (73). In Sweden 84% of the total working population perform computer work, and of those 58% use the computer half of their working hours or more (8). Two Swedish studies using objective measurements showed that office workers spent about 65%-75% of their work day sitting (64,74). Owen et al. (75) describe the importance of further studies focusing on adult SB, with the aim of finding effective methods for behavioral change (19). To be able to develop recommendations and policies regarding occupational SB, there is a need for research that supports workplaces in assessing and controlling the possible risks of excessive sitting (22,76).

Interventions aiming to decrease sedentary behavior in offices

Mackenzie et al. performed a qualitative review that explored factors of importance in office-based interventions, and concluded that studies with multicomponent strategies, including both individual, social, organizational, and environmental approaches, were reported to have the potential to generate more comprehensive and sustainable changes in the workplace (77). A review by Prince et al. showed that multicomponent interventions, including a combination of activities focused on reducing SB, compared to activities focused on increasing PA in terms of exercise, resulted in more promising results regarding sitting time. Interventions based on both physical and social environmental components as well as education, self-monitoring, and motivational measures showed the most promising results (78). Chu et al. also showed that multicomponent interventions, followed by environmental and

educational components in the workplace seem to lead to the greatest reductions in SB (79). Recent multicomponent interventions with sit-stand tables in combination with multilevel strategies have shown reductions in SB, that are likely to lead to clinically relevant improvements in health outcomes like weight and waist circumference (24,65,80,81). Most studies using objective measures of SB and PA show wide interindividual variations. Several factors, like personal health, type of work tasks, and work load might influence SB and PA behavior among office workers, but only a few studies have explored these underlying factors (82–84).

The most common way to intervene in the office environment in order to decrease SB is the use of sit-stand workstations. To further influence PA and facilitate walking during productive work, treadmill workstations could be installed in offices. Studies have shown that short-term use of treadmill workstations could increase the number of steps and the mean EE at work (85,86). Koepp et al. performed a 12-month treadmill intervention among office workers with sedentary jobs and showed increased PA; decreased SB, weight, waist circumference, and systolic blood pressure; and increased high-density lipoprotein cholesterol among participants (87). Two other treadmill studies have also reported decreased sitting time and increased PA in combination with improvements in weight and waist circumference (88,89).

The importance of variation for good health, well-being and performance is usually emphasized in ergonomic recommendations. Three basic aspects of variation can be identified by *how much* an exposure changes over time, *how often* it changes, and to what extent *similar* periods of workload occur during work (90). If replacing sitting by standing in offices, this might create new risks (91). To date most studies on prolonged standing at work are performed in industrial environments and are not directly applicable in office settings. The literature shows contradictory results when it comes to musculoskeletal disorders from standing work, where some studies show increased symptoms when working in a standing position (92,93) and others show decreased symptoms (94,95). An increased risk of varicose veins has been shown among workers with high exposures of standing (92,96). Both metabolic and musculoskeletal aspects of sitting, standing and moving are important to consider when developing future policies, and more evidence regarding dose-response relationships of SB, PA, and health is needed to build a platform for evidence-based policies (22,76). There are yet no national or international ergonomic or occupational safety and health policies targeting occupational SB, although numerous policy documents mention the risk of excessive sitting (76). The knowledge of the long-term efficacy and cost-effectiveness of interventions aiming to decrease SB and increase PA in office settings is also limited. Further, there is a need to understand how and why interventions work. Intervention studies in organizations could be seen as complex interventions, meaning that the interventions usually contain several interacting components. The interacting components should be considered by evaluators (97). Examining the processes behind the results of an intervention study could lead to more knowledge of how and why interventions bring about change and why they

sometimes fail. Based on that, the need for process evaluations (PEs) of interventions studies is highlighted (24,77,98,99).

Development and evaluation of SB interventions
During the development and implementation of an organizational intervention, the assessment of local needs, understanding of local barriers and facilitators, the use of participatory or collaborative approaches, and the use of theoretical models as a basis for intervention strategies are of importance (77,100,101). Outcome evaluations of a broad range of outcomes are recommended, and in addition to measures of SB and PA, aspects like musculoskeletal symptoms, productivity, and organizational culture are suggested as important targets. To date, most intervention studies on SB and PA in offices present inadequate information about contextual factors, the ongoing health-promoting initiatives in the workplace, the physical work environment, the hierarchical structures, and the organizational culture (77).

To assess the contextual factors and program fidelity in interventions, process evaluations of interventions are warranted (77,97,102). PEs of complex interventions aim to analyze the implementation strategy in the studied organization, and recently updated guidance from the Medical Research Council in the UK describes how PEs "can be used to asses fidelity and quality of implementation, clarify causal mechanisms and identify contextual factors associated with variation in outcomes" (101). The PE provides a deeper understanding of hindering and facilitating factors for the desired outcome, and is recommended as a complement to the primary outcomes, because it helps to put results and effect sizes into context (77,101,103,104). Gathering rich contextual and process-oriented data will increase the understanding of factors that promote or hinder intervention effectiveness, and this will enhance the efficiency in implementation research (77,105). In the field of SB in office workplaces as well as in other sectors, there are variations in workplace context, i.e. in terms of workplace sector, organizational culture, and structure. Depending on the context, an intervention might lead to different results because interventions that are effective in one setting, might not be effective in another. Thus, there is a need for studies that facilitate the knowledge of how to transfer intervention results to different office settings (77).

The workplace as an arena for health promotion
Due to the high prevalence of chronic diseases along with increased costs for public health and decreased productivity at the workplace, there is a growing emphasis on the promotion of health and active lifestyles (33,106,107). The WHO has for many years advocated an approach to target health promotion in different settings (108). By stimulating healthy behaviors in workplaces, large groups of the adult populations can be reached, which is of importance for both organizations and public health (1,79,108). Because there are possibilities for controlling both environmental, individual, and organizational-level activities in the workplace, the workplace is considered to be an important and influential and important setting for health-promotion activities (5,102,109). Due to the

demographic developments, there will be future needs to keep the ageing population working, and this will further increase the need to prevent chronic diseases among the working population (106). Work-site health promotion (WHP) supports primary, secondary, and tertiary prevention efforts (107). Primary prevention is directed to employees who are generally healthy, and the interventions aim to maintain good health or to prevent or delay disease progression. Secondary prevention activities are directed to employees who are at high risk of becoming ill, due to lifestyle behaviors. Sometimes WHP also includes tertiary prevention, which includes support for disease management, such as musculoskeletal disorders or depression (107)(Figure 3). WHP can target different lifestyle behaviors like diet, tobacco use, stress or PA. Health promotion programs have shown favorable results for weight-related disorders, while interventions only targeting PA show more inconclusive results, compared to those including both diet and PA (106,109). High-quality WHP programs are likely to improve health and productivity among workers, and WHP might also be of importance for being seen as an attractive employer in the competition for labor (107). It seems like interventions consisting of multiple components, are more likely to be effective compared to single-component interventions (106,107,110), and this also seems to be the case in interventions aiming to decrease SB and increase PA in workplaces (78).
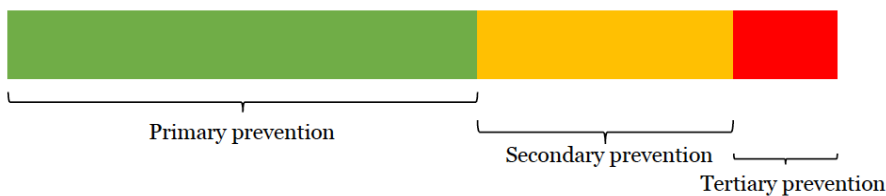
Figure 3. Different types of program efforts in WHP programs (107).

There is still a need for well-designed, theory-based health promotion research in order to understand the effectiveness of workplace interventions and to be able to identify what types of interventions that seems to be the most promising. To date, there is uncertainty about what components, dose, and frequency to recommend for interventions aiming to decrease SB, which makes it difficult to formulate recommendations for organizations (76,106). To date, the knowledge about the effects of environmental modification on SB in office settings, like sit-stand tables or different types of office design is limited, and the effects from environmental approaches are important in future research (102).

Flex offices with activity-based work
Flex offices with activity-based work (ABW) have increased in popularity in recent years (111). The main reasons for relocating to a flex office are usually to reduce facility costs and suggested facilitation of communication and creativity within the organization (111,112). Fifteen percent of Swedish office workers reported that they did not have a personal workstation in 2017 (113), as is the case in flex offices with ABW. The basis of the interior design in flex offices is to have workstations in open landscape areas. In addition, the office often

provides some workstations in cell offices, small and large meeting rooms, break-out spaces, and lounge areas or other areas needed in the organization (114,115). The term ABW does not refer to PA in the office, but to work-task performance. In flex offices with ABW, employees have shared workstations, and everybody uses wireless computers. The goal is to work without papers. Different spaces in the office are designed to meet different needs, and employees are supposed to choose workstation depending on the current work task. It is well known that the traditional open-plan offices have adverse effects on wellbeing and health (111,112), but the knowledge of the effects on different health aspects related to flex office environments is still limited (114). Theoretically it appears likely that flex offices with ABW can increase PA at work. The different types of environmental spaces combined with shared workstations might increase both breaks from sitting and walking time (64,116). Even though environmental changes are highlighted as a possibility to increase PA in offices, only a few studies have been performed. Table 1 shows the design and results of six studies that have evaluated SB and PA in relation to different office designs. Three of them have evaluated SB and PA in offices with "active design" where employees have personal workstations, while the office environment is developed to facilitate PA by i.e. centrally placed stairs and sit-stand tables (117-119). Three of the studies have evaluated flex offices with ABW, where employees have shared workstations (64,116,120). A Swedish study (64) followed four office sites relocating to flex offices with ABW, and a comparison site. In that study, employees had sit-stand tables already at baseline, and limited effects on occupational total sitting or sitting accumulation patterns after relocation were seen, although more walking time was observed. Heterogeneous results were seen across sites, which implies that specific determinants of sitting behavior in flex offices need further focus (64).

Table 1. Studies evaluating sedentary behaviour and physical activity in offices with a "Active design" or flex offices with ABW

Author, year, country	Study type and design	Setting and population	Measures of SB and PA	Anthropometr metabolic mea
Gorman 2013 (117) Canada	Evaluation of a "Active building design" Pre-post design 3-6 months follow-up	Office workers in an academic PA research centre n=24	Thigh worn ActivPAL	Height, weigh fasting blood glucose, HDL, cholesterol an triglycerids
Jancey 2016 (118) Australia	Evaluation of a "Active building design" Pre-post design 4 months follow up	Office workers in advocacy service and product agreement associations n=42	Hip worn ActiGraph	Height, weigh at baseline
Engelen 2017 (119) Australia	Evaluation of a "Active building design" Pre-post design 4 months follow up	Office workers in a University Campus n=118 baseline n=62 pre-post	Self-reported sitting, standing and walking time. Self-reported musculoskeletal disorders	
Hallman 2017 (64) Sweden	Evaluation of a flex offices with ABW. Pre-post design with comparison group. 12 months follow up	Office workers in a governmental agency n=110 (I: 79 C:31)	Thigh worn ActiGraph	
Foley 2017 (116) Australia	Evaluation of a flex office with ABW Non-randomized cross over design, 4-weeks trial	Office workers in a commercial building n=88	Hip worn ActiGraph and self-reported SB and PA.	Self-reported weight and BM baseline
Arundell 2018 (120) Australia	Evaluation of a flex office with ABW Pre-post design with a comparison group 6-9 months follow up	Office workers in a municipal workplace n=146 (I: 82 C:64)	Hip worn ActiGraph	

[a]ABW = Activity-based work
[b]MPA = Moderate physical activity
[c]SB = Sedentary Behavior
[d]LPA = Light Physical Activity
[e]MVPA = Moderate to vigorous physical activity

Rationale of the thesis

Work-site interventions among office workers show promising results to reduce SB, and they seem to have a clinically meaningful effect on mediators to improving health. However, there is still a need for more studies of high quality and long-term follow-up, evaluating the impact of environmental factors in the office, such as office design and office type. More knowledge is also needed on how successful interventions should be designed to fit the contextual situation, and to stimulate behaviors towards less sitting and more movement in the office.

