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“A 6 month physical activity intervention in university staff: Effectiveness and health outcomes – The ASUKI Step Study”

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In the name of God, the beneficent the merciful

TO MY FAMILY

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ABSTRACT

Physical inactivity is regarded a major public health concern and regular physical activity (PA) has been considered as an important lifestyle modification to improve health and prevent chronic disease. Setting the goal at walking 10,000 steps/day as a moderate-intensity form of aerobic PA has been advised to have beneficial health effects in the research and practice areas. The health benefits of walking 10,000 steps per day in regards to cardiorespiratory fitness (CRF), blood pressure (BP), and body composition (BC) still requires further research, since current knowledge is mostly based on data from a limited number of studies. The pedometer is a simple and low maintenance device to create awareness of steps taken and have often been used in challenges and in low cost PA monitoring programs in different settings.

The current thesis aimed to identify demographic determinants for maintenance of walking behavior over the six month intervention among employees from Arizona State University (ASU) and Karolinska Institutet (KI) participating in ASUKI Step study. The study also aimed to examine the results of a 6-month pedometer-determined PA intervention in regards to health in a subgroup of the targeted population, and more precisely to identify health outcomes (BC, CRF, and BP) from a six month pedometer intervention in regards to the number of steps walked. The voluntary participants were asked to maintain a level of 10,000 steps per day. The study used a single group quasi-experimental design. The study included 2,118 employees from ASU and KI. A sub-sample including 357 ASUKI Step participants (ASU = 143, and KI = 214) from the two universities was randomly selected to complete physical fitness testing to determine their BC, resting BP, and CRF and to wear an accelerometer for one week at 0, 3, and 6 months. The pedometer was used as intervention tool as well as to monitor steps taken. Anthropometric measures included height, weight, waist circumference (WC), percent body fat, and sagittal abdominal diameter (SAD). CRF was measured by a submaximal Åstrand-Rhyming cycle ergometer test. Systolic and diastolic BP were taken using an Omron automated BP cuff.

The main findings: There was a significant linear and curvilinear change in steps per day over time, with reported number of steps per day decreasing from the first month of intervention to the last month when all participants were included in the model, and when dropouts were excluded from the analysis, there was no significant decrease in steps from month 1 to month 6. KI participants had a higher initial step count and a slower rate of decline over time. Overall, 52.9% (n = 1105) of the participants accumulated 10,000 steps on at least 100 days of the study. More participants from the KI (59.1%) than ASU (39.8%) met this goal. Older age, being married, working in a non-managerial position, having normal weight, and being categorized with a high activity level (using IPAQ) at baseline were all factors positively associated with meeting the step goal of 10,000 steps per day to a higher level during the days of the intervention. The mean number of steps in month one exceeded the goal of 10,000 steps per day with KI test group participants recording more steps per day than ASU test group participants. Using a conditional model, there was a significant reduction in BMI over time for older participants for the KI test group and there was a significant reduction in WC for middle aged and older participants. There was also a significant reduction in WC over time in the subgroup of females. For ASU test group participants, there was a significant reduction in WC, and minimal changes were found in other anthropometric variables in conditional model over time. There were significant linear and quadratic trends in systolic and diastolic BP over time. There was a significant difference between ASU and KI participants’ estimated VO2 max. The change over time varied by site, where VO2 max decreased for ASU but stayed essentially the same for KI participants. The number of steps taken was significantly related to changes in estimated VO2 max over time.
The data reported in this thesis will contribute to better understanding of the association of pedometer-based PA intervention with BC, BP, and CRF, a prerequisite for more efficient health promotion program. Future public health guidelines should consider the evidence-based importance of cues and support as well as of the goal of walking 10,000 steps per day in high risk segments of the population.

*Keywords*: Physical activity, pedometer, accelerometer, lifestyle intervention, walking 10,000 steps, cardiorespiratory fitness, VO2 max, body composition, blood pressure, sociodemographic characteristics
LIST OF PUBLICATIONS

This thesis is based on the following papers, which will be referred to in the text by their orders.


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LIST OF ABBREVIATIONS

ACSM  American College of Sports Medicine
AG    Actigraph
AHA   American Heart Association
ANOVA Analysis of variance
ASU   Arizona State University
ASUKI An acronym for Arizona State University and Karolinska Institutet
BC    Body composition
BFP   Body fat percentage
BMI   Body mass index
BP    Blood pressure
CDC   Centers for disease control and prevention
CRF   Cardiorespiratory fitness
DBP   Diastolic blood pressure
DXA   Dual-energy X-ray absorptiometry
EKG   Electrocardiograph
GXT   Maximal graded exercise test
HEPA  Health enhancing physical activity
IPAQ  International physical activity questionnaire
KI    Karolinska Institutet
METS  Metabolic energy turnover
NCD   Non-communicable disease
P     P value
PA    Physical activity
SBP   Systolic blood pressure
SAD   Sagittal abdominal diameter
SD    Standard deviation
SE    Standard error
SM    Sports Medicine
TBW   Total body water
VO2 max Maximal oxygen consumption
WC    Waist circumference
WHO   World health organization
1 INTRODUCTION

Physical inactivity or sedentarism and obesity are regarded as major public health concerns [1-3]. As a risk factor for chronic diseases, such as obesity, hypertension, cardiovascular disease, type 2 diabetes, osteoporosis, several types of cancers, depression, and anxiety, physical inactivity is responsible for 2 million deaths annually around the world [2, 4, 5]. The importance of regular PA in reducing risk of morbidity and overall mortality is overwhelming [2, 6-8]. The benefits of a habitual physically active lifestyle are well documented, including weight management, decreased risk of cardio-metabolic disease, longer life expectancy and an improved overall quality of life [9]. Health promotion programs in the 21st century may therefore focus on establishing support systems and policy initiatives, including interventions, to target individuals’ modifiable lifestyle factors such as PA and dietary habits to control the overweight and obesity problem. A better understanding of these modifiable lifestyle factors and the associations between these factors and obesity and chronic diseases may improve the possibilities for successful health promotion. The thesis evaluates the effects of a 6-month pedometer-based intervention on maintenance of a high level of step counts over time, the proportion of individuals who accumulated at least 10,000 steps per day for a minimum of 100 days, and accelerometer-determined PA levels over time in a sub-set of individuals and examined the socio-demographic predictors of success. Furthermore, the association of PA with body composition (BC) characteristics, resting systolic and diastolic blood pressure (BP), and cardiorespiratory fitness (CRF) are thoroughly examined in a sample of the U.S. and Swedish adults who participated in the workplace intervention, the ASUKI Step study.

1.1 HEALTHY LIFESTYLE

You are hearing a lot about living a healthy lifestyle, but what does a healthy lifestyle mean? In general, a person with a healthy lifestyle eats healthy and exercises, doesn’t smoke, and has a healthy weight. A healthy lifestyle helps to improve and keep people’s health and well-being [10]. The complete definition of lifestyle normally includes all those behaviours closely related to the nutritional and physical activity aspects which are aimed at maintaining wellness [11]. Nowadays, many governments and non-governmental organizations have produced policies and action plans in regards to the support, promotion and maintenance of a healthy lifestyle [12]. Promoting a healthy lifestyle is about offering useful information that inspires healthy eating, regular daily PA, and wellness in the communities [13], and gives you the helpful information you need to focus on key areas such as PA, diet and nutrition, weight management, tobacco cessation, and stress management [14]. Good nutrition, a physically active lifestyle and absence of the use tobacco may prevent or delay the onset of chronic disease such as diabetes and cardiovascular disease. It is well documented that a healthy lifestyle depends on several determinants, such as the level of education, employment, climate, cultural, structural, social and physical environment. Appropriate PA is a fundamental part of a healthy lifestyle [15]. Internationally there has been growing interest in using incentives to promote healthy lifestyle behaviors within an educational and public health arena [16]. Lifestyle modification is the foundation of prevention and treatment of diabetes and cardiovascular disease. Lifestyle intervention as a primary prevention of type 2 diabetes and atherosclerotic cardiovascular disease could typically include regular PA, diet, and limited energy intake in order to reduce weight, and behavioral intervention and follow-up [17].
1.2 LIFESTYLE PHYSICAL ACTIVITY INTERVENTION

Lifestyle PA interventions are effective to increase and maintain levels of PA that meet or exceed public health recommendations for PA in representative samples of previously sedentary adults and obese individuals [18]. Lifestyle PA is defined as daily accumulation of at least 30 minutes of self-selected activities, which includes all occupational, leisure, or household activities with moderate to vigorous intensity and could be unplanned or planned activities that are part of everyday life [18, 19]. This amount of daily PA can be obtained in short bouts of 10 minutes during the day as a part of an active lifestyle. It is well documented that a moderate level of regular daily PA decreases the risk of cardiovascular disease and diabetes, compared with subjects of the same weight but with a lower level of PA [18, 19]. Epidemiological studies show that only 15% of the populations attain the levels of vigorous PA prescribed by the American College of Sports Medicine. Similarly a large majority of the population (60%) is inadequately active and of these, 25% are completely inactive [20, 21]. Generally, the effect of any intervention can be assessed in numbers of people who adopt a physically active way of life (short-term effect) or whether subjects maintain the change over time (long-term effect) [21]. Lifestyle PA interventions demonstrate long-term effects, both on reducing sedentary activity and increasing moderate-intensity PA [21].