For this purpose, two workplace interventions were performed and evaluated. The first intervention was the Inphact treadmill study. This was a longitudinal randomized controlled trial, implementing treadmill workstations among office workers. The second intervention was the Active Office Design (AOD) study. This study included a multicomponent PA-promoting program, implemented in parallel with an office relocation to two different office types, either traditional cell offices or a flex office with ABW.

Aims

The overarching aim of this thesis was to evaluate two workplace interventions among office workers, to clarify if these led to increased PA and reduced SB, and to describe the underlying factors behind these results.

Specific aims

Determine if the interventions led to changes in objectively measured SB and PA at work. If changes in SB and PA at work were seen, we aimed to determine if there were compensatory effects during leisure time.

Determine if the PA promoting program influenced self-reported behaviors, social acceptance, and/or culture for SB and PA in the workplace.

Determine if the interventions led to positive effects on health outcomes like body measurements, body composition and metabolic function.

Determine the underlying factors that might be related to SB and PA among office workers.

Determine the factors during the implementation process that might have affected the interventions effects.

Hypotheses

In the Inphact treadmill study, we hypothesized that the daily time spent walking, standing and in LPA would increase and that SB would decrease in the intervention group using the treadmill workstations compared to the control group with regular office work.

In the AOD study, we hypothesized a decrease in SB and an increase in breaks from prolonged sitting and increased PA both in the cell office and the flex office group, but we expected larger effects to occur in the flex office group.

For both studies we hypothesized that the increased PA would lead to positive effects on health outcomes like body measurements, anthropometry, body composition and metabolic function.

Materials and Methods

This thesis is based on two research projects, the Inphact treadmill study and the AOD study. Table 2 shows the study design and type of data in paper I–IV.

	Treadmill study	AOD study		
	Paper I	Paper II	Paper III	Paper IV
Table 2. An overview of study designs and analyzed measures in paper I-IV				
Study design	RCT	Longitudinal case study with control group	Cross sectional	Longitudinal mixed methods
Number of participants	80	86	53	152/70*
Objective measures				
SB and PA	x	x	x	
Energy intake	x			
Body measurements	x	x	x	
Body composition	x			
Metabolic outcomes	x			
Salivatory cortisol	x			
Questionnaire data				
Lifestyle and health	x	x	x	
Usage of PA possibilities at work				x
Ratings of PA possibilities at work				x
Motivational impact from PA-promoting program				x
Psychosocial factors at work			x	
Stress and energy	x			
Anxiety and depression	x			
Musculoskeletal symptoms			x	
Work tasks			x	
Qualitative data				
Interviews				x

*Data from 152 questionnaire respondents and 70 participants in interviews analyzed

Theoretical models

The development of the Inphact treadmill study was influenced by two models – the Ecological model of SB and the International Classification of Functioning, Disability and Health (ICF). The PA-promoting program in the AOD study was based on three models – *Five Keys to workplace health promotion*, the *Social ecologic model of influence on physical activity* and the *Social cognitive theory*.

The assumption that behaviors are influenced by multiple factors, including those at the individual, social, organizational, environmental, and policy levels, is described as an ecological approach (75,121). To be able to develop interventions targeting SB and PA, there is a need to have a context- and behavior-specific approach and to understand the multiple factors influencing behaviors. Owen et. al. developed the ecological model of SB, and this includes factors related to SB in different contexts (75). ICF recognizes the impact of a disease or disability incorporating both body function, personal factors and environmental factors (122).

Five Keys to workplace health promotion highlights five main areas that should be considered in health promotion in the workplace: 1) commitment from leaders and managers, 2) involvement of employees, 3) business ethics and laws, 4) the use of a systematic process to ensure efficiency, and 5) continuous improvements, including development of strategies to maintain and integrate health-promoting activities (100). The model influenced the PA-promoting program due to anchoring with management and leaders, and the participatory approach in the development of the program content.

The *Social ecologic model of influence on physical activity* describes how personal, social/organizational, and environmental factors interact and affect human movement behavior in a building (123) (Figure 4). When developing the contents of the lecture, the workshop with managers, and the communication campaigns, all of these aspects were kept in mind, in order to develop all factors in parallel.
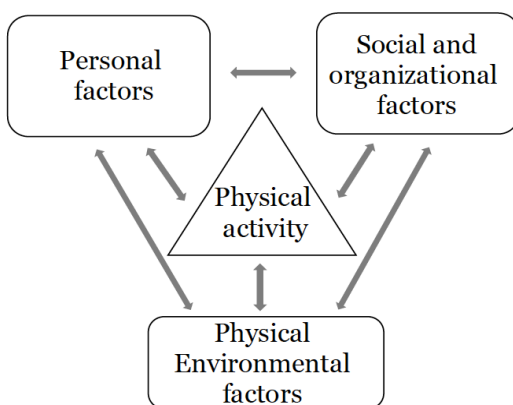
Figure 4. A social ecological model of influences on PA. Modified by Zimring et al. (123).

The *Social cognitive theory* developed by Bandura describes knowledge, outcome expectations, and perceived social as well as structural facilitators and barriers for change (124). The PA-promoting program targeted both knowledge, social and structural factors of interest for change. Repeated examples on how to implement small changes, and rhetorical questions aiming to create reflection and goal setting, aimed to support self-efficacy to behavioral changes. The combined influences from the theoretical models led to a broad approach of the PA-promoting program.

For the PE we used a modified version of a theoretical model developed by Nielsen et al. (103) for planning, performing and evaluating organizational interventions. As guidance for both data collection and evaluation of the intervention process, the model has a connected framework, including aspects that are crucial in PEs. The model and framework are influenced from other disciplines, such as participatory ergonomics and organizational development. Originally the model included aspects on mental models of actors, contextual factors, intervention design and implementation (104). To meet the aims of our study (paper IV), we modified the model by adding an element for behaviors (Figure 5). This made it possible to use the model when analyzing both the implementation process and the behaviors.

Figure 5. The modified process evaluation model used in paper IV. The model includes aspects on contextual factors, the intervention, behaviors, and mental models.

The Inphact treadmill study (Paper I)

Study design
A 13-month randomized controlled trial of healthy overweight or obese office workers (n = 80).

Recruitment
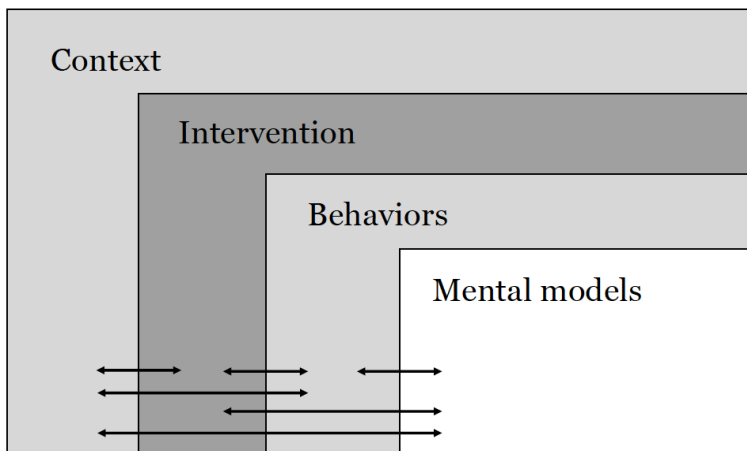Participants were recruited from 13 office workplaces in the city of Umeå, Sweden. Governmental agencies, municipal administrations, and private sector employers were represented among the workplaces. Most of the participants, 78%, worked in non-shared cell offices, and 22% worked in open office landscapes.

Inclusion and exclusion criteria
To be included, participants should have mainly sedentary work tasks, a BMI of 25–40 kg/m², and be of age 40–67 years. Exclusion criteria were severe depression and/or anxiety, chronic fatigue syndrome, diabetes mellitus, severe cardiovascular disease, severe kidney disease, musculoskeletal disorders with walking problems, contraindications for PA, thyroid disease, pregnancy, and if being away from the office more than one day per week. Participants had to have an individual sit-stand workstation to be included.

Screening
Prior to inclusion in the study, the participant filled in a questionnaire and a clinical investigation for health status was performed by a doctor at a clinical research center at the University Hospital of Umeå. Fasting blood samples were taken for analyses of full blood count, lipids, electrolytes, plasma glucose, HbA1c, and thyroid status. Participants assessed their daily sitting time using the "Workforce Sitting Questionnaire" (125).

Randomization
The participants were randomized after the baseline measurement to a control condition or an intervention with an active workstation with a treadmill desk. Stratification was based on BMI.

The intervention
After randomization all participants received an individually adapted health consultation with advice and recommendations on diet and PA. They also got feedback on their personal results for anthropometric measurements, blood pressure, lipids, and HbA1c taken at baseline. Participants in the intervention group received a treadmill desk at their individual workstation. They were instructed to use the treadmill at the speed of their choice and to gradually increase walking time. The goal was to use the treadmill at least one hour per work day. At four time points during the study period, participants in the intervention group received booster e-mails from the research group (at 5–6, 19–20, 31, and 50 weeks after baseline). These e-mails included information

about health risks of excessive sitting as well as gains of PA and aimed to encourage and inspire the participants to continue to use the treadmills. The e-mails also repeated the study goal to use the treadmill at least one hour per workday. Participants in the control group proceeded working as before, sitting and/or standing throughout the study.

Data collection and processing

Sedentary behavior and physical activity
Assessments of both SB and PA were performed at baseline and at 2, 6, 10 and 13 months. To be able to measure both SB and PA at different intensity levels, we used both the ActivPAL and ActiGraph accelerometers. To be able to evaluate the effect of total PA, and to study possible compensatory effects, all waking hours were assessed. During each measurement period, the participants registered non-wear time and their usual sleeping- and working hours in a log book. For both devices data had to include 4 days of valid data (3 work days and 1 non-work day) to be eligible for analysis.

Outcomes for sitting, standing, walking, breaks from sedentary time, and number of steps were measured with the tri-axial accelerometer ActivPAL3 and ActivPAL3 micro (PAL Technologies, Glasgow, Scotland, UK). Participants wore the ActivPAL on the right thigh 24 hours a day for 7 consecutive days. The device was attached with a surgical dressing, and removed only for water-based activities. ActivPAL has been proven to provide valid, reliable, and sensitive measurements on changes in body postures and steps (126,127). ActivPAL has also been shown to be valid and sensitive in detecting changes in sitting time and breaks from sitting (61,128,129). In paper I, data were processed to provide outcome measures for work time and total time on workdays and non-workdays. Data were eligible for analysis if there were ≥10 hours of wear time, more than 500 steps, and 95% or less of the time in a sitting or standing position per day (130).

Outcomes for LPA and MVPA were measured with the commonly used tri-axial accelerometer ActiGraph GT3x-BT (ActiGraph, Pensacola, Florida, USA). Participants wore the device in a belt around the waist for 14 consecutive days, of which the ActivPAL was worn simultaneously during the first week. ActiGraph has been proven valid for measuring the duration, frequency, and intensity of PA at different intensity levels (62). We used a composite vector magnitude from all three axes (VM3). Using accelerometer counts from all three axes, compared to only using vertical axis counts, has shown stronger associations between PAEE outcome variables and the doubly labeled water-technique (131). The raw data were collected at 30 Hz, and an epoch length of 60 seconds was used. Non-wear time was defined by using a modified version of the Choi algorithm, with 60 minutes of consecutive zero counts, no spike tolerance, and a small 1-minute window length, using VM3 (62). For the ActiGraph, data were analyzed if there were ≥10 hours of wear time. Cut-points for the different intensity levels were based on the Freedson Adult VM3 (2011) algorithm (62,132). Based on a small pilot study, we modified the cut-points for

LPA as 201–2689 counts per minute. We reported MPA and VPA together as MVPA using the cut-point ≥2690 counts per minute (Figure 6). In paper I, ActiGraph data were processed for total time on workdays and non-workdays.
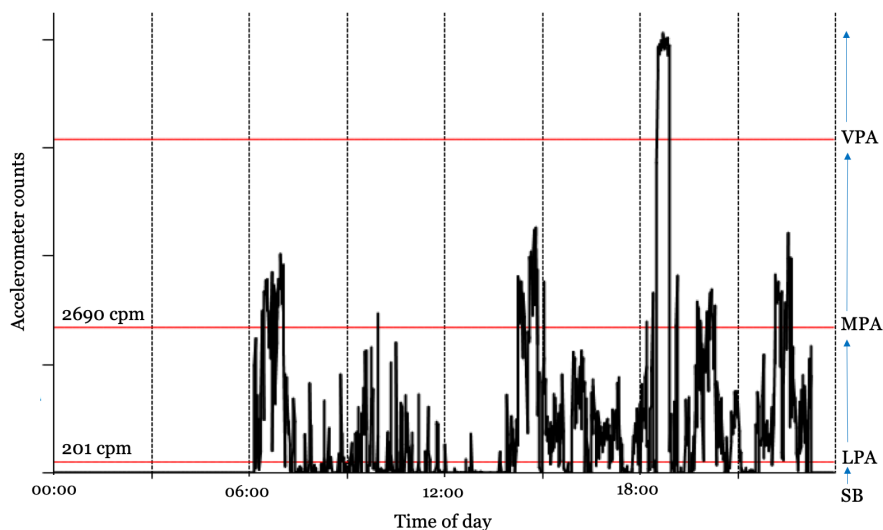
Figure 6. Example of accelerometer data output from the ActiGraph GT3x-BT, measured over one day. The raw data illustrate the intensity of the activity. The cut-points used in the Inphact treadmill and AOD study are illustrated by the red lines.

Dietary intake
Dietary intake was recorded with a food diary, filled in for 4 days per period of each PA measurement.

Body measurements and body composition
Length, weight, BMI, waist and hip circumference, sagittal height, body composition measured with dual x-ray absorptiometry (DXA) were measured at 0, 6, and 13 months.

Metabolic function and salivary cortisol
Systolic and diastolic blood pressure, salivary cortisol, and metabolic variables, including an oral glucose tolerance test (75 g, glucose and insulin analyses at baseline and after 30, 60, 90 and 120 min), lipids, and HbA1c were measured at 0, 6, and 13 months.

Psychological health questionnaires
Assessments of depression and anxiety were made using the HAD-scale (133) and perceived stress and energy were assessed using the Stress-Energy-Questionnaire (134) at 0, 6, and 13 months.

The AOD Study (Paper II-IV)

Setting and recruitment

The AOD study was performed among office workers in a municipal administration in the north of Sweden. The study had the overall aim to evaluate work environment and health after a planned relocation to two different office types, a flex office with ABW and a cell office. Approximately 450 officials within the municipality were involved in the office relocation. Before the relocation employees worked in two different office buildings with traditional cell office designs. Approximately 250 of the employees moved to a flex office with ABW and 200 to a new office with a traditional cell office design. Employees were allowed to participate in study procedures during working hours. Prior to the study and the planned relocation, information sessions at the workplace were held. In addition, information was sent out by e-mail to all employees. The objective measurements of SB and PA were described as a substudy of the AOD study.

Study design and participants

The AOD study consisted of an open cohort, and all employees involved in the office relocation were invited to participate and to fill in questionnaires about working conditions, work environment, well-being, health and PA. To be included in the substudy with objective measurements of SB and PA (Paper II), the inclusion criteria were 1) age 18–63 years, 2) working 75% or more, 3) spending more than 60% of work hours inside the office, and 4) not planning to change workplace or retire during the study period. In paper III, an exploratory analysis was performed of the cross-sectional data from the 18-months of follow-up. In paper IV, longitudinal data and mixed methods were used to study the group that relocated to the flex office (Table 2).

The PA-promoting program

The development of the PA-promoting program was based on three previously described theoretical models, *Five Keys to workplace health promotion, Social ecologic model of influence on physical activity*, and the *Social cognitive theory* (100,123,124). An ongoing collaboration between the researchers and workplace representatives ensured a participatory approach in the development of the intervention program.

Lecture

All employees were invited to a lecture approximately one month before the office relocation. The 45-minute lecture held by the research staff aimed to increase awareness of the relationship between SB, PA, and health, to initiate reflection and discussions, and to inspire employees to pursue small behavioral changes.

Workshop for managers

A seminar for managers was held 5 months after the relocation. The goal of the seminar was to repeat the importance of decreasing SB and increasing PA, to discuss culture and norms regarding PA in the organization, and to share ideas on how managers can lead by example. The written workshop material was sent to the managers by e-mail after the session.

Communication campaigns

Three communication campaigns were developed in collaboration with voluntary employees who were recruited from "health inspirers" within the organization. The campaigns were launched between 10 and 17 months after the relocation, and they focused on breaking up prolonged sitting, the importance of everyday PA, and taking the stairs and/or using treadmill workstations if available at the workplace. The campaigns also aimed to create reflection and individual goal setting regarding behaviors for everyday PA, both at work and during leisure time. For communication of the campaigns, we used posters, table-top messages in the break spaces and conference rooms, information on the workplace intranet and communication via managers. More details on the content can be found in paper II.

In total, intervention activities were rolled out over a period of 18 months, and they were separated in time from the measurement periods and the office relocation. The same program and materials were used for both office groups, and they got the same information and activities at the same intervals in relation to their office relocation.

Data collection

Table 3 gives an overview of the data collection in the AOD study, and the data that were used in this thesis.

Table 3. Overview of data collection in the AOD-study.							
Time point in relation to relocation	–6 m	–1 m	+6 m	+11 m	+18 m	+20 m	+24 m
	Baseline		Follow-ups				
Objective measures of SB and PA	x	x	x	x	x		
Body measurements	x		x		x		
Questionnaires	x				x		
Focus group interviews			x		x		
Individual interviews with managers						x	
Interview with key persons							x

Sedentary behavior and physical activity

We used the same methodology for measurements of SB and PA in the Inphact treadmill study and the AOD study, with a few exceptions. In the AOD-study participants measured SB and PA at 6 and 1 month before, and at 6, 11 and 18 months after relocation. Participants reported time for getting up, going to bed, and working hours day by day in a log book, and ActiGraph was only worn for one week. In paper II data from both ActivPAL and ActiGraph were processed for work- and leisure time on workdays, non-workdays, and for total time measured time, including both workdays and non-workdays.

Body measurements

Body measurements were performed at 6 months before and at 6 and 18 months after the relocation. Measurements were performed at the workplace and participants wore underwear. Standardized methods were used when measuring body height, body weight, and waist- and hip circumference. For more detailed information, see paper II.

Questionnaires

All employees involved in the office relocation were invited to participate in a large survey with questionnaires at 6 months prior and at 6 and 18 months after relocation. The questionnaires included background variables such as age, gender, position at work, employment rate, amount of computer-bound work tasks, and office location. Health and lifestyle were registered with questions about self-rated health, sleep quality, cognitive and musculoskeletal symptoms, exercise habits, and smoking. Psychosocial aspects of the work environment and feelings and experiences of physical, mental and social well-being were assessed using the Work Experience Measurement Scale and the Salutogenic Health Indicator Scale (135,136). Usage of possibilities to be physically active at work (e.g. standing while working, using a treadmill workstation, taking the stairs) and perceived appreciation of using the active alternatives at work were assessed by specific questions. Cultural and social acceptance regarding sitting and moving at the workplace were also registered. At 18 months after the relocation the questionnaire was extended to contain some questions about the perceived motivational impact of different components in the intervention and questions about time spent on various work tasks.

Interviews

In paper IV, we studied the group that was relocated to the flex office. Focus group interviews were conducted at approximately 6 and 18 months after the relocation. Individual interviews with managers were conducted at approximately 20 months and a focus group with key persons for the PA-promoting program and office relocation were performed at 24 months after the relocation. Recruitment to focus group interviews was performed by e-mail invitations and convenience sampling. Recruitment to interviews with managers and the key persons was done by personal invitations by e-mail. Both focus group interviews and individual interviews used a semistructured interview guide, they lasted about 60 minutes, and they were performed by

researchers not involved in the development of the PA-promoting program
(137). Prior to the analyses, all interviews were transcribed verbatim.

Data analysis

Quantitative analysis
In papers I and II, the analysis of objective measurements of SB and PA and
body measurements were performed by using linear mixed models to test for
interaction effects and within-group changes. In all models, the participant was
used as the random intercept. In the Inphact treadmill study (paper I), SB and
PA outcomes for total time awake on weekdays was tested using three-way
interactions between group (intervention/control), time point (baseline, 2, 6, 10
and 13 months) and day of week (weekday or weekend). Further, estimated
means for work time, non-work time, energy intake, and body measurements
were tested using two-way interactions between groups and between time-
points. In the AOD-study (paper II), the two baseline measurements were
weighted, and two-way interactions between groups (flex office and cell office)
and time-point (baseline, 6, 11, and 18 months) were used for all activity
outcomes. For body measurements the model included group (flex office and
cell office) and time-point (baseline, 6, and 18 months). For analysis of total
time of SB and PA (both weekdays and non-work-days) in the Inphact treadmill
study and the AOD-study, a two-way interaction between groups and time-
points was used. For both studies, data for total time (both time on work days
and non-work days) were analyzed and are reported as standardized 16-hour
day values.

In paper III, cross sectional data from employees in both office groups at 18
month's follow up were analyzed. We included 53 participants with complete
data for both questionnaires and measurements of SB and PA in the analysis.
Factor analysis of mixed data is a generalized principal component method that
allows for both categorical and continuous data, and it was combined here with
multiple linear regressions. We used a Scree plot to determine the number of
dimensions. Interpretation of the combination of factors was done by two of the
authors.

In paper IV, questionnaire data from 152 participants were included in the
analysis. Wilcoxon matched-pair t-tests were used due to the non-parametric
nature of the data.

In papers I, II, and IV we used SPSS software v.24 (IBM Corp, Armonk, NY,
USA). In paper III, the analyses were performed in R computing software, version
3.5.2. For all studies the significance level was set at $\alpha \leq 0.05$.

Power analysis
In the Inphact treadmill study (paper I) participants were stratified for BMI
(25–30 and >30–40). A sample of 30 individuals in each group gave 85% power
to find a statistically significant difference of 30 minutes walking time per day

(standard deviation 60.8 minutes) ($p<0.05$). Forty individuals in each group were included to compensate for an anticipated participant drop out of 30%. In the AOD study (paper II), 84 individuals were needed, to compensate for an expected participation drop-out of 20%, to achieve a power of 80%, and to detect a statistically significant difference between groups of 30 minutes sitting time per day ($p<0.05$).