There is growing evidence that lifestyle PA can bring both fitness and health benefits for sedentary individuals. Furthermore, there is encouraging, if not convincing evidence that, among the sedentary population, the lifestyle approach to PA may result in superior levels of adherence than the traditional approaches [22]. The lifestyle approach is making physical activity as a habit, akin to a healthy diet, putting on a seatbelt when you get in the car or brushing your teeth. To become a habit, PA requires to become an easy enjoyable and sustainable choice [23]. Allowing individuals to self-selected activity rather than prescribing them is a very important feature of the lifestyle approach. Reported dropout rates from traditional prescribed exercise programs are higher than new lifestyle approaches [22].

1.3 LIFESTYLE ACTIVITY FOR HEALTH

During the past decades there has been a progressive decline of PA in people’s daily living in industrialized societies. For the majority of people, little physical effort is nowadays involved in their work, transportation, leisure, and domestic chores. Physical inactivity is becoming increasingly prevalent and is regarded a major public health concern and a significant risk factor for many common non-communicable diseases (NCD), and regular PA has been recognized as an important element in the promotion of public health by both the sport and the health community [24]. Although the research interest on PA and health dates back to the 1950s, the breakthrough in scientific evidence on fitness and health outcomes of PA took largely place in the 1980s and 1990s [24]. Promotion of PA is very important across the lifecycle, because it supports growth and development in children and youth, prevents disease in adults, benefits maintaining functional capacity and independence in the ageing population [24].

Significant health benefits could be obtained by attaining a moderate amount of physical activity on most, if not all, days of the week through a modest increase of daily PA [24]. Additional health benefits can be achieved through a greater amount of PA. People who can maintain a regular regimen of vigorous intensity of PA that is of long duration are likely to derive greater fitness and health benefits [24]. While the knowledge-base on the health risks of sedentarism or inactivity and health benefits of increased regular PA as well as the characteristics of health-enhancing PA have
become increasingly well documented, until recently less has been known how to effectively increase PA on the individual, group, community and population levels. Theoretically based models and practices of PA promotion have been created according to the principles of health promotion, health behavior, and ecological models of health behavior [24].

An important feature of the lifestyle approach is the use of unplanned or planned activities. This makes greater possibilities and opportunities for PA than the traditional approach. By evaluating how their time is spent or how many steps they walk over the course of the day, individuals may be able to organize additional PA into their daily life, such as biking to work or going for a walk at lunchtime. Parking further from the office, getting off the bus or train one stop early, or taking the stairs instead of an elevator may allow people to accumulate activity up to the daily 30 minute or 10,000 steps per day goal. These measures may make part of the schedule to meet activity targets throughout the day [22].

1.4 PHYSICAL ACTIVITY RELATED CONCEPTS

PA is defined as any bodily movement created by skeletal muscles that results in energy expenditure [25]. PA includes sports, exercise and other activities such as playing, walking, doing household chores or gardening. This broad term means that PA includes almost everything that a person performs and physical inactivity is, in contrast, the time spent to do things that do not markedly increase energy expenditure. There is no uniform practical definition of sedentary behavior or physical inactivity. Physical inactivity generally is considered as a relative lack of PA (e.g. not meeting the PA recommendation) [26].

Another related term is physical exercise that is defined as a subset of PA where planned, structured, systematic and repetitive bodily movements are used to maintain or improve one or more components of physical fitness [25]. Physical fitness is a set of attributes that relates the ability to perform physical activities which need aerobic fitness, strength, endurance, or flexibility. Physical fitness is determined by a combination of genetically inherited ability and regular physical activity [25]. Health Enhancing PA (HEPA) is defined as PA that improves health and functional capacity without undue risk or harm [27]. HEPA includes a broader view of PA than physical exercise and acknowledges the health benefits of daily PA such as occupational related PA, chores, and tasks in and around the house [28]. HEPA emerged as a research field drawing its substance from diverse areas of PA related health sciences with powerful elements of both basic and applied research [24]. The primary aim of HEPA research is to establish a reliable evidence-base to improve PA and exercise for the well-being and health of the individual, communities and populations. It is a multi-disciplinary field of research encompassing a broad spectrum of scientific disciplines. These include established sports science disciplines such as sports psychology, exercise physiology, adapted PA, and sociology of sports. Pertinent medical and health science disciplines are epidemiology, rehabilitation, clinical medicine, preventive medicine, sports medicine (SM), health education, behavioral medicine, and health promotion [24].

1.5 PHYSICAL ACTIVITY AND HEALTH

Physical inactivity has indicated to be a major risk factor for several Non-communicable diseases, especially coronary heart disease and stroke. There is scientific evidence to consider physical inactivity as a risk factor of some kind of cancer such as colon and breast cancer, as well as several common neurological disorders such as cognitive impairment, Alzheimers disease and dementia [29]. PA declines these risks and should be considered a part of
rehabilitation and secondary prevention of these conditions. Several previous studies have shown that regular PA plays an important role for the optimal health of the individual as well as for population health [1, 2]. The seminal studies by Morris et al in London, in the 1950s on bus drivers and conductors were among the first to indicate a link between habitual PA and coronary heart disease [30]. The relationship between PA and health outcomes is complex [31]. Hereditary and other factors such as lifestyle, physical and social environments play important roles in the relationship between PA and Health. These factors are often known correlates of PA and they are also important to better understand and identify to design and implement PA interventions for the right group of populations [32]. Regular PA at a certain dose increase health-related fitness even if large individual differences exist [33]. PA provides substantial stimuli for most human body organs, to develop and maintain their functions and structures to provide the requirements of life. Physical inactivity leads to deterioration while regular PA leads to improvement and maintenance in organ function. Many of these effects are related to several conditions that are categorized as disease or their risk factors or precursors. In the musculoskeletal system, PA is effective in reducing the risk of muscle waste or developing sarcopenia, osteoporosis and related fractures, and low back pain, and in rehabilitation and secondary prevention of chronic low back pain and osteoarthritis. Regarding metabolic conditions, overweight and obesity, hypertension, type 2 diabetes mellitus, and metabolic syndrome, physical inactivity will increase the risk while regular PA will be effective in reducing the risk and in the management of these conditions, particularly in combination with the proper diet [29].

Increased regular PA, however, may not be able to abolish, at least not completely, the health risks assumed to be due to physical inactivity since A part of the increased risk associated with physical inactivity may be due to other factors, e.g. other psychosocial factors or living habits, even when these kinds of effects have been attempted to be eliminated by study design and statistical treatments. Genetic factors that increase risk of disease may also decrease people’s responsiveness to PA [29]. The stimulating effects of regular PA will be mediated by gene expression. Genes are considered to have adapted to a state of regular PA on the period of time when our ancestors were habitually active hunter-gatherers [34]. Typical physical activities among these people, such as brisk walking for a long periods of time, caused improved loading to loco-motor, cardio-respiratory, metabolic, endocrine, nervous, and excretory organs, and sustained PA led to adaptations in these organs to increase their tolerance [34].

1.6 PHYSICAL ACTIVITY RECOMMENDATIONS

The earliest PA guideline provided by Swedish National Board of Health and Welfare stated already in the early 1970s: ‘‘Do moderate physical activity daily, in combination with more intense two to three times per week’’ [35], together with the advice on improving dietary habits. PA guidelines from the U.S. as well as from the Nordic Council of Ministers suggest that healthy adults should achieve at least 30 min of daily moderate to vigorous intensity PA or walk a minimum of 10,000 steps per day to improve health and well-being [20, 36]. Two sets of PA and exercise recommendations are frequently referred to. The first is for general health improvement [37], and the second is for strength training and cardiorespiratory fitness [38]. The U.S. National Guidelines for PA from the American College of Sports Medicine (ACSM) and the American
Heart Association (AHA) have recently been updated [39]. According to this update [39], all healthy adults should attain at least 150 minutes per week of moderate intensity aerobic PA (e.g. brisk walking) or 75 minutes per week of vigorous-intensity aerobic PA (e.g. jogging), or a combination of the two intensities, to maintain and promote mental and physical health. Increasing the intensity and volume of daily PA provides additional health benefits [39]. This amount of daily PA can be obtained in short bouts of 10 minutes during the day as a part of an active lifestyle. Muscle-strengthening activities should be done involving major muscle groups on 2 or more days a week [36]. In addition, the updated guideline has separated healthy adults and older adults (older than 64 years), or adults (50-64 years) with chronic conditions.