Qualitative analysis

Data from 12 focus group interviews at 6 and 18 months, and interviews with managers (n=6) at 20 months and key persons (n=2) at 24 months after relocation were included in the qualitative data analysis (paper IV). In total, 70 individuals participated in the interviews, whereof 19 of those participated in more than one interview.

Data were analyzed using qualitative content analysis. We used a deductive approach to the modified PE model previously described. Data were coded, and categories of data emerged in relation to the different elements in the model (138,139). Results were discussed among the five authors, and preliminary results were also presented and discussed with researchers who were well acquainted with the AOD study.

Ethical approval

Because our studies collected data on health and aimed to affect participants' behavior, ethical applications were performed for both studies. Both studies received ethical approval from the Regional Ethical Committee in Umeå – the Inphact treadmill study (No:2013/338-31) and the AOD study (No:2014/226-31). According to the Helsinki Declaration, participants were informed that participation was voluntary and that they had the possibility to withdraw their participation at any time during data collection. All participants signed an informed written consent.

Results

Participants with objective measurements (Paper I & II)

Table 4 shows the demographic data for participants in the Inphact treadmill study and the AOD study performing objective measurements of SB and PA. The Inphact treadmill study comprised more men compared to the AOD study. In the Inphact treadmill study, 33% of the participants rated their health as very good or excellent at baseline, and the corresponding number for the AOD study was 49%. Half of the participants in the AOD-study and 45% of the participants in the Inphact treadmill study reported that they exercised twice a week or more at baseline.

In table 4, activity outcomes at baseline are presented standardized to 8-hour workdays or 16-hour total awake time. In both studies, approximately 50% of the time at work was spent sitting and 40% standing. Participants in the Inphact treadmill study walked for almost 10% of their workday at baseline, while participants in the AOD-study spent about 8% of their workday walking at baseline.

Table 4 here

Walking time and PA intensity

Work time

In the Inphact treadmill study the intervention group increased their walking time and number of steps at work compared to the control group. The effects were largest in the beginning of the study. At 13 months, the intervention group walked 18 minutes (confidence interval, 9 to 26) more per weekday compared to baseline, whereof 15 of those minutes took place at work, indicating that the main effect of increased walking time was related to the intervention at work.

In the AOD study a significant interaction effect was seen for walking time at work (p=0.001). This was driven by a within-group increase in walking time at work in the flex office group at all follow-ups, while the cell office group showed a within-group increase of walking only at the 11-month follow-up. Both groups showed within-group increases in MVPA – the flex office group at all follow-ups, and the cell office group at 11- and 18-month's follow-up – but the increases in the flex office group were greater, which resulted in a significant interaction effect also for MVPA at work (p<0.001).

Non-work time

In the Inphact treadmill study, no interaction effects were seen for MVPA during weekdays (p>0.05) or weekends (p>0.05). For both weekdays and weekends, MVPA decreased within the intervention group at all follow-ups, while the control group decreased their MVPA at 13 months follow-up.

In the AOD study, both groups showed increased numbers of steps and walking time at 11 month's follow-up during leisure time on weekdays. This increase returned to normal levels at 18 months. Significant interaction effects were seen for walking time during weekends (p<0.01), where the flex office group showed increased walking time at all follow ups compared to baseline and the cell office group remained stable. No interaction effects were seen for MVPA during weekends (p>0.05), but the flex office group showed increased MVPA at the 6- and 18-month follow-ups.

Total time - both workdays and non-workdays

Figures 7 and 8 show the relative time spent walking, standing and sitting for total awake time for both workdays and non-workdays in the Inphact treadmill study, where both groups spent 11% of the total time walking at baseline. The intervention group increased their walking time from 11% to 15% from baseline to the 2-months follow-up, and for follow-up at 6-, 10, and 13 months walking time stabilized at 13%. One percent corresponds to 9.6 minutes per day.

Intervention group for total time

Figure 7. Relative time spent walking, standing, and sitting of the total time, at the different time points in the intervention group in the Inphact treadmill study.

Control group for total time

Figure 8. Relative time spent walking, standing and sitting of the total time, at the different time points in the control group in the Inphact treadmill study.

Figures 9 and 10 show the relative time spent walking, standing, and sitting for total awake time for both workdays and non-workdays in the AOD study, where the flex office group walked for 11% and the cell office group walked for 12% of the total time at baseline. The flex office group increased their total walking time by 1% from baseline to 18 month's follow-up, while the cell office group remained stable.

Flex office group for total time
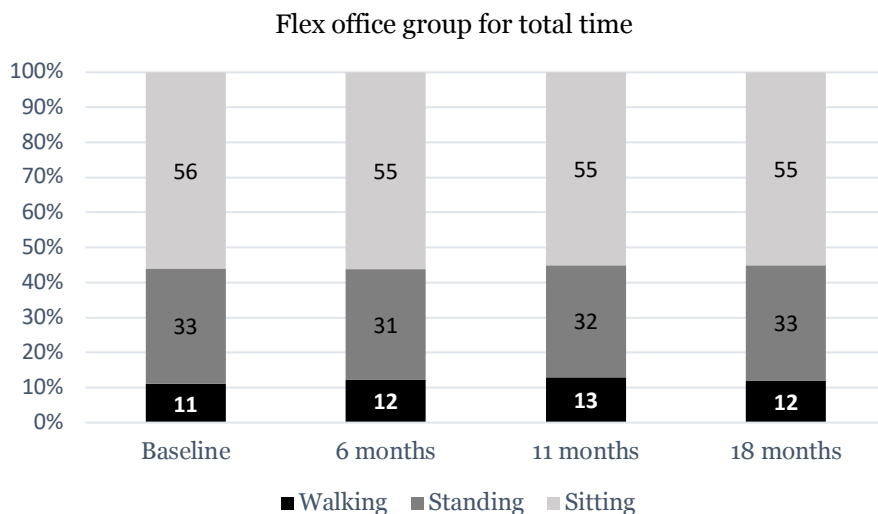
Figure 9. Relative time spent walking, standing and sitting of the total time, at the different time points in the flex office group in the AOD study.
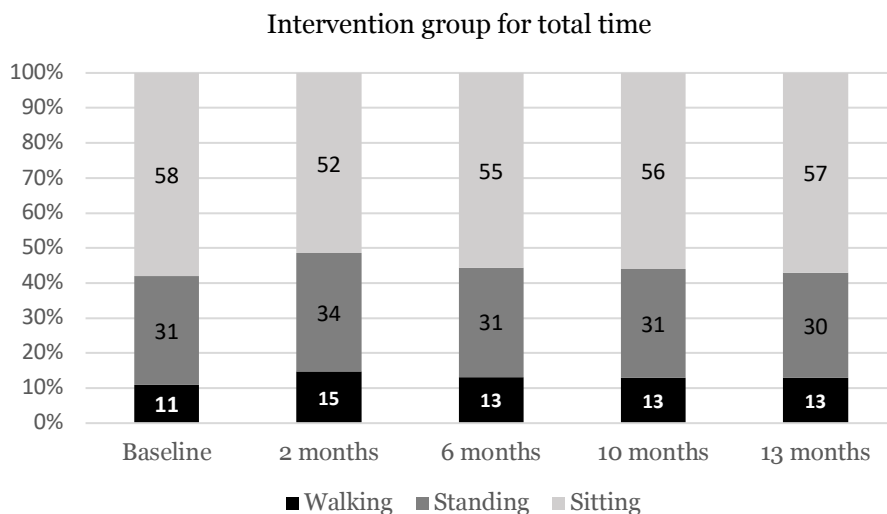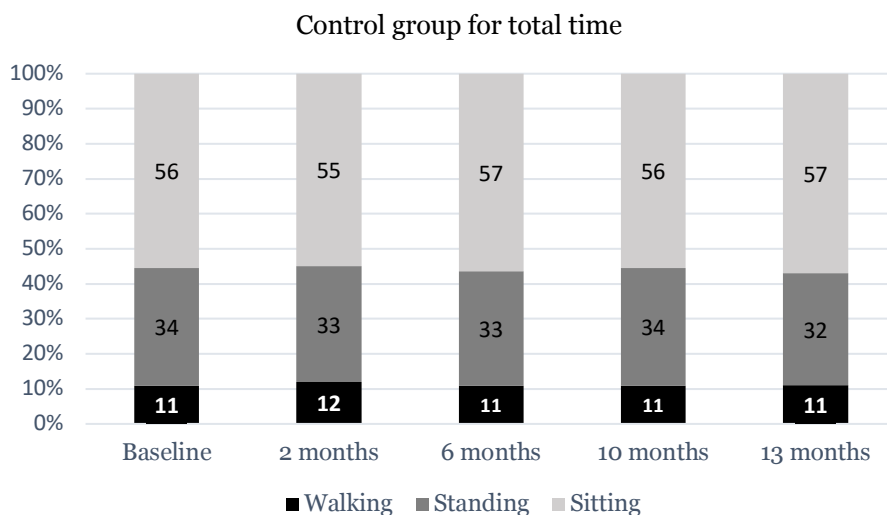
Cell office group for total time
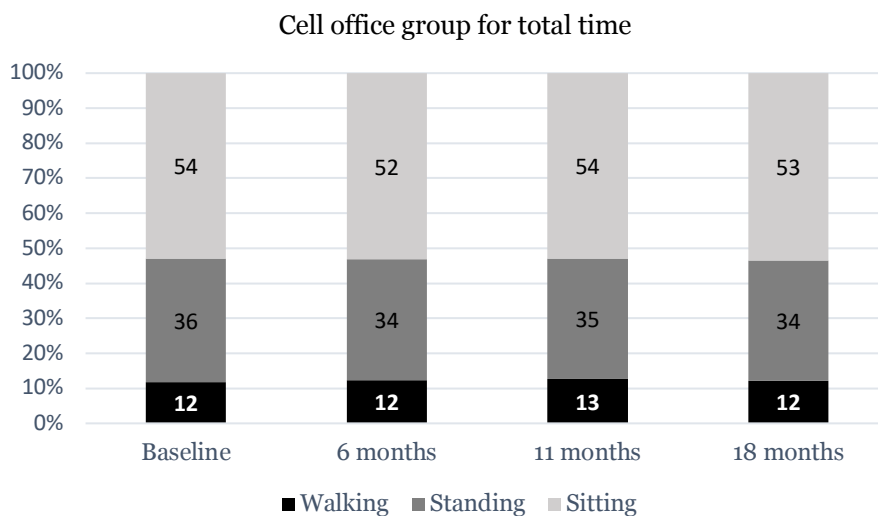
Figure 10. Relative time spent walking, standing and sitting of the total time, at the different time points in the cell office group in the AOD study.

In the Inphact treadmill study, there was a decrease in MVPA of 15 minutes per day from baseline to 13 month's follow-up in the intervention group and a decrease of 9 minutes per day in the control group. In the AOD-study, there was an increase of 11 minutes per day from baseline to 18-month's follow-up in the flex office group, and an increase of 6 minutes per day in the cell office group (Figure 11).
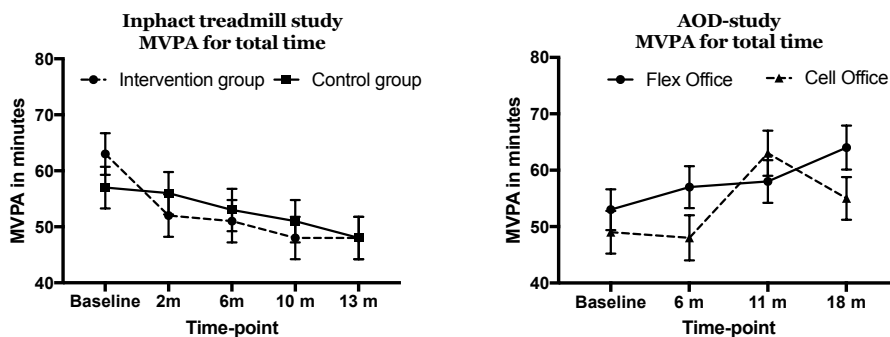
Figure 11. Estimated means and standard errors for MVPA per 16-hour day, for total awake time in the Inphact treadmill study and the AOD study.

Sitting and standing

In the Inphact treadmill study, the intervention group decreased their sitting time at work at all time points except the 13-month follow-up, while the control group remained at the same level over the whole study period. None of the groups showed any changes for standing time, neither at work or out of total time on weekdays or weekends.

In the AOD study, no changes for total sitting time at work were observed during the study. For standing time at work, no significant interaction effects were seen, but standing within the flex office group decreased at all follow-ups.

Breaks and patterns for sitting accumulation

In the Inphact treadmill study, interaction effects were seen for breaks shorter than 3 minutes (p<0.001) and for breaks longer than 20 minutes (p<0.01). This was due to stability in break patterns at work in the control group, while the intervention group decreased their short breaks and slightly increased their long breaks. No major effects for sitting accumulation patterns were seen for weekdays or weekends.

In the AOD study, a significant interaction effect for break rate at work was seen (p=0.001). This was driven by an increased mean sitting duration and decreased break rate (number of breaks per sitting hour) in the cell office group at 18 month's follow-up, while the flex office group remained stable for mean sitting duration and break rate (Figure 12).
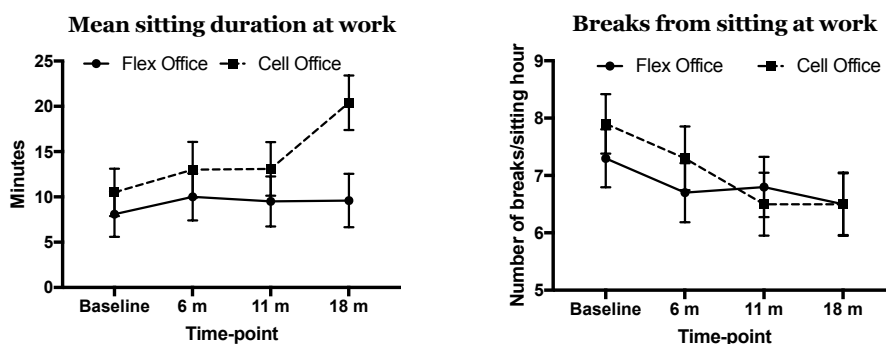
Figure 12. Estimated means and standard errors for mean sitting duration and breaks from sitting at work per 8-hour workday in the AOD-study.

Body measurements and metabolic function

In the Inphact treadmill study, self-reported daily energy intake decreased within the intervention group at the 6-month and 13-month follow-ups, but there was no interaction effect. No interaction effects or within-group differences were found for body measurements or body composition. No significant intervention effects were found for metabolic function, salivary cortisol, perceived stress and energy, anxiety, or depression outcomes.

In the AOD-study, there were significant interaction effects for weight (p=0.01) and waist circumference (p<0.05). This was driven by weight increases within the flex office group at 18 month's follow-up and a decreased waist circumference within the cell office group.

Exploration of underlying factors for SB and PA (Paper III)

From the first step of the analysis– the factor analysis of mixed data – six dimensions emerged. Every dimension described a combination of underlying factors that were interpreted and presented as six character types. These character types were 1) harmonic and healthy 2) disabled with poor health, 3) manager who spend a lot of time in meetings and has very high workload, 4) engaged with high workload, 5) employee with creative and computer intense work, with high workload, and 6) employee with high BMI, and creative and collaborative work.

The next step of the analysis – the multiple linear regressions – showed that the character types that to a high degree were "engaged with high workload" and "harmonic and healthy" spent more time sitting and less time standing. The character type that to a high degree were "engaged with high workload" spent more time in prolonged sitting, while the character type describing employees with "high BMI, and creative and collaborative work" tended to sit less and stand more. "No statistically significant results were seen for office type related to sitting, standing or walking at work. The multiple regressions explained 22% of the variation in sitting time, 20.5% of the variation in standing time, and 17.7% of the variation in walking time.

Process evaluation and PA behaviors in the flex office (Paper IV)

This paper focused on the flex office group within the AOD study and evaluated both the implementation process of a PA-promoting program and self-reported and perceived PA behaviors at work. A theoretical model for PEs and a mixed methods design, with repeated questionnaires (n=152) and individual and focus group interviews (n=70) were used in the analyses. Qualitative and quantitative results were intertwined in the presentation of results. In total 70 individuals (73% women) participated in interviews, and 16 of those were managers. Among the questionnaire respondents, 67% were women and 47% were over 50 years of age. A majority (60%) rated their general health as very good or excellent.

Context

For contextual aspects, the category *support for physical activity* described how the organization had a strong culture of encouraging both posture variation and exercise. Sit-stand tables were available already at baseline. The social acceptance for walking and standing at work was high at baseline, where 71% reported that standing or walking at work was socially accepted to a large extent, and this further increased to 84% at 18 months (p=0.001). Employees described how they appreciated that the office environment provided possibilities for posture variation and walking. Musculoskeletal discomfort, the habit of sitting, and an awkward feeling of "standing out" were described as barriers for standing.

> *"But sometimes I think it is really nice to be able to just lean back. The Pilates stool feels good for a while, but it also becomes static. And if you stand too long you also get tired in the back. At least that is the case for me. I want variation."*

The category *environmental and ergonomic challenges* describe factors of influence for PA behaviors. During the study, the organization needed to hire more employees. Due to this, the office sometimes became crowded, and employees described walking around the office to find a suitable workstation. This was perceived as frustrating and time-consuming. The lack of workstations was also mentioned as a barrier to workplace rotation.

> *"I would say that people are afraid of losing their workstation, otherwise I think you would move much more."*

After relocation to the flex office with ABW, employees were expected to rotate between workstations, depending on the task at hand. However, ergonomic adjustments of chairs were perceived as difficult and time- consuming, and were described as a barrier to rotation. The tendency to avoid making the adjustments was perceived to be a future risk for increased musculoskeletal disorders.

> *"It is difficult to adjust the workstation every day. Sometimes I do it. Sometimes I don´t have the energy. It´s annoying because it takes time."*

"I am a little worried about this in the long run. We have such a nice working environment, but since I think I am only going to sit for two hours, and then move on, I do not care. But over time, my posture might deteriorate, which might be a problem."

Intervention

The category *clarity in the organization* describes how the intervention was supported by both senior leaders and middle managers and how all activities in the PA-promoting program were performed as planned. Regarding motivation and responsibility to sit less and move more, both employees and managers thought that it was important that managers promoted PA and acted as role models, but that the final decision to change behaviors was up to the individual.

"Thus, we have a manager talking a lot about using the health and wellness hour and that we should have walking meetings and things like this. So, it is not the managers' fault if I don't do it."

"I think one barrier is that some do not see their responsibility, it sounds hard, but maybe I'm exaggerating a little. It is easy to become comfortable and think that it is the employer who has to fix things. Here we have the best possible opportunities, compared to other organizations."

The perception of the motivational impact from the different parts of the PA-promoting program varied, but the physical environment and the lecture had the highest ratings in the questionnaires at 18 months, while managers' behaviors and communication campaigns had the lowest (Figure 13).
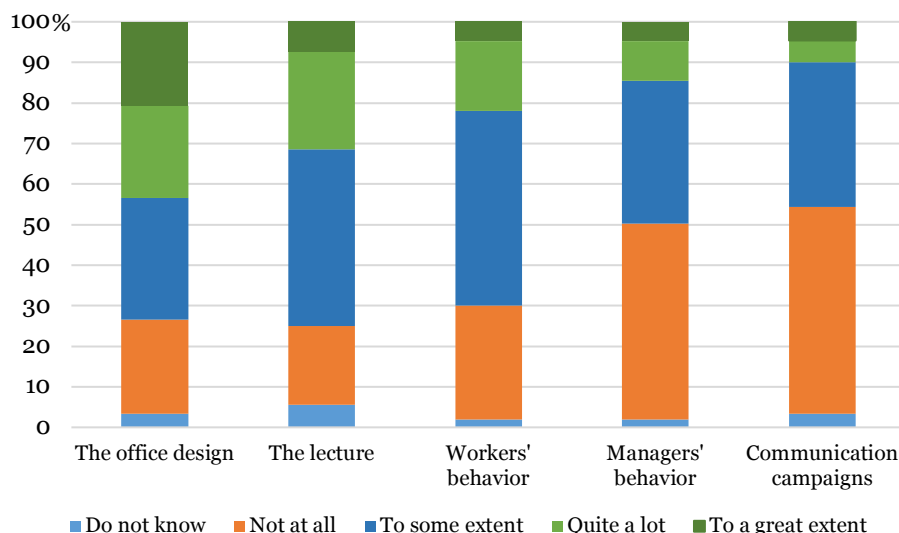
Figure 13. Motivational impact of factors related to the PA-promoting program reported at 18 months.

Behaviors

The category *voluntary and involuntary physical activity* described how employees strived for variation, how the equipment and activities were stimulating and how they walked to find a suitable workplace. The category *mediators* described how employees always put their productivity in the first room and that how the pursuit of physical comfort influenced their behaviors.

> *"I don´t use the traditional chairs any more; I stand up or use Pilates stools and pallets. It doesn't work with a chair because then I would have to spend half the day adjusting it."*

At baseline, 72% took the stairs daily and 38% stood while working individually on a daily basis. Standing and walking meetings were unusual. The most appreciated possibilities to be active at work were to take the stairs, walk or cycle to meetings outside the office and to stand while working individually. There were no changes in the reported frequency of standing while working individually between baseline and 18 months, but the reported appreciation of standing while working decreased ($p<0.01$). At 18 months it was reported as more common to stand at meetings ($p<0.001$) and the frequency of breaks from sitting during meetings increased from baseline to 18 months ($p<0.01$) (Figure 14).
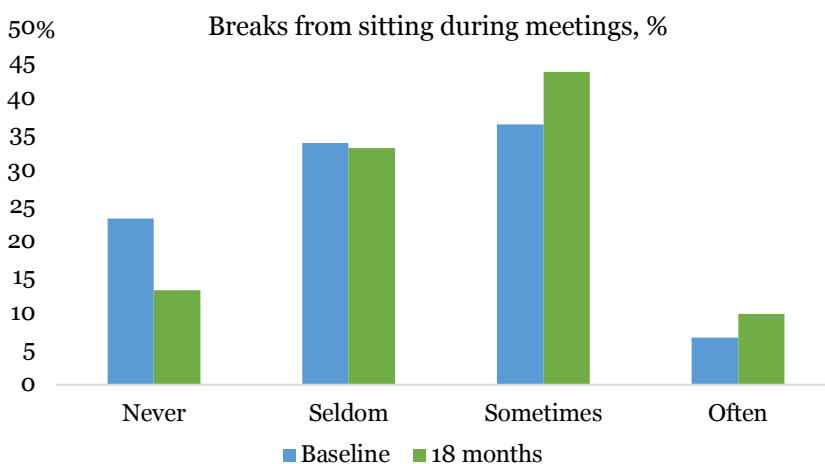
Figure 14. Frequency of breaks from sitting during meetings at baseline and 18 months.