The significance of PA for public health, the global mandates for the work carried out by WHO in relation to promotion of PA and non-communicable disease (NCD) prevention, and the limited existence of national guidelines on PA for health in low- and middle-income countries underline the need for the development of global recommendations that address the links between the intensity, frequency, duration, type and total amount of PA needed for the prevention of NCDs. The focus of the Global Recommendations on PA for Health is primary prevention of NCDs through PA at population level and the primary target audiences for these recommendations are policy-makers at national level.

Overall, across all the age groups, the health benefits of implementing the above mentioned recommendations, and of being physically active, outweigh the harms. At the recommended level of 150 minutes per week of moderate-intensity activity, musculoskeletal injury rates appear to be rare [36]. In a population based approach in order to decrease the risks of musculoskeletal injuries, it is appropriate to encourage a moderate start with gradual progress to higher levels of PA. Inactive people should start with small amounts of PA and gradually increase intensity, frequency, and duration over time. Older adults, inactive adults, and those with disease limitations will have added health benefits when they become more physically active. In older adults of the 65 years and above age group, PA includes leisure time PA, occupational (if the individual is still engaged in work), transportation (e.g. walking or cycling), play, games, household chores, sports or planned exercise, in the context of daily, family, and community activities.

1.7 PHYSICAL ACTIVITY ASSESSMENT

The recognition of the importance of PA for optimal health has led to an increased interest in assessing PA behavior. PA assessments serve as independent variables in studies determining relationships with health outcomes and behavioral or physiological correlates of PA. PA assessments also serve as dependent variables in studies designed to improve PA. To address progressively more complex questions in these studies, it is essential to obtain an accurate measure of PA [40]. Assessment of PA under free-living conditions is difficult due to its complex nature [41-43]. Many different methods for assessment of PA have been described in the literature. Some methods are adaptable for use with a variety of populations (self-report, pedometer, activity monitors, heart rate monitors, doubly labeled water, and indirect calorimetry), and others have been developed specifically for children (direct observation). Several reviews of PA assessments have explained the relative merits of the various techniques [40]. PA as a construct of body movement can be measured either as the energy expenditure of the body movement, or as the behavior (Figure 1). PA is normally measured in terms of intensity, duration, and frequency. In
addition, PA will take place in several different domains, such as leisure time, occupational, transportation, games, household chores, sports or planned exercise. Ideally, an instrument which aims to measure PA should be able to assess PA in all domains. There is no single method to do that and different approaches often will be used in combination. As shown in a conceptual framework in Figure 1, regardless of the method used, PA scores can be computed to describe the association between PA and health [44]

In short, the methods to assess PA are grouped into three categories including subjective techniques, objective techniques, and reference techniques. Subjective techniques to assess PA are available such as, self reported questionnaires, interviewer administered questionnaires, mail surveys, and diaries. Objective techniques are increasingly used such as pedometers, accelerometers, and heart rate monitors. The most common reference techniques include direct

Figure 1. Principles of PA behaviors and energy expenditure assessments [45]
observation, assessment of total energy expenditure by using doubly labeled water and indirect calorimetry. Each of the techniques has specific advantages and disadvantages that must be considered when selecting an instrument [40].

1.7.1 Assessment of physical activity as behavior

The main objective of assessing PA behaviors is to identify the type of PA and to quantify the amount of body movement people are performing. Direct and indirect methods can be used to assess physical activity across the lifespan. PA as a behavior can be assessed using two conceptually different methods including subjective and objective techniques. Subjective methods to assess PA behavior include self-reported questionnaires, interviewer administered questionnaires, mail surveys, and diaries. Self-report questionnaires are the most commonly used methods in population-based surveys, due to their low cost and ease of implementation. Pedometers, accelerometers, and heart rate monitors are the increasingly used objective methods to assess PA behavior, including smartphone applications to assess distance moved combined with step counting [46].

1.7.1.1 Subjective techniques

Physical Activity Questionnaires (Self-report techniques)

PA questionnaires are the most common measure used to assess PA behaviors in epidemiological studies, and in some intervention and clinical research settings. Asking individuals to report their PA has for a long time been the preferred method to measure PA using detailed PA log books or diaries, or with asking simple questions such as “How often do you exercise in your leisure time?”. Subjective methods are often used in epidemiological studies because of low financial cost, easy to administer, and high feasibility, but they are often hampered by low accuracy [47]. The term self-report techniques include a variety of assessment methods: self-administered questionnaires, physical activity diaries, interviewer-administered questionnaires, and proxy reports (e.g., information reported by parents on children PA patterns) [40, 47]. PA questionnaires used in health-related research can be designed as recall [48], global, and quantitative history questionnaires [45, 47].

International Physical Activity Questionnaire (IPAQ)

To overcome problems with the existing PA assessment instruments, in 1998, a group of researchers from centers for disease control and prevention (CDC), Karolinska Institutet, and University of Sydney invited a group of global researchers to World Health Organization (WHO) headquarters in Geneva, to develop a standardized questionnaire measuring all types of health-related PA (walking, moderate and vigorous PA) to use in many different culture settings. This group of researchers proposed and developed the International Physical Activity Questionnaire (IPAQ) [48, 49]. The questionnaire assesses time spent in walking and moderate to vigorous intensity PA in the seven days prior to IPAQ completion. The IPAQ has a short and a long version.
The short form (IPAQ-short) has 7 items and long form (IPAQ-long) is available with 27 items. The short version of the IPAQ includes 7 items to assess the hours per day and days per week spent in combined forms of recreational, occupational, transportation, and household moderate and vigorous intensities, walking activities, and inactivity. The short version IPAQ has been piloted in several different countries to assess validity and reliability [48]. The results indicated that the questionnaires are acceptable for use in different languages and in different settings, and suitable for national population-based prevalence studies. The short IPAQ has seven items about the number of days per week (frequency) and hours and minutes per session (duration) spent in moderate-intensity (4.0 Metabolic energy turnover (METs)) and vigorous-intensity (8 METs) PA and walking (3.5 METs) during the past week. The IPAQ is scored by (a) multiplying the frequency, duration, and MET intensity values for each PA to compute MET-minutes, and (b) identifying combinations of days and minutes per day spent in moderate- and vigorous-intensity PA. Three categories of PA are identified: low, moderate, and high. The long version of the IPAQ separates the different domains of PA (e.g., occupational, transportation, household, walking, moderate intensity exercise, vigorous intensity exercise, and sitting). The use of self-reporting technique to assess PA is well known to be subject to error. For example it has been shown that IPAQ overestimates PA compared with accelerometer [50, 51] and compared to doubly labeled water, IPAQ underestimates PA energy expenditure [52]. Otherwise, research indicates that IPAQ is able to relatively accurately discriminate between people that met the PA recommendation and those who did not [51]. The questionnaires are produced in various languages and details about the IPAQ scoring protocol can be obtained at [53].

1.7.1.2 Objective techniques

Motion detectors are mechanical and electronic instruments worn on the body to provide a direct measure of body movement. Pedometer and accelerometer are the most commonly used objective devices for measuring PA. Heart rate monitoring devices [54] and a new kind of a combined technique [55] are also commonly used objective techniques for measuring PA. For example ActiReg® (PreMed AS, Oslo, Norway) is a device that combines movement and body posture with heart rate. This device measures the PA energy expenditure in three categories including low, moderate and high.

Pedometer

Pedometer has gained widespread popularity in practice and research settings to quantify walking directly in terms of accumulated steps in free-living conditions. Pedometer with all its modern features may seem to be a recent invention, but the history of the pedometer dates back and it seems credit for the invention of the pedometer goes to Leonardo da Vinci in the 15th century when he developed the idea of a mechanical device to monitor the distance walked by roman soldiers on foot [56]. Used originally by physical fitness and sports enthusiasts, pedometers are now popular as a daily PA recorder and motivator. The pedometer is a popular tool for recording steps and improving PA behaviors [57, 58]. The pedometer is a simple, affordable, accessible, enjoyable, motivational, and user friendly body-worn movement counter but cannot give any information about intensity, frequency, or duration of PA [8], since it is
designed to count the number of steps taken [58, 59]. Pedometers are worn on the hip and detect the vertical force transmitted through the hip, representing a step. Different brands of pedometers have shown high validity with respect to number of steps taken and can estimate distance walked if stride length is known. Most pedometers estimate mean distance but they might overestimate distance at slower speeds and underestimate distance at faster speeds [60]. The high quality pedometers have been proven as a valid and reliable method to measure ambulatory movement [61]. Generally, pedometers are most accurate for assessing steps, less accurate for assessing distance, and even less accurate for assessing energy expenditure or kilocalories [60]. The cheaper brand pedometers are not recommended for research studies [62]. Pedometers can also be used to estimate PA energy expenditure by estimating the energy cost associated with walking activity. Thus the output can be displayed in various ways, including steps, distance, and calories. The main advantages of pedometers are the ease of use and the low cost, and the primary disadvantages of these devices are the inability to examine the rate or intensity of movement, and the inability to record non-locomotor movements. The pedometer is useful in a variety of settings where an objective, inexpensive measure of PA is needed and as an intervention tool for increasing awareness of daily number of steps. They are helpful in projects that range from cross sectional research studies and investigations relating PA to health outcomes to longitudinal interventions designed to improve activity in sedentary populations, more as an awareness-raising device than as an accurate PA assessment device. Pedometer scores have also been used as an outcome measure in PA intervention studies. The modern versions of pedometers are more advanced and becoming more similar to accelerometers. Simple pedometers are nowadays available as smartphone applications, where they can be combined with GPS to assess distance. Figure 2 shows an example of the type of pedometer (Yamax SW-200) that was used in the ASUKI Step Study.

Figure 2. An example of a pedometer (Yamax SW-200) used in ASUKI Step Study
Activity monitors (Accelerometers)

Accelerometers have become one of the most popular techniques for assessing PA in free-living conditions [63]. These instruments typically use an electronic component within the device designed to measure acceleration (the rate and magnitude) of the bodily movement in a specific dimension as uniaxial (vertical) or in multiple dimensions (vertical plus mediolateral and anteroposterior) [40, 47]. Acceleration describes the changes in speed with respect to time (e.g., change in position), which is assessed in gravitational acceleration units (e.g., 1 g = 9.8 m.s$^{-2}$). Accelerometers are commonly worn on the waist belt, ankle, or arm. Detailed information of the PA intensity, duration, and frequency can be obtained using accelerometers over extended periods of time (weeks), but it is normally used for about a week [55]. Accelerometer is used to identify bodily movement patterns, quantify association between physical activity behaviors and health outcomes, and validate PA questionnaires [54].

Actigraph (AG) is one of the more commonly used accelerometer-based activity monitor. The AG accelerometer model GT1M which used in ASUKI Steps Study (Figure 3) weighs 27 grams and has the dimensions 3.8 $\times$ 3.7 $\times$ 1.8 cm. The AG provides information on frequency, intensity, and duration of PA by utilizing a built-in single axis accelerometer which measures vertical accelerations at the hip. It is designed to detect accelerations ranging in magnitude from approximately 0.05 to 2.00g with a band limited frequency response from 0.25 to 2.5 hertz. The manufacturers indicate that these parameters have been carefully chosen to detect normal human motion and to reject motion from other sources (e.g., vibrations while driving or on a train). The uniaxial monitors have been extensively tested for validity, reliability, and are also used in the studies with large sample sizes. Validation studies have been done to establish cut-offs for different intensities to estimate time spent at moderate and vigorous PA [64-66]. The AG accelerometer correlates significantly with activity energy expenditure ($r = .82 - .89$) compared to walking and running on treadmill [67], and it correlates significantly with maximal oxygen update during level treadmill walking at varying speeds ($r = .80 - .95$) [68]. It is determined that to characterise PA behaviors (moderate and vigorous PA) with at least 80% reliability, persons needed to wear the AG at least for 3-4 days continuously and 7 days to determine physical inactivity behaviors [69].

Figure 3. An example of an accelerometer (AG, model GT1M), used in ASUKI Step Study
The device provides information about body movement, or the intensity of acceleration at user-specified intervals which can be downloaded to a computer for data processing. It is important to note that the acceleration of the hip (or other part of body if accelerometer attached elsewhere) will be measured by accelerometer, not the absolute acceleration of the person as he or she moves in a car. In other words, the limitations to accelerometers include inability to detect with accuracy a wide array of PA, including upper-body movements (if the device is worn at the hip), walking on an incline, carrying a heavy load, or other non locomotor movements. Nevertheless, accelerometers are attractive to researchers for several reasons. Activity monitors are very easy to operate (e.g., initializing, downloading the data), you can collect data over an extended period of time (e.g., several weeks), and they are very light and non-invasive for participants. Unfortunately, the high cost of commercially available accelerometers still prohibits using the monitors for most studies with large sample sizes.

1.7.2 Assessment of physical activity as energy expenditure

Energy expenditure is also used as a composite measure of PA. An advantage of energy expenditure as an outcomes measure is that it takes into account individual demographic variables such as body size and intensity of PA. For example, moderate PA requires a smaller effort than vigorous activity, and larger people need to expend a greater amount of energy for a given amount of PA [40]. A common unit that is used for calculations of energy expenditure is multiples of resting energy expenditure (METs), and the accepted figure for resting energy expenditure is 3.5 ml.kg\(^{-1}\).min\(^{-1}\) oxygen consumption. People expend energy when they are physically active, of course, they also expend energy while at rest. Depending on activity level, about two-thirds of the energy that the average individual expends in a day is used for the body’s basal metabolism for an inactive person. Metabolic activities maintain the body temperature, the heart beating 100,000 times a day, keep the lungs inhaling and exhaling air, the bone marrow making new blood cells, and the kidneys filtering waste. In short, they support all the basic processes of life [70]. Most of the methods allow for an estimation of energy expenditure, but the approach used to calculate this estimate is different for each technique. Indirect calorimetry and doubly labeled water are based directly on physiological processes and therefore provide an accurate determination of energy expenditure [40]. The doubly labeled water method is recognized as the reference method (gold standard) for the assessment of energy expenditure in free-living conditions [71]. Total daily energy expenditure in kcal/day is derived from doubly labeled water [72]. In doubly labeled water method individuals drink a standardized amount of the two stable isotopes \(\text{H}_2\text{O}\) (deuterium) and \(\text{H}^\text{18}\text{O}\) (oxygen-18), which compose doubly labeled water (\(\text{H}_2\text{O}^\text{18}\)), and it is allowed to return to a normal lifestyle with urine samples collected and measuring the elimination of \(^2\text{H}\) and \(^1\text{O}\) from the individual’s body, total carbon dioxide (\(\text{CO}_2\)) production will be determined for the assessment period and, ultimately, an estimation of PA energy expenditure. Aside, from determining daily PA energy expenditure, total body water is derived from doubly labeled water. The total body water is used to estimate fat and fat-free mass. Thus, if people are told that body composition is being tested instead of PA, they may be less likely to change their daily routine [72]. This method is mainly used for validation studies of dietary intake and it is a powerful method for the accurate assessment of daily energy expenditure, but it is very expensive and not well suited for population-based studies. The main outcome of the doubly labeled water is energy expenditure. Intensity, frequency,
and duration of PA cannot be determined, but incorporation of indirect calorimetry allows the energy expenditure of activity to be determined [72].

Energy expenditure or the capacity of human bodies for doing work can be measured by direct or indirect calorimetry methods. Direct calorimetry method assesses energy expenditure by directly measuring heat production, such as a calorimetric chamber to assess energy content of foods. The indirect method assesses energy expenditure by measuring O₂ consumption. In the other word, in indirect method, energy expenditure will be calculated from respiratory exchange ratio of CO₂ and O₂. It is clear that heat production is equal to liberated chemical energy, thus the indirect method can be used to measure energy expenditure by indirectly assessing O₂ consumption association with metabolizing food items and not by directly assessing production of heat [72]. Indirect calorimetry is considered as an accurate and valid method of short term energy expenditure using a portable and computerized tool.

1.8 PHYSICAL ACTIVITY CLASSIFICATIONS

Exercise or PA intensity could be considered as a continuum from rest through to intense effort. The muscular contraction rate, and the force required by muscle with each contraction will determine the energy demands. These energy requirements in turn determine the ATP resynthesizing rate in the body. As the demand increases, the body will increase its cardiac output and utilization of oxygen (VO₂) to provide this demand using the aerobic energy system. For example, moderate intensity is defined either as PA which needs 40-50% of a subject’s Heart Rate Reserve (the difference between maximal and resting heart rate) or VO₂ reserve (the difference between maximal and resting oxygen consumption) or 55-69% of individuals’ Maximal Heart Rate [22, 73]. A revised PA chart presented by Howley indicates the absolute intensity levels in terms of maximal aerobic capacity rather than age. This allows the different exercise intensity classifications (e.g., very light, light, moderate, hard, very hard, and maximal) to be compared for subjects with varying levels of fitness (Table 1) [74]. As Table 1 indicates for hard PA, the intensity range from 3.4 to 4.3 METs for a person with a VO2 max of 5 METs and from 7.6 to 10.2 METs for a person with a VO2 max 12 METs [74].
PA as a behavior can be categorized in several ways. PA is often characterized by type, intensity, duration, and frequency. PA can also dichotomize into leisure or occupational, weight bearing or non-weight-bearing, continuous or intermittent, as well as other classifications. Different types of PA could be commonly equated through metabolic equivalents (METs). One MET will be considered to represent resting energy expenditure, or approximately equal 3.5 ml/kg/min oxygen consumption. 1 MET is roughly equivalent to 1 kcal per kilogram body weight per hour (1kcal/kg/hr). Since progressively more vigorous forms of PA need proportional increases in oxygen consumption, physical activities can be quantified in terms of multiples of this resting oxygen consumption (3.5 ml/kg/min). Activities that require 5 times the oxygen consumption of rest could be defined as 5 METs, and another that need 9 times the resting level would be considered as 9 METs. The METs system allows all forms of PA to be considered and compared on a standard scale. For example bicycling and walking are very different in terms of form and type of activity, but the overall oxygen consumption and aerobic challenge to the body could be compared in terms of oxygen consumption or METs. Using METs classification and taking into account the decrease in resting metabolic rate and maximal exercise capacity (VO2 max) that occur with age, moderate intensity PA has been defined for different age groups in Table 2 [22].