At 18 months the treadmills were used by 12% of the employees. Employees thought that the most suitable work tasks for the treadmill were reading, checking e-mails or walking while having a phone conversation. Barriers to using the treadmills were noise and difficulties in finding compatible work tasks. Another barrier was perceived motion sickness when walking.

> *"Because they make a bit of annoying noise. Maybe they should be placed on the same floor, next to each other, and they can be noisy together."*

"I have back pain, so personally the use of the treadmill workstations has saved me."

The reported usage of stairs increased in the flex office after relocation (p<0.001) and the stairs were perceived as more positive to use compared to before relocation (p<0.001).

"I take the stairs much more often now. The stairs are nicer, but they are also naturally placed. One does not even think about the elevator."

Mental models

In the process evaluation model used in our study, mental models relate to openness and readiness for change, motivation for change, and perceptions of an intervention. The category *balance of communication intensity* described perceptions of the PA-promoting program. There were reflections on the timing for the program, were a need of supporting activities in order to handle the challenges of transition to ABW, like using different digital tools, clarifying rules or further adjusting the office interior design.

"It is exciting to try new ways of working. But there has been much more focus on the opportunities to stand or sit at the desk than the aspects of working in an activity-based manner. We must learn more about that."

A few employees were of the opinion that there had been an unbalanced focus on performed activities in relation to the needs for health promotion. They thought that the focus on SB and PA had been too strong, and stress-management activities were requested instead. The challenge of balancing the amount of communication about PA was discussed, related to both equality and inclusiveness, and employees described that employees with disabilities might feel excluded, by not being able to be that physically active. It was also described that too much focus and messages on SB and PA could be provoking and create an opposite effect. There were also a few reflections on the PA-promoting program as a compensation for a perceived deterioration of the work environment.

"To talk about physical activity and have treadmills is all good, but we cannot discriminate. We must ensure that everyone feels welcome."

"I take responsibility for my health. I think it feels a bit contrived. For me, it is contrived, and a bit like we do this to compensate for something else."

The category *openness for activity* described how there was a consistent acceptance for, and a striving to incorporate more bodily movement so long as productivity was not affected. It also highlights that trust from leaders is important, the possibility to try alternate ways of working, and that it takes time to incorporate behavior changes.

"You have to feel trust. With time, we will find our ways."

Discussion

We have shown that it is possible to increase PA among office workers. In the Inphact treadmill study, the intervention group increased their walking time and number of steps compared to the control group. Notably there was a compensatory effect, with decreased MVPA during non-work time within the intervention group at all follow ups, while the control group only showed a decrease at the 13-month follow-up. In the AOD study no changes in sitting time at work were observed, while walking time and number of steps increased, especially in the flex office group. No compensatory effects for PA were seen during leisure time. The exploratory study showed that a complex combination of factors, such as self-reported health, job scope, and workload influenced PA behaviors among office workers. The PE revealed that all activities in the PA-promotion program in the AOD study were performed as planned and that the program had strong leadership support. This study also suggests that the timing of the intervention to some extent came in conflict with needs related to the office relocation, and it describes the challenge of finding a suitable balance in health messaging at the workplace.

Sedentary behavior and physical activity

Sitting and standing at work

In papers I and II, the results showed that participants sat for approximately 50% and stood for 40% of their time at work at baseline. Previous intervention studies among office workers have shown sitting levels of 64%-67% at long-term follow-ups (65,80,81). Sit-stand tables are common in Sweden, but also when compared with Swedish studies our results differ for sitting and standing times. A longitudinal study by Hallman et al. where all participants had sit-stand tables showed that they sat on average 70% of their work time at baseline, and at 12 months after relocation to flex offices with ABW, no changes in total sitting time were seen (64). In a Swedish cross-sectional study, the participants sat for 60% of their work time (74). We did not observe any significant reductions of sitting time, and our results might indicate a ceiling effect for the amount sitting time can be reduced in office workers.

The low levels of sitting and high levels of standing in our studies were probably due to the availability of sit-stand workstations in combination with regular reviews of the workplace ergonomic work environment. In studies evaluating barriers, facilitators and possibilities to decrease sitting and increase PA among office workers, the physical environment and furniture design have been highlighted as barriers (140–142), which means that the starting point in our studies differed from many other studies. In Sweden sit-stand tables are standard for purchase in many workplaces, and the legislation requires employers to perform regular risk assessments of the work environments (143). The risk assessments are usually performed by safety inspections by representatives within the organization or staff from the occupational health

care provider. During these safety inspections it has become a tradition to encourage employees to vary between sitting and standing. Initially this tradition aims to reduce the risk of musculoskeletal symptoms related to sitting but it might be so, that the increased media attention and awareness about the risks of SB have further increased the utilization of the possibility to stand at work. Another possible explanation for our results could be that the recruited organizations had an interest in health promotion among employees and thus the health awareness among participants was high. The interview data from the AOD study confirmed that there was a strong organizational culture to promote health. Already before the study, employees were stimulated to be physically active through exercise, and also variation between sitting and standing as well as active transport was encouraged and facilitated.

In the interviews employees described how they appreciated and used the possibility for variation between sitting and standing because both postures were perceived as static after a while. Similar results are reported in experimental studies in office settings, where short-term effects on discomfort from prolonged standing have been investigated. Prolonged standing led to increased musculoskeletal pain (144,145), but sitting for prolonged periods also seems to cause short-term musculoskeletal symptoms (147). Previous qualitative studies have also described that standing could be perceived as uncomfortable and tiring, and thereby a barrier for standing (74,77,141). A systematic review of laboratory studies showed that standing for prolonged periods resulted in increased musculoskeletal symptoms. To avoid the risk of getting symptoms from standing, the authors recommend not to stand for more than 40 minutes at a time (147). A review and meta-analysis on the impact on low back discomfort from using sit-stand workstations, showed that sit-stand workstations might reduce low back pain, and the possibility to control the ratio of sitting to standing transitions was of importance for the result. This indicates that the reduction of low back pain is greater when workers can change their body posture by their own choice (148). In line with this, multicomponent intervention studies have shown decreased symptoms from lower back and/or neck-shoulder when standing time at work increased (81,95). The results in paper III indicated that employees with poor health were prone to sit less and to stand more than healthy coworkers. To speculate, this might be due to the fact that people with musculoskeletal disorders to a higher degree use the opportunity to vary between sitting and standing as a way to cope with their symptoms, and that people with poorer health might be more easily reached with interventions aimed at reducing SB. To summarize, it seems to be important to provide possibilities for posture variation in office settings, and the variation intervals should be self-chosen and controlled by the individual.

The objective measurements of SB and PA in papers I and II were reported as estimated mean values, and the wide SD suggests wide interindividual variations for all activity outcomes. This was somewhat confirmed in the interviews in the AOD study, where some employees described how they always sat while working, others most often stood, and some varied between sitting and standing. In previous qualitative studies, computer-based work and work pressure have been reported as barriers for standing (140,142,149,150), and the

results from the exploratory analysis are in line with these results, where the character type that were "engaged with high workload" spent more time in prolonged sitting. These results are also in line with productivity aspects described in the interviews, where emplyees described that they forgot to take breaks during meetings or did not utilize the health and wellness hour during intense work periods. The results in paper III also showed that the character types that to a high degree were "harmonic and healthy" and "engaged with high workload" spent more time sitting and stood less. This result was somewhat unexpected. It might be likely to think that health-promoting lifestyle activities at work usually attract employees who are already the most active and healthy, but our results for sitting and standing points in the opposite direction. Similar results are described in previous qualititative studies. Flint et al. (151) reported that regular exercisers or individuals with small children were less motivated to reduce their sitting time at work, and Nooijen et al. (74) found that a higher proportion of younger workers, that could be assumed to have better health, reported that they thought standing was uncomfortable and tiring, and they were less motivated to stand at work. To conclude, our exploratory results contribute by describing underlying factors within character types explaining different patterns for sitting and standing at work.

Patterns for sedentary behavior

As previously described, accumulation patterns of sitting time could be of importance for metabolic response and health (7,27,28). Standing during meetings and phone calls, walk-and-talk meetings, and screen-based prompts have been described as feasible possibilities to decrease sitting and break up prolonged sitting (74,140,142,149). Although the PA-promoting program highlighted the importance of breaking up prolonged sitting and taking breaks, no group effects or within-group changes were seen for time spent in prolonged sitting in the AOD study. In activity-based flex offices, workers are supposed to move between different workstations depending on the work task at hand, and theoretically this could increase breaks from sitting. We hypothesized that breaks from sitting time would increase in both groups, with greater changes in the flex office. Contrary to our hypothesis, no changes in break rate were seen in the flex office group, but the mean sitting period increased, and the break rate decreased in the cell office group. During the study period, many refugees arrived in Sweden, and to manage the reception of refugees the organization hired more staff. This could imply that the social service workers working in the cell office, had an increased workload, which could be an explaining factor for longer sitting periods and less breaks from sitting in the cell office. The interviews revealed that employees in the flex office perceived no need to change workstations, and found it difficult and time consuming to do so, and thus they usually used the same workstation all day. They also described how they, to facilitate their work, often worked in the same area in the office as their closest colleagues. Thus, they did not use different spaces but changed locations in the office just as before the relocation, for example, when attending meetings or during breaks. This could somewhat explain the stability in break rates in the flex office group also after the relocation. In line with our findings, stationary behaviors in activity-based flex offices are described in a report from Leesman,

presenting data from more than 11,000 office workers from 40 activity-based workplaces around the world (152). That report identified four types of mobility groups: *the camper* (30%) who performs most activities at a single workstation and rarely uses other office locations, *the timid traveler* (41%) who performs the majority of activities at a single workstation but sometimes uses other locations in the office, the *intrepid explorer* (19%) who often switches between locations in the office, and the *true transient* (10%) who always switches between locations in the office (152). The reason for being stationary is discussed to be due to a work profile that does not benefit from the flexible environment, while the intrepid explorers and true transients have adopted and benefit from the central concepts of working in an activity-based manner and are mobile in their space use (152). Hoendervanger et al. (153) reported that the reasons for choosing the same workstations might be having homogenous tasks or work that require collaboration with the same colleagues. We have no data on how often employees changed workstations, but the results described by both Leesman and Hoendervanger are also confirmed in the interviews in the AOD study. Even though it is claimed that employees should move more in flex offices, Hallman et al. did not observe any changes in total sitting time or sitting accumulation patterns among office workers moving to activity-based flex offices (64). To summarize, many factors might influence how sitting time is accumulated, but the claim that people working in flex offices take more breaks from prolonged sitting is not supported by our results, and should not be viewed as scientifically proven.

Physical activity at work and compensatory effects

While cardiovascular health benefits might be achieved by replacing sitting time with standing, it has been suggested that, to address overweight and obesity, sitting might need to be replaced with ambulatory activities, such as walking or running (154). Both of the intervention studies in this thesis led to increased walking time during working hours, but the Inphact treadmill study resulted in compensatory effects with decreased MVPA, while the AOD study showed no decrease, and rather a slight increase in PA during leisure time.

Because compensatory effects from worksite interventions vary between studies, it seems to be important to include intervention components targeting both work and leisure time. Just as the results in the two studies in this thesis differ in terms of compensation effects, previous studies have also shown conflicting results. A Swedish study, using questionnaire data, found that people changing from sedentary to physically active occupations compensated by exercising less, while people changing from physically active to sedentary occupations compensated by exercising more during leisure time (155). Two Finnish studies using hip-worn accelerometers show contrasting results. Both studies aimed to decrease SB both during work and leisure, and one of the studies showed reduced SB and increased PA only during leisure time (156), while the other study showed decreased SB and increased PA at work, but compensatory effects with decreased PA during leisure (157). However, there are also studies, including multicomponent interventions, and/or the installation of sit-stand desks or treadmill workstations, where no compensatory effects have been observed

(65,158). In the AOD study, the response to the PA program could to some extent have been achieved by active initiatives like lunch walks or increased utilization of the health and wellness hour. Because the PA-promoting program was performed in both office types, the more pronounced increase in steps, walking time, and MVPA seen in the flex office group, could also depend on differences in office design and desk sharing. In the interviews, employees described how the office became crowded and how they had to walk around the office to find a workstation. Because all employees shared all spaces in the office, the total walking distances were probably also longer compared to only walking in a regular corridor. Similar to our results, a Swedish study also found unchanged sedentary patterns but increased walking after relocation to flex offices, although the results differed between office sites, suggesting that effects might be site specific, and depend on the size and the design of the building (64). In the AOD study, longer walking distances in the flex office, difficulties in finding a workstation, and walking to look for colleagues could thereby have contributed to the increased walking time at work. If the increased walking in the flex office was spread out over various occasions, such as going to the centralized printer room, or looking for a workstation, they might not be perceived as conscious initiatives specifically aimed at being physically active. This might have facilitated the transmission of the PA-promoting program's message to be active also during leisure, putatively explaining the small additive effects during leisure in the AOD study.

In the Inphact treadmill study, the intervention group increased their walking time during weekdays by 18 minutes per day, wherof 15 minutes during worktime, indicating that the main effect was related to the workplace intervention. At the same time, a decrease in MVPA was observed at all follow-ups in the intervention group on both weekdays and weekends, while the control group only had decreased MVPA at 13 months. The decrease in MVPA in the intervention group might be a compensatory effect related to the intervention. Compared to the PA-promoting program in the AOD study, treadmill use in the Inphact treadmill study might have been perceived as more consciously planned and carried through, which could have led to a compensatory effect that was more or less reflected upon and voluntary by participants. For total time, at 13 month's follow-up compared to baseline, the decline in MVPA was 15 minutes per 16-hour day ($15 \times 7 = 105$ minutes per week) in the intervention group, and 9 minutes per day in the control group ($9 \times 7 = 63$ minutes per week). Even if the activity levels at 13 month's follow-up in the Inphact treadmill study were still meeting the PA guidelines, the decrease in MVPA could have negative effects on health on the long run. This decrease could be discussed to occur for different reasons. When recruiting for this kind of study, participation might be more attractive for individuals who are struggling to maintain weight balance. In the beginning of the study, the motivation and enthusiasm to be in the program could be high, but might decline over time, which is often seen in long-term lifestyle interventions (159). Furthermore, the decrease might depend on social desirability during the first measurement periods, showing more "true" behaviours during the last measurements.

The different characteristics of the intervention types in the Inphact treadmill study and the AOD study might explain the differences in compensatory effects. While the Inphact treadmill study was more of a single-character intervention, the PA-promoting program in the AOD study targeted different ways to be active at work, but also emphasized leisure time PA and active commuting. To be able to evaluate mutual effects between domains of PA, it is important to evaluate effects both at work and during leisure, using objective measurements in future studies.

LPA, MVPA, and what is just enough?

SB and MVPA are separate behaviors, but for health outcomes it is not clear whether they are independent or not. Because most people are both sedentary and active at different times, it is important to understand how SB and PA at different activity levels interact and affect health. In 2016 Ekelund et al. (21) published a meta-analysis based on self-reported data. Their study focused on effects from leisure time and recreational PA, and showed that the mortality risk was offset for those who sat for many hours a day but also were highly physically active (about 60-75 minutes per day), compared to those that sat a lot, but had low levels of PA. This suggests that exercise might buffer the harmful risks of excessive sitting, but more studies are needed to clarify the independent and joint effects of SB and PA (23). A recent meta-analysis (44) investigated the relations between objectively measured PA and all-cause mortality. The meta-analysis was based on data from eight studies, with approximately 36,000 participants, with a mean age of 62.6 years and a median follow-up period of 5.8 years. The study showed that all intensities of PA led to reduced risks for death, and the maximal risk reductions were seen at 375 minutes of LPA and 24 minutes per day of MVPA, while SB over 9.5 hours per day significantly increased the risk of death. In line with studies based on self-reported PA, the risk reductions were greatest when the least active quartile was compared to the second least active quartile. Interestingly, the effect sizes were considerably larger than in studies using self-reported data. In our studies, the participants spent on average between 345 and 395 minutes of their total time in LPA and about 50 minutes per day in MVPA, which is in line with or above the levels presented as providing maximal risk reductions. A limitation when using mortality as an outcome is the relatively short follow-up period and the possible risk of a reversed causation. Participants with low levels of PA could, due to illness, be inactive already during the assessments, and this makes it difficult to directly apply these results to our study populations.

A study using compositional data analysis and objectively measured SB and PA found that the strongest positive effects for BMI, waist circumference, triglycerids, plasma glucose, plasma insulin and blood pressure were related to the proportion of time in MVPA. This study also showed that diabetes risk markers became more favorable when replacing SB with LPA (26). The conclusion from this study was that MVPA is the most important target for intervention, but transferring time from SB to LPA might lessen the negative effects of low MVPA-levels. To speculate, it might be so that even though walking time increased at work in the intervention group in the Inphact treadmill study, the compensatory decline in MVPA, might have led to a

detoriated effect from total PA. For future studies, a higher walking speed might be needed, and focus on preventing compensatory behaviours for MVPA are recommended. An increased walking speed might on the other hand compromise productivity when walking faster than the self-chosen speed (160).

Office workers might be exposed to excessive sitting that is harmful for health, but occupational groups with high physical demands have also been shown to have increased risk for ill health and cardiovascular disease (161,162). In 2018 Coenen et al. (163) published a review and meta-analysis that assessed the association of high-level occupational PA (OPA) with all-cause mortality. Their study showed that men with high OPA had an 18% increased risk of all-cause mortality, compared to the group with low OPA. The risk increase remained after adjustments for confounders such as leisure time PA and socio economical status, presenting a potential PA paradox. The reasons for this paradox are yet not known, but it is suggested that it might depend on different factors, for example, on the fact that OPA is of too low intensity or too long durations to maintain or improve cardiorespiratory fitness. OPA also often includes heavy liftning which elevates 24-hour blood pressure, and that the recovery periods are often too short (164). Coenen et al. (163) suggests that PA guidelines should differentiate between occupational and leisure time PA. Further studies are needed to determine the optimum level of PA at work and at leisure.

Anthropometry and metabolic measures

Studies show that the greatest gains from increased PA are seen among those who are the most inactive (44,165). In the Inphact treadmill study, no changes in anthropometric or metabolic outcomes were seen. Even though all participants had a BMI ≥25 and were ≥40 years of age, they were metabolically healthy, and the increase of walking time at work might not have been intensive enough to lead to significant improvements in health. As previously mentioned, the compensatory effect in the Inphact treadmill study, with a decline for total time MVPA in the intervention group might also explain the lack of effects. Because humans tend to increase in weight as they age, it might also be of interest to consider whether a long-term use of treadmills might be useful to maintain weight stability, rather than to lose weight. Our intervention lasted 13 months, which is a long-term study, but even longer interventions might be needed to be able to detect possible positive effects on health variables when adding LPA. Previous studies have shown that effects on postprandial glucose and insulin levels from active breaks from sitting, have been stronger among individuals with lower fitness and lower insulin sensitivity (27,28,30). The participants in the intervention group decreased their frequency of short breaks during the intervention, which might also be an explanation for the lack of results on the metabolic outcomes.

In the AOD-study, the waist circumference decreased in the cell office group at follow-ups 2 and 3, even though their increase in PA was quite modest. On the other hand, the flex office group, which showed a more prominent increase in PA simultaneously increased in weight, BMI, and waist circumference. It is hard to interpret these results, but they might have been influenced by factors, such

as food intake among the participants or an increased muscle mass, which were not measured in this study.

The importance of contextual understanding

By highlighting facilitators and barriers to being physically active at work, but also by scrutinizing the implementation of the PA-promoting program, the PE of the AOD study contributed to an understanding of underlying causes of the study results. Other studies have described the importance of leadership encouragement and social support as both possible barriers and as facilitators, depending on the existing culture and norms within the organization. (74,140,142,149). In the AOD study, the leadership encouragement for being physically active was strong and social acceptance was high. Due to the availability to sit-stand desks, the strong organizational culture, and the awareness of the benefits of posture variation already before baseline, the need for the intervention could be argued. The intervention also somewhat came in conflict with the perceived need to learn new working methods related to the concept of ABW.

In the interviews with key persons and some of the focus groups, the difficulty to find the "just right" frequency and amount of communication about SB and PA was discussed. The focus on PA was also reflected on as a difficult balancing act regarding equality, inclusiveness, personal integrity, and responsibility. In the interviews, managers described an ambivalence regarding how much to emphasize the importance of PA, and they thought that the final decision on behaviour is up to the individuals. Similar to our results, managers in a Dutch study described how the organization can provide possibilities and encourage PA, but the final decision on behavior must be up to the employee (141). The ethical perspective, and the aspects of equality and inclusiveness, is to our knowledge, despite its importance, not previously described as an aspect to consider in SB intervention development. These results indicate the need for a thorough understanding of the local conditions before intervention planning, both in research and in organizational practice. The conditions and the starting point for SB and PA in an organization can differ considerably, both in terms of culture, work tasks and physical environment, which means that the intervention designs could, and probably should, vary between organizations. The importance of understanding the local conditions before interventions, and of having a participatory process during intervention development is confirmed by our results. Even though we used a participatory approach, our results indicate that we did not fully succeed in finding the "just right" level. These results show the complexity of fitting the content of an intervention to actual needs and of getting the right timing, dose, and frequency of the communication within the organization. Because the relocation to a flex office with ABW meant that employees would have to learn to work in a new way, it might have been better to deleniate the PA-promoting program. The new office could have been equipped with furniture facilitating posture variation and PA when equipping the office, just as it was, but it might have been more appropriate to postpone the other activities in the program. The performance of lectures, workshops with managers and communaction campaigns might have been perceived and

received in another way if they had been performed in a later, more stable phase. It might even be worth considering whether interventions should be developed differently also within organizations due to different work tasks and physical environments in different sections in order to actually target what works for different people under different circumstances.

PA is described as a complex behavior, which is reflected in the results from the exploratory analysis (paper III) and the interviews (paper IV). SB and PA at work seem to be influenced by interpersonal, environmental, and organizational aspects in combination with workload and work tasks, which emphasizes the importance of assessing and evaluating underlying factors for intervention results. Future studies can be designed with these results in mind. By collecting data with a broad perspective, these variables could be used when evaluating intervention effects, because they might affect the outcomes. As an example, our results from the exploratory study indicate that work tasks, workload, intensity of computer work and musculoskeletal disorders might be mediators, that to some extent might explain the causal pathway for change in PA behaviors. The results from the PE suggests that information about conflicting initiatives, leadership support, and conditions in the physical environment are also of interest.

Methodological considerations

A strength of this thesis as a whole, is the use of results from two long-term interventions studies, combined with exploratory analysis and a PE study with mixed methods. When used together, the different types of data and methods provide a comprehensive view of interventions to increase PA and decrease SB in office settings.