<table>
<thead>
<tr>
<th>Intensity</th>
<th>%HR max&lt;sup&gt;a&lt;/sup&gt;</th>
<th>%VO2max&lt;sup&gt;b&lt;/sup&gt;</th>
<th>RPE&lt;sup&gt;c&lt;/sup&gt; (Borg scale)</th>
<th>5 METS&lt;sup&gt;d&lt;/sup&gt;</th>
<th>8 METS</th>
<th>10 METS</th>
<th>12 METS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>&lt;50</td>
<td>&lt;20</td>
<td>&lt;10</td>
<td>&lt;1.8</td>
<td>&lt;2.4</td>
<td>&lt;2.8</td>
<td>&lt;3.2</td>
</tr>
<tr>
<td>Light</td>
<td>50-63</td>
<td>20-39</td>
<td>10-11</td>
<td>1.8-2.5</td>
<td>2.4-3.7</td>
<td>2.8-4.5</td>
<td>3.2-5.3</td>
</tr>
<tr>
<td>Moderate</td>
<td>64-76</td>
<td>40-59</td>
<td>12-13</td>
<td>2.6-3.3</td>
<td>3.8-5.1</td>
<td>4.6-6.3</td>
<td>5.4-7.5</td>
</tr>
<tr>
<td>Hard</td>
<td>77-93</td>
<td>60-84</td>
<td>14-16</td>
<td>3.4-4.3</td>
<td>5.2-6.9</td>
<td>6.4-8.6</td>
<td>7.6-10.2</td>
</tr>
<tr>
<td>Very hard</td>
<td>&gt;94</td>
<td>&gt;85</td>
<td>17-19</td>
<td>&gt;4.4</td>
<td>&gt;7</td>
<td>&gt;8.7</td>
<td>&gt;10.3</td>
</tr>
<tr>
<td>Maximal</td>
<td>100</td>
<td>100</td>
<td>20</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

<sup>a</sup>%HR max: percentage of maximal heart rate  
<sup>b</sup>%VO2 max: percentage of maximal oxygen uptake  
<sup>c</sup>RPE: Rating of perceived exertion (RPE), is a subjective scale. The RPE uses a 6 – 20 point Borg scale that describes exertion from very, very light to very, very hard  
<sup>d</sup>METs: metabolic energy turnover
1.9 WORKPLACE-BASED HEALTH PROMOTION PROGRAMS

Worksites are ideal settings for promoting PA programs. Worksites often provide opportunities for PA through on-site facilities, trails or locations for exercise and may also provide social support for employees to attain in physical activity programs. It is acknowledged that the workplace is an excellent environment to implement health promotion programs, particularly those with a goal to improve the PA levels, as the majority of employees spend half their waking hours there. Worksite wellness programs are effective in helping to control health care cost associated with illness, disease, and disability. Accordingly, most employers know that employer-sponsored health promotion programs are effective ways to reduce health care cost due to modifiable risk factors and to increase productivity [76]. The benefits to the employer of implementing health promotion programs in the worksite can include healthier workers resulting in increased productivity within the workplace, job satisfaction, reduced absenteeism, improved workplace morale, decreased job stress and staff turnover, and increased energy levels amongst staff [76]. Worksite-based employee health promotion programs are recommended by the U.S. Guide for Community Preventive Services to promote PA, reduce obesity and prevent chronic disease in adults [77].

1.10 WALKING AS THE KEY COMPONENT OF A LIFESTYLE PA APPROACH

Walking as a moderate-intensity form of PA has a positive impact on health [78]. It is popular, accessible, and there is no need for facilities or expensive equipment to walk [78]. Walking is frequently reported as a moderate intensity aerobic PA that adults can engage in throughout the day to reach the minimal goal of 150 minutes per week [7, 79]. Several studies have also indicated that walking 30-60 minutes per week is beneficial in reducing risk of chronic NCDs [80]. More importantly for the current discussion, walking is a very versatile PA that is perfectly suited and likely to be the cornerstone to a lifestyle approach to PA. If subjects choose gym-based exercise or swimming to meet their daily PA targets, it is unlikely that they choose a lifestyle approach. Subjects who choose walking however could accumulate the walks as a part of their daily routine in a lifestyle approach. From a practical standpoint, when individuals consider how they may be able to incorporate additional PA in the daily routine, walking is an obvious point to start. Parking further from the office, getting off the train or bus one stop earlier, walking during breaks or lunch time, walking with friends, family are relatively simple additions to a daily routine [81]. Lifestyle PA approaches are difficult to perform, due to the long intervention periods needed for

<table>
<thead>
<tr>
<th>Age groups (years)</th>
<th>Moderate intensity PA (METs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-39</td>
<td>4.8-7.1</td>
</tr>
<tr>
<td>40-64</td>
<td>4.0-5.9</td>
</tr>
<tr>
<td>65-79</td>
<td>3.2-4.7</td>
</tr>
<tr>
<td>80+</td>
<td>2.0-2.9</td>
</tr>
</tbody>
</table>
maintenance and due to the difficulty of finding control groups and to identify funding for such long term controlled trials. A new initiative from the American College for Sports Medicine is dealing with this, in a project related to the US Comparative Effectiveness Research initiative (ADD REF). This initiative is much more related to how research can take place in reality, using client-oriented approaches, rather than clinical exactness in order to reach larger audiences [82, 83].

1.11 10,000 STEPS PER DAY: A PUBLIC HEALTH RECOMMENDATION

Hatano has proposed accumulating 10,000 steps per day as a public health recommendation to confer health benefits [41, 58]. This goal was originally established in Japan by evaluating the number of steps taken per day using an electronic device (pedometer). A pedometer was first used in Japan in 1965 and is known Manpo-kie which means “10,000 steps meter” [58]. The pedometer, along with the goal of 10,000 steps per day, has received considerable attention in the media, research, and practice areas over the last few years [84]. Public health researchers recommend that walking at least 10,000 steps a day has beneficial health effects [60]. Walking 10,000 steps per day expends about 2,000 kcal energy per week, and thus this amount of daily PA is suitable to improve health and prevent chronic diseases such as obesity and diabetes mellitus [60]. Using pedometers to track walking, Awain et al. showed that walking at least 10,000 steps per day resulted in reductions in elevated BP and an improved exercise capacity in hypertensive adults [85]. Other studies support walking at least 10,000 steps a day to promote health and prevent cardiovascular disease [60, 79, 85]. The steps recommendation could apply to most adults, regardless of body size. In contrast, kcal-based recommendations do not apply equally to small and large subjects. For example, young individuals could accumulate recommended steps through running or vigorous exercises, middle-aged individuals could perform brisk walking, and elderly people could walk at a moderate pace. The 10,000 steps per day recommendation is highly beneficial to a sedentary population whose barriers to PA might include a dislike to perform vigorous sports or lack of access to gym or traditional fitness center facilities.

While pedometers do not capture all activities (e.g., cycling and swimming), the 10,000 steps recommendation remains attractive for the aforementioned reasons. It should be emphasized, however, that at present the recommendation has not undergone comprehensive scientific investigation to establish its true physiologic effects, and there is a strong scientific demand to establish the health outcomes of accumulating a targeted number of steps per day. More recent studies have used pedometers to monitor the walking dose with a minimum goal of walking 10,000 steps per day instead of walking a specified number of minutes per week to achieve better health outcomes [86-89]. Setting the goal at 10,000 steps per day has been debated over the several last years [58], in the media and in research and practice areas [84, 90, 91]. Preliminary evidence suggests that the goal of 10,000 steps per day may not be sustainable for people living with chronic disease or old adults. Another concern about 10,000 steps per day as a universal goal is that it is probably too low for children to prevent obesity [58]. Welk, Differding et al. [92] has compared the recommendation of 10,000 steps per day with the traditional public health PA guidelines and they showed a reasonably good correspondence between the two. Participants who performed >30 min of total PA during the day attained the 10,000 steps goal 73% of the time. Conversely, only around 30% of the participants who did <30 minutes of self-reported PA reached 10,000 steps a day.
1.12 ASSESSMENT OF BODY COMPOSITION

Body composition is referred to the body’s chemical composition. Several models are discussed regarding BC including chemical (fat, protein, carbohydrates, water, and mineral), anatomical (adipose tissue, muscle, organs, bone, other), and two-component models (fat mass and fat free mass) [93]. BC is the term used to describe the different components that, when taken together, make up a person's body weight. Over the past 70 years, numerous studies have focused on BC and how best to measure its various components. Most methodologies partition the body into two distinct compartments including (1) fat-free body mass, and (2) body fat mass. Body Composition studies expanded the two-component model to account for biologic variability in three (water, protein, fat) or four (water, protein, bone mineral, fat) distinct components [94]. Fat mass is often discussed in terms of relative body fat, that is the percentage of the total body mass which is composed of fat and fat free mass simply is referred to all body tissue that is not fat [93].

Women and men differ in relative quantities of specific BC. Consequently, gender-specific reference standards provide a framework for evaluating “normal” BC. BC is one of health-related components of physical fitness [25]. Standard body weight scales provide a measure of total weight, but don't determine the lean-to-fat ratio of that weight. Standing on most scales can tell you only if you weigh more than the average person, but not if that weight is fat or muscle. There are many advanced methods of assessing a person's BC including under-water weighing (hydrostatic weighing or hydrodensitometry) [93], Dual-energy X-ray Absorbiometry (DXA) [93], and Air-Displacement Plethysmography (using a device such as a BOD POD for measuring total body volume by air displacement) [93]. Other procedures to predict body fat use skinfold thickness and girth measurements [95], total-body electrical conductivity or impedance (bio-electrical impedance analysis (BIA)) [94], ultrasound, computed tomography, magnetic resonance imaging (MRI) [94] and basic measurements of body weight and height to calculate Body Mass Index (BMI) which is the simplest, frequently used, and most convenient method for assessing the relative proportion of fat mass in the groups. Many laboratory techniques are available to assess BC, so we will discuss BIA in this section, and other anthropometric variables such as BMI, waist circumference (WC), and sagittal abdominal diameter (SAD) will be explained in the methods and discussion (methodological considerations) sections.

Bioelectrical Impedance Analysis (BIA)

BIA is a method of measuring BC. There are a variety of BC and body fat analyzers to examine total weight, the percent and amount of body fat, water, muscle mass, and even bone mass. While the readings can be affected by food intake, skin temperature, hydration levels, and other factors, if you follow the directions and take the reading under similar conditions, you will obtain the best results from BIA. Tanita (Tanita Body Composition Analyzer. Model TBF-300A; Tanita Corporation: Arlington Heights, IL) as shown in Figure 4 was used in ASUKI Step Study to assess BC characteristics. This device utilizes a patented “foot to foot” pressure contact electrode Bioelectrical Impedance Analysis technique. The BIA is based on the fact that lean tissues have a higher water content, and thus provide a good electrical pathway. Fat mass contains a lower percentage of body water, and thus is a poor conductor for the electrical signal. By inducing a low energy, high frequency, electrical signal (50 kHz 500 microamp), a measurement of the baseline resistance to the flow of electrical current can be made. This current is passed through the anterior electrode platform, and the voltage drop is then measured on the posterior electrode. The resistance
measurement relates directly to the volume of the conductor which is used to assess total body water, lean body mass and fat mass. Percent body fat, as calculated by the Tanita scale, is a highly researched proprietary formula combining impedance and weight measurements with height, age and gender information. Weight, BMI, Fat Mass, Fat Free Mass (FFM), and Total Body Water (TBW) will be determined using BIA [94].

Figure 4. Tanita BC Analyzer (Model TBF-300A), foot-to-foot bioelectrical impedance analysis used in ASUKI Step Study

1.13 BODY COMPOSITION AND EXERCISE PERFORMANCE

Body composition can affect an athlete’s agility, appearance, endurance and strength [96]. Weight and Body composition are two of the important factors that contribute to optimal physical exercise performance. Taken together, these factors may affect an athlete’s potential for success in a given physical exercise [96]. A lean body, for example, individual with a larger muscle to fat ratio, is often advantageous in exercise where speed is involved. To find the right balance between weight, hydration, muscle and fat and reach peak performance, it is important to observe body composition variables over time and in conjunction with your training program. Generally, having a relatively low body fat percentage may improve athletic performance by increasing the strength-to-weight ratio and decreasing resistance. On the other hand, having too little body fat could be dangerous, as it is an essential energy store, which is very important for endurance sports and race training [96]. Muscle mass and body fat percentage varies depending on the athlete’s gender and the Kind of physical exercise and sport. A person’s optimal 'body fat-to-muscle ratio' must therefore be determined on an individual basis. Because the amount body fat, not total weight, is the most important factor in living a healthy lifestyle. As you do exercise more, your weight may not change, even if your muscle mass increases and your body fat percentage drops. This change will ultimately affect your Basal Metabolic Rate (BMR) and hydration levels and your diet should be changed accordingly [96]. Body size and composition is one of the most important fitness
components for success in many physical exercise and sports. For many individuals, this is an area that they concentrate on to achieve an optimal body shape for their sport. Consequently, many exercise or training programs focus to modify body composition and size in some way. Training program could be effective in changing muscle and fat proportions and distribution in the body [97].

Body composition can also significantly affect PA performance. Body composition and size can be considered very important in sports where you have an advantage of being small (jockeys), tall (e.g. basketball) or light (e.g. gymnastics) or, heavy (e.g. sumo wrestling). In many other kind of sports, including team sports, correcting body size and composition is also important as a part of the overall fitness profile [97]. There is considerable evidence that excess body fat is detrimental to PA performance. It was determined that the added weight significantly and systematically decreased VO2 max expressed relative to body weight [98].

1.14 PHYSICAL ACTIVITY AND CARDIORESPIRATORY FITNESS

Physical exercise has well-documented positive effects on the cardiorespiratory system in both healthy and unhealthy subjects. In healthy people regular PA has large long-term health benefits with very few direct risks. For the vast majority of subjects with known cardiovascular disease regular PA has positive effects regarding their quality of life, and may reduce morbidity and mortality. In subjects with known cardiovascular disease PA programs should, however, be individualized with respect to the underlying health problem [99].

The cardiovascular system delivers oxygen and nutrients to, and removes CO2 and other metabolic waste products from every cell in the body [93]. This system also transports hormones from endocrine systems to the target receptors as well as supports body temperature regulation and the blood’s buffering capabilities control the body’s PH. This system maintains appropriate fluid balance in the body and helps prevent infection from invading organisms. Although these functions are just an abbreviated list of roles, the cardiorespiratory functions listed here are important for understanding the physiological basis of PA. Obviously these roles will be changed with the challenges imposed during exercise [93].

The functional consequences of physical training can be reflected by CRF as an objective measure [100]. Recent studies showed that the link between poor CRF and cardiovascular mortality is mediated by the development of several cardiovascular disease risk factors such as adiposity, dyslipidemia, hypertension, and glucose intolerance [100, 101]. People of all age groups can improve their health and quality of life through a regular lifelong moderate- and vigorous-intensity PA designed to increase CRF [102].

Cardiorespiratory fitness as a physical fitness component reflects the overall functional capacity of the cardiovascular and respiratory systems and the ability to perform prolonged and strenuous physical exercise [25, 103]. Many terms have been used in the literature to describe the physical fitness component including cardiorespiratory fitness, cardiorespiratory endurance, cardiovascular fitness, aerobic capacity, aerobic power, aerobic fitness, maximal aerobic power, physical work capacity, and aerobic work capacity [104]. Another important related term is maximal oxygen uptake, or maximal oxygen consumption (VO2 max). VO2 max is generally accepted index of CRF and functional aerobic capacity. VO2 max as an objective measure of CRF attained during a graded maximal exercise [105]. VO2 max or maximal oxygen consumption is indicated either as an absolute rate (l/min), or normalized by body weight as a relative rate (ml/kg/min). The relative rate is often used for comparison of performance of endurance sports athletes. There are two methods to measure maximal oxygen uptake or aerobic capacity (VO2 max) including maximal graded
exercise tests (GXT) and sub-maximal tests. Currently, the criterion method of assessing CRF is the direct assessment of maximal oxygen uptake (VO\textsubscript{2} max) at a maximal GXT. However, the direct measurement of VO\textsubscript{2} max is often limited to the field of sports, clinical, and laboratory setting, because it is costly and needs trained personnel and specialized equipment [100, 106, 107]. In maximal exercise tests, the individual bikes or runs until total exhaustion. Sub-maximal exercise tests are based upon the linear relationship between workload and the subject’s heart rate response and they are safe and more acceptable to the participants [108]. The Council of Europe’s expert group on adult health-related fitness has suggested targets for the given age and sex groups, for health-related aerobic capacity (Table 3). Several studies with random samples of national or local adult populations exhibit consistent age-dependent decline in maximal oxygen uptake in both men and women [109].