Study design and participants

The main strengths of the Inphact treadmill study were the randomized controlled design, the long-term follow-up, and the repeated measures of SB and PA for both workdays and non-workdays. Due to the randomization of individuals, instead of clustering by organization, there might have been a contamination effect between participants in the intervention versus the control group, which is a limitation. It would also have been desirable to have data on how much the intervention group actually used the treadmills. The main strengths of the AOD study were the prospective controlled design, the long-term follow-up, and the repeated objective measures of SB and PA. In the AOD-study there was no possibility for randomization, neither on the group or individual level, which is a limitation. The combination of a relocation and performance of the PA-promoting program, complicates the possibility to draw conclusions on the reasons for the effects of the program. Through the qualitative data and the PE, we could to some extent evaluate the effect contributions of the different parts of the PA-promoting program and the effect of office type.

Further strenghts of both studies were the use of both ActivPAL and ActiGraph, which made it possible to evaluate both body postures and intensity levels of PA

with high validity. The use of different time filters for both workdays and non-workdays made it possible to evaluate compensatory effects. When using accelerometers, the cut-points used for defining MVPA are absolute and do not consider the fitness level of an individual. In our study we used vector magnitude and ≥2,690 counts per minute to define MVPA for all participants (166). Due to interindividual variability of fitness, this cut-point could, for individuals with high cardiorespiratory, mean that some of the time defined as MVPA might actually be LPA, and for individuals with low cardiorespiratory fitness, this might mean that some of the time defined as LPA might be MVPA. Santos Lozano (167) have suggested a MVPA cut-point ≥3,208 counts per minute for adults. If we had used a higher cut-point, our result might have shown less time in MVPA and more time in LPA. We based our decision of cut-points on a review (62), and the idea was to use a cut-point for vector-magnitude that had been previously used in the literature, and thus would facilitate the interpretation of our results in comparison with other studies. Individually tailored cut-points are suggested to give a more accurate measurement of an individual's activity levels, which could reduce the risk of over- or underestimating PA in different activity levels. Although the application of individualized cut-points is not always feasible, it should be considered whether results can and should be adjusted for some type of assessment of cardio-respiratory fitness (63). In both studies, data on the utilization of the health and wellness hour during work hours as well as perceived motivation and self-efficacy for PA behavior change would have been desirable.

Participants in both studies had more or less of a pre-understanding of the risks of sitting, both through media attention on risks from SB during this period and the brief information presented in the recruitment procedure. This might have influenced the recruitment to the studies and might have been more pronounced in the Inphact treadmill study. Participants with BMI ≥25 were recruited to this study, and the study included a thorough health investigation. In the Inphact treadmill study, participants accepted the obligation to increase their PA at work by one hour per day, and it is possible that individuals who were interested in health-related questions, or who were motivated to change their lifestyle were more prone to sign up for participation.

The development of SB interventions among office workers

Both interventions in this thesis were based on theories and targeted both environmental, organizational and individual factors. The development of the PA-promoting program in the AOD study had a participatory approach, which is recommended for a sustainable and contextually costumed intervention (46). Renaud et al. (168) recently published a study performed among office workers who had long-term availability of sit-stand workstations. Three user groups were identified – the non-users, the monthly to weekly users, and the daily users. The daily users perceived standing at work as healthier and more appealing, and standing made them feel more energetic and productive compared to the non-users. The non-users perceived the use of sit-stand workstations to be distracting, uncomfortable, and impractical compared to the other user groups. According to the aim of the study, the researchers developed

a new set of questions, including questions on background characteristics, the frequency of use of the sit-stand workstations, self-reported SB and PA, and perceptions of barriers and facilitators to using the sit-stand workstations. For future studies, this set of questions could, as a whole or partly, be used to tailor future interventions aiming to reduce occupational sitting, both for practitioners and in research. In addition, questions regarding motivation to reduce sitting at work, organizational culture and leadership support for health promotion, and social acceptance for standing or walking in the office could be measured.

Traditionally, primary prevention interventions are directed to people who are generally healthy, and the aim is to maintain health or to prevent disease occurance, while secondary prevention is directed to people with risk factors related to their lifestyle, that might lead to long-term risk of illness. In previous multicomponent interventions aiming to decrease SB, individual counseling has been included as one important intervention component (65,81,95). The cost-effectiveness of individual counseling, compared to health information provided to all employees, is of interest in assessing the return on investment for the intervention. The results from recent years, where for example active breaks have been shown to have a greater effect on blood glucose levels among people with poorer metabolic health suggest that it might be of interest to consider the return on investment from different intervention types and intensities. It could be conceivable that it is more justified to offer individual coaching to individuals with more pronounced risk factors, while it might be sufficient to stimulate and inspire employees who are in good health through environmental support and cultural support, combined with information. However, this might lead to employees who are overweight or obese could feel that they are being singled out as as problematic. In future research it would be of interest to consider the health economic aspects of different types of SB interventions, in relation to subgroups with different health status.

Data analysis
We used linear mixed models for analyzing our objective data for SB and PA. It could be questioned whether this is the best approach, because these analyses report each outcome separately. Times spent in different PA behaviors are codependent, meaning that if one behavior increase another decrease. To be able to determine the most advantageous distribution of sleep, rest, and PA at different intensity levels, the data should preferably be collected and analyzed with a 24-hour perspective. Compared to more traditional analytical procedures compositional data analysis might be used to evaluate the distribution of different activities that sums up to a constant value (26,170). This statistical approach might might increase the likelihood of identying the optimum distribution of activities over a certain time period and thus provide a basis for development of guidelines for SB, PA, and sleep.

In paper IV we used qualitative content analysis with a deductive approach to analyze the interview data (139). We have sought to strengthen the trustworthiness of the results. The credibility was strengthened by the fact that

the focus groups included many employees, and both men and women of different ages were represented. In addition, managers and key stakeholders were interviewed, and quarterly meetings between the researchers and the project leaders for the relocation were held (171). During the analysis we had regular meetings between the researchers, in order to compare and discuss the analyzed results. Researchers had different competencies, which broadened the perspectives of the results, and discussions continued until consensus was reached. To further strengthen the trustworthiness, preliminary results were presented to researchers in the AOD study, who had a good overview of the study as a whole (139). To facilitate the reader's interpretation of the transferability of results, we have described the settings, participants, and contextual details. The qualitative and quantitative results are integrated, which complements and further strengthens the trustworthiness. The results in paper IV are presented according to recommendations for how to report mixed-method studies (172).

Ethical considerations

There is an ethical risk in implementing lifestyle-related interventions in working life. This could, for example, mean that employees might perceive a social expectation or pressure to participate from managers or co-workers. In a research study in a workplace setting, feelings of guilt towards the researchers might also arise if recommendations of the study obligations are not met, and this might also lead to difficulties in cancelling one's participation in the study. In the Inphact treadmill study, participants with BMI ≥25 were recruited. Signing up for the study might have been perceived as a sensitive issue, because weight might be related to feelings of shame, and this is important to consider in many steps of the research process such as during recruitment, when performing measurements, during data handling, and in the dissemination of results (173). In the AOD study, results from questionnaires and interviews were repeatedly fed back to the organization and employees on a group level. This allowed for the organization to continuously make changes, and this transparency strengthened the ethics of performing data collection for a long period of time.

Organizations have many reasons to promote health among employees – such as cost-saving aspects, maintenance of a sustainable employability in light of the ageing workforce, and building a positive company image – by providing good employement practices (174). In an editorial article, Allegrante and Sloan discuss possible ethical dilemmas that may arize related to lifestyle interventions at the workplace (175). They describe how professionals who are developing and implementing interventions in the workplace might encounter moral dilemmas such as whether their loyalty lies with the employed individual or the client of the service (the employer). There might also be a risk that, even though the intentions are good, screening for health risk factors, might lead to job discrimination (175). In the interviews, the aspects of integrity and equality were reflected on, in relation to intervention intensity. These reflections demonstrate the challenge to design health messages in the workplace.

Implications for working life

Regardless of office type, a supportive workplace culture and a stimulating physical environment are paramount for promoting PA at the office. A supportive culture can include managerial support, positive attitudes and social acceptance towards stand and walk behaviors while working. A supportive interior design makes it easy to choose whether you want to sit, stand, walk or ride a bicycle when performing your tasks. On top of this, interventions to further increase PA can be performed. Our results showed a large variation in movement behavior between individuals. These variations are due to many different factors, such as motivation, musculoskeletal disorders, workload, work tasks and general health. Since employees appreciate and use different approaches to increase workplace PA, we recommend offering a variety of opportunities to stimulate both the physical environment and activity participation. In this context, the activities could target both posture variation and the use of light PA during work, for example, by using treadmill workstations or office workstation bikes, as well as possibilities to be active in MVPA.

The prerequisites for PA in organizations can differ substantially. When tailoring intervention activities, both in research and in organizational practice, it is important to thoroughly assess local conditions and organizational needs. Assessments should include both cultural and environmental aspects, such as the possibility for posture variation, stair use and walking while at work. Our results showed no changes in sitting time at work despite increased PA stimulation both through environmental and activity opportunities, which may indicate there is a ceiling effect to further decreased sitting. To assess whether an intervention is needed, sitting and standing behaviors, usage of sit-stand tables, and exercise habits should be assessed. Further, information should be collected about what kind of PA the employees consider important and feasible to incorporate both at work and during leisure. Intervention planning should be conducted as a participatory process, with representatives from different parts of the organization.

Flex offices may lead to increased walking, but our results showed office workers were not more likely to break up prolonged sitting periods when working in the flex office with ABW compared to when working in a cell office. Prior to a transition to a flex office with ABW, it is important to purchase equipment that is robust and easy for employees to adjust, to make it feasible for workers to properly tune each workstation to their individual ergonomic needs when changing workstations. If treadmill workstations are installed, placement should be carefully planned to avoid noise disturbances in surrounding areas.

To conclude, a supportive culture, a stimulating physical environment, ergonomic knowledge and stimulating activities that are tailored to the specific context can create sustainable positive PA behaviors among office workers. It is important to provide a range of possibilities for increasing physical activity at the workplace so employees can choose what suits them best without interfering with their productivity.

Future research

- It is important to further study the relationship between PA intensity levels and health effects using objectively measurements to provide a solid base for guidelines about SB and PA at work and during leisure, as well as to further investigate the interaction between work and leisure PA.

- Additional studies are needed to determine whether there is a ceiling effect for sitting time among office workers and, if one exists, to determine the minimum time.

- Assessment of the impact of alternative office environment designs, e.g. meeting rooms and lounge areas, on PA, perceived collaboration and creativity are required.

- There is a need for studies that include health economic evaluations to assess the possible return of investment of decreasing SB and increasing PA among office workers.

- A study to evaluate the instantaneous effects on arousal, energy levels and creativity of breaking up prolonged periods of sitting, standing or walking in office workers, and to assess whether any such effects are related to productivity in office settings.

Conclusions

- It is possible to increase PA in office settings in the long-term.

- A multicomponent PA-promoting program did not result in any changes in sitting time at work among office workers, where everybody had sit-stand tables before the intervention.

- Our results suggest a possible ceiling effect for the amount sitting time can be reduced in office workers.

- There is a risk of compensatory behaviors with decreased MVPA when walking time is increased or when using treadmill workstations during work hours.

- When intervening at work, it is important to promote PA also during leisure.

- Social acceptance for PA and breaks during meetings could increase following a PA-promoting program in the workplace.

- The interventions that were performed in this thesis, among office workers who already were quite active led to increased PA in the workplace, but no improvements in body measurements.

- A complex combination of underlying factors, such as work tasks, work load and musculoskeletal symptoms are of influence for PA behaviors among office workers.

- A facilitating physical environment, leadership support, knowledge, and a strong organizational health culture, can create positive and sustainable PA behaviors among office workers.

- To tailor a worksite intervention, a thorough understanding of the context, current status on SB and PA behaviors, organizational needs, and a participatory approach are needed.

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