Table 3. Optimal target levels of VO\textsubscript{2} max suggested by European Council [109]

<table>
<thead>
<tr>
<th>Age group</th>
<th>Sex</th>
<th>VO\textsubscript{2} max (ml.kg\textsuperscript{-1}.min\textsuperscript{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>Male</td>
<td>46-52</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>42-48</td>
</tr>
<tr>
<td>60-70</td>
<td>Male</td>
<td>35-40</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>30-35</td>
</tr>
</tbody>
</table>

During exercise heart rate and blood pressure increase, resulting in increased myocardial oxygen demands. The autonomic tone will be changed towards increased sympathetic activity. Depending on the intensity and duration of PA, and climatic conditions, metabolism will change towards lactic acidosis and electrolyte imbalances might occur. It should be emphasized that higher levels of physical fitness appear to delay all-cause mortality, with mortality rates found to be 3.4 and 4.6 times higher among the least fit subjects compared with the most fit men and women, respectively [110]. While total mortality among physically active individuals is less than among the inactive people, there is an increased risk for myocardial infarction or sudden death during PA as compared with during rest [99]. In ASUKI Step Study, estimated maximal oxygen uptake was obtained using Submaximal Åstrand-Rhyming Cycle Test [111]. The test was conducted on a Monark bike ergometer model 839E. The test procedure is described in more detail in methods section.

1.15 PHYSICAL ACTIVITY AND BLOOD PRESSURE

Regular physical exercise causes a series of physiological responses resulting from hemodynamic and autonomic adaptation that affect the cardiovascular system. Several studies have indicated PA’s beneficial effect on blood pressure. Regular PA and CRF are associated with an inverse risk of hypertension [112]. Chronic hypertension is intimately associated with increased risks of coronary heart disease, stroke and heart failure [113]. Regular PA has been indicated to be one of the most effective nonpharmacological treatments or as adjuvant to drug treatment in hypertensive patients [85, 114]. Investigators found significant reductions in resting BP of hypertensive patients after regular physical activity. Programs of moderate intensity aerobic exercise and light exercise may have similar effects on blood pressure in previously sedentary older individuals [115]. A study showed that rates of systolic and diastolic hypertension were significantly lower in women participating in low, moderate, or vigorous PA compared to sedentary women [116]. Evidence
indicates that exercise is a cornerstone therapy for the prevention, treatment and control of hypertension [117]. The risk of high blood pressure will increase with age, but getting some physical exercise makes a big difference, and if the blood pressure is already high, exercise can help to control it. People don't need to join a gym or run a marathon. Instead, they can start slow and work more PA into their daily routine. Therapeutic lifestyle changes are important for the prevention and management of, as well as adjuncts to, pharmacotherapy of hypertension. Regular, moderate-intensity aerobic exercise training for 30 to 60 minutes, 3 to 5 times per week, can lower systolic and diastolic BP, with a greater reduction observed in patients with hypertension compared to those with normal BP levels [118]. A diet rich in vegetables, fruits, and whole grains, with a moderate intake of fat-free or low-fat dairy products, and low in saturated and total fat, sodium, and alcohol, such as the dietary approaches to prevent hypertension, also significantly reduces BP levels [118]. A therapeutic lifestyle change program including dietary modifications and regular exercise along with weight management can result in a greater BP reduction than either intervention alone [118]. Therapeutic lifestyle changes can also significantly decline other risk factors for cardiovascular disease commonly accompanying hypertension. For exercise, these include improvements in arterial endothelial function and compliance, left ventricular structure and function, and perhaps vascular blood supply with improved cardiorespiratory endurance [118]. The evidence is robust in support of therapeutic lifestyle changes for management of elevated BP and for the primary prevention of hypertension, supporting the recommendations by the joint national committee seventh report on prevention, detection, evaluation, and treatment of high blood pressure and the European Society of Hypertension guidelines [118, 119].

1.16 RATIONALE FOR THIS STUDY

According to the WHO health is “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” [120]. PA has long been associated with promoting advances in well-being, and can improve positive mental health states and alleviate negative mood states. Although the worksite has been recommended as an appropriate setting for improving lifestyle PA, and the pedometer is found to be an effective tool to promote PA, only a limited number of workplace programs, using pedometer as intervention tool, could be found in the literature [121]. Research that extends our knowledge of the extent to which PA can promote well-being, and the conditions in which this effect can be maximized is important for informing future practice and research. Furthermore, the public health burden of physical inactivity or sedentarism is huge and it is very important to target the right population when planning PA interventions. As well as, the resources to promote PA in the population are limited and should be utilized effectively, in order to enable the formulation of better public health strategies and health promotion programs, to be able to follow and evaluate health promoting PA interventions, feasible and valid tools are needed to assess the pattern and level of health-enhancing PA programs in the population. The papers included in this thesis target to advance the field of PA assessment and health promotion in workplace settings.
2 AIMS

The overall purpose of the ASUKI Step Study was to increase the understanding of the associations among pedometer-determined PA interventions to increase PA and reduce physical inactivity in adults employed in worksite settings in the ASU and KI, and to better understand the associations among PA, BC characteristics, resting BP, and CRF. The papers forming this thesis are parts of the ASUKI Step Study and include the following specific objectives:

1. To enroll at least 1400 staff at each site in the ASUKI-Step project in teams (3-4 persons/team) or as individual participants (paper I)
2. To use pedometers (step counters) as the main intervention tool (papers I-V)
3. To use additional physical activity information from accelerometers to the information from step counters in a randomly selected subgroup of 150 staff at each site (Paper II)
4. To examine the changes in daily steps over time among participants in the ASUKI Step program and to describe the socio-demographic predictors of month one step counts and changes in steps over time (paper II)
5. To examine the socio-demographic characteristics (e.g., age, gender, educational level and work position) that were associated with meeting the goal of 10,000 steps/day for at least 100 days in a mixed group of employees (paper II)
6. To examine changes in objectively measured PA over time in a subset of individuals and the socio-demographic characteristics associated with baseline PA and changes over time (paper II)
7. To estimate how helpful a six-month pedometer-determined PA intervention in university settings can be in regards to changes in BP, and CRF (paper III)
8. To estimate how helpful a six-month pedometer-determined PA intervention in university settings can be in regards to changes in anthropometric measures (papers IV and V)
3 MATERIAL AND METHODS

The papers presented in this thesis are parts of the “ASUKI Step Study”. The acronym ASUKI represents a collaborative six-month pedometer-determined workplace PA intervention with three months follow-up between university staff from ASU and KI, to increase PA by walking 10,000 steps per day. “ASUKI Step” was designed to evaluate the impact of a worksite pedometer intervention at increasing PA levels, decreasing inactive days and improving physical fitness and health outcomes in university employees.

3.1 ETHICS

The study was undertaken in ASU and KI after approval by the Research Ethics Committees of the ASU and KI, and the study was carried out in accordance with the national guideline (Medicinska forskningsrådet), and the 1975 Helsinki Declaration (revised in Hong Kong in 1989). Participants were provided with information about aims, methods, and objectives of the study before the start of monitoring of their PA using pedometers. Participation was voluntary and participants gave written informed consents before inclusion the study, and were informed that they could withdraw from the study if they wished. The study was also registered as a clinical trial (ClinicalTrials.gov Identifier: NCT01537939).

3.2 SAMPLE AND STUDY DESIGN

The study used a single-group, pre-post, quasi-experimental design and the intervention was based on the theory of social support [122]. The study included 2,118 faculty, staff, and graduate students from ASU (n = 712, 82.5% female) and KI (n = 1,406, 78.0% female) who participated in teams of 3-4 persons (Figure 5). ASU recruited participants from the Tempe (n = 492), Polytechnic (n=91), and the Downtown Phoenix campuses (n = 129). KI recruited participants from the Solna (n = 865) and Huddinge campuses (n = 541). The average age for participants was 42.4 ± 12.0 (ASU 41.4 ± 12.0; KI 42.9 ± 12.0). The intervention required participants to accumulate 10,000 steps each day for six months, with a 3-month follow-up period. Steps were recorded onto a study-specific website [123]. Participants completed a website-delivered questionnaire four times to identify socio-demographic, health, psychosocial and environmental correlates of study participation. A sub-sample (one person from each team at each university location), including 357 ASUKI Step participants from the two universities (ASU = 143 and KI = 214), was randomly selected to complete physical fitness testing to determine their anthropometric, resting BP, and cardiovascular health and to wear an accelerometer for one week at each time point. Figures 6 and 7 show the recruitment flowchart for KI and ASU subgroup participants.
Figure 5. ASUKI Step Study flow and participant retention over time.
Figure 6- Recruitment flowchart of KI subgroup participants (paper IV)

KI participants in study IV
N = 1406

Randomly selected subgroup to assess fitness measures
n = 320

Attended at first month measurement
n = 214

Attended at 3rd month measurement
n = 188 (87%)

Attended at 6th month measurement
n = 174 (81.3%)

Figure 7. Recruitment flowchart of ASU subgroup participants (paper V)

ASU Participants
Enrolled in ASUKI Study
Total N = 712

Participants randomly selected for fitness group
n = 143

Month 1 measurement
n = 142

Month 3 measurement
n = 130

Month 6 measurement
n = 99
Inclusion criteria

Inclusion criteria were, a) employed at ASU or the KI, b) the ability to read, speak and understand English (ASU only), c) not currently pregnant or lactating, and d) ages 18 and older. Each university had multiple campuses from which to recruit participants.

Eligible participants

Knowing the number of eligible participants would have been interesting, but in practice it is impossible to define how many staff that are working in the workplace and also meeting the study inclusion criteria. In brief, the Karolinska Institutet has a staff of roughly 4000 steadily employed, 2000 PhD students and an unknown number of short term staff while the corresponding numbers at the relevant campuses at ASU are 9,191 full and part-time faculties and staff and 4,420 doctoral students.

Recruitment

Recruitment procedures were similar at both universities. Participants were recruited by announcements placed in university, staff newsletters and through e-mail messages that were sent to faculty, staff, and graduate students employed at the universities. Announcements indicated the purpose, organization, and duration of the study, cost, benefits, the registration website, and where to call for more information about the study. A recruitment meeting was held on each university campus to inform potential participants about the study. A letter of invitation signed by the University leadership (President and Provost at ASU; and the President at KI) was sent to University Deans, Directors, and Department or Program Chairs inviting their faculty and staff to participate in the study. The study details also were posted on the KI website, the KI internal newsletter and the ASU website for selected campuses (Polytechnic and Downtown) and press releases were sent to the local popular newspapers.

Timeline

“ASUKI Step Study” was lasting from March 16 to September 16, 2009, with a 3 month non-intervention follow-up period (September 16-December 16, 2009). Figure 8 shows the ASUKI Step Study data collection timeline. The workplace intervention took place on ASU and KI campuses simultaneously. A comprehensive web-based questionnaire was used to collect participants’ sociodemographic characteristics and initial physical activity levels one week prior to starting the study and at months 3, 6, and 9 and physical fitness assessments occurred for a randomly selected sub-set of participants during the periods.
Workplace pedometer-determined physical activity intervention

Figure 8. ASUKI Step Study Data collection Timeline

*Q: Questionnaire
3.3 MEASUREMENTS

Outcome measures and instruments
Pedometer steps, accelerometry, questionnaires, anthropometric, and cardiorespiratory laboratory measures were used in the “ASUKI Step Study”.

3.3.1 Questionnaire
A comprehensive web-based questionnaire, developed in collaboration with researchers at the KI and ASU was used to collect socio-demographic characteristics, job information, health-related quality of life, sleep pattern, general health, stress, self-efficacy for exercise, and social support for exercise, self-reported physical activity levels, neighborhood environment, and mindfulness information. Participants completed the survey on the study website [123] at one week before starting the study, and months three and six, and followed by month 9.

3.3.2 International Physical Activity Questionnaire (IPAQ)
PA categories were assessed with the self-administered, short version of the IPAQ [48], prior to the participants starting the walking intervention and at midpoint (month three), and end of the study period (month six) and followed by month 9. The short IPAQ has seven items about the number of days per week (frequency) and hours and minutes per session (duration) spent in moderate-intensity (4.0 METs), vigorous-intensity (8 METs) PA and walking activity (3.5 METs) during the past week. The IPAQ produced repeatable data (Spearman's rho clustered around 0.8), with comparable data from long and short forms. Criterion validity had a median rho of about 0.30, which is comparable to most other self-report validation studies [48, 124]. Papathanasiou G et al. showed that total weekly PA energy expenditure presented by IPAQ-short was well associated with cardiorespiratory fitness and exercise capacity [125], and IPAQ-short was found to present acceptable reliability properties in adults. As well as, the IPAQ-short indicated high repeatability values for vigorous and total PA, and good for walking and moderate PA [126]. More detailed information about IPAQ is described in pages 7 and 8. Details about the IPAQ scoring protocol can be obtained at www.ipaq.ki.se.

3.3.3 Pedometer-determined physical activity assessment
Pedometer. Upon enrolling, participants received a study instruction booklet and a pedometer for the six-month pedometer program, and they were instructed on appropriate use of the pedometer and asked to register the daily number of steps on a website developed for this study [123] at the end of each day with a goal of walking more than 10,000 steps per day. Participants enrolled in teams of three to four persons per team with one person from each team followed more closely through physical measurements at the beginning, midpoint (month three), and end of the study period (month six) and followed by month 9. The Yamax pedometer SW-200 (Yamax Corporation, Tokyo, Japan) was used to monitor steps taken (figure 8). This pedometer is a valid and reliable tool for recording steps in healthy adults [60, 127]. Participants were asked to wear the pedometer on their waist band over the right hip, and to register their daily number of steps on the
ASUKI registration website [123] throughout the study period. For other activities, such as biking or fitness classes, the participants were instructed to add 2700 “steps” per half hour of activity [128]. Based on the step categories suggested by Tudor-Locke et al, participants were divided into PA categories: sedentary (< 5,000 steps per day), low active/inactive (5,000-7,499 steps per day), somewhat active (7,500-9,999 steps per day), active (10,000-12,499 steps per day), and highly active (> 12,500 steps per day) [58]. Pedometer steps data were used in the analyses in the papers II-V.

3.3.4 Accelerometer

In order to more accurately assess PA intensity level, frequency, and duration in subgroups, an ActiGraph (AG) accelerometer was used (Figure 9). For this study, subjects wore the AG for seven consecutive days to characterize the frequency and intensity of daily activity. The cut points for intensity counts will be as follows: 0-100 counts/minute is sedentary [129]; 101-759 is light activity, 760-5724 is moderate lifestyle activity [65]; 1952-5724 is moderate intensity PA (walking), and 5725+ is vigorous intensity PA [64] (Paper II).

Figure 9. A GT1M accelerometer, and a Yamax SW-200 pedometer used in the ASUKI Step Study

3.3.5 Body composition

Anthropometric measures were assessed at one week prior to start of intervention and months three, six, and nine, including height, weight, waist circumference, percent body fat, and sagittal abdominal diameter. All measurements were done in duplicate or triplicate if the first two measurements differed. Height (cm) was measured with bare feet using a Seca (MedexSupply, Road Rod, Monsey, NY) Portable Stadiometer. Body weight (kg), body mass index (BMI; wt kg/ht m²), and body fat percentage were determined by bioelectrical impedance analysis with the Tanita TBF-300A scale (Figure 4). The analysis is a highly researched proprietary formula assessing impedance to measure fat-free mass and determine body fat percentage [130]. To categorize body fat percentage, the cut-offs recommended by Gallagher, et al. were used [131]. We dichotomized the body fat percentages into two categories (under/normal fat and over fat/obese) due to the limited number of participants in the underweight and obese ranges. WC
(cm) was determined with a Gulick II 150 cm anthropometric tape. Measures were taken at the level of the umbilicus with reading taken at the end of a normal exhalation in standing position. The sagittal abdominal diameter (SAD) (cm) was measured using a Holtain-Kahn Abdominal Caliper (HOLTAIN Ltd. Crosswell, Crymych. Dyfed. U.K.). This measure reflects abdominal obesity [132]. SAD was measured while subjects were reclining in supine position on a firm bench with the knees bent. Measures were taken during a normal expiration at the level of the iliac crest (L₄-₅) [133]. Anthropometric measures were used in the papers IV and V.

### 3.3.6 Blood pressure

Systolic and diastolic BP were taken in the left arm using an Omron automated BP cuff (HEM-711 DLX and M6 Comfort) (Figure 10) [134, 135]. BP was taken after participants were seated for five minutes with an appropriately sized cuff. Two measures were made with a minimum of one minute between measurement trials. The main advantages of the OMRON automated device are accuracy comparable to manual mercury sphygmomanometry, with reduced potential for observer bias and less demand on research assistants in terms of training and effort in data collection [136-139]. No other fitness assessment testing event was performed until participants had their resting BP measured and deemed to be within the normal range. To define categories of blood pressure and recommended follow-up the seventh report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) was used [140]. Systolic and diastolic BP values were used in paper III.

![Figure 10. An Omron automated cuff used in ASUKI Step Study to assess resting systolic and diastolic blood pressure.](image)

### 3.3.7 Cardiorespiratory fitness

Estimated maximal oxygen uptake (VO₂ max) was obtained using the Åstrand-Rhyming cycle ergometer test at one (week -1) and six months to examine CRF [103, 141, 142]. The Åstrand-Rhyming submaximal test protocol is feasible and cost effective in healthy individuals VO₂ max estimation [143-146]. The predicted VO₂ max from the Astrand-Rhyming ergometer test correlated significantly with VO₂ max measured by direct measure of VO₂ max using
treadmill (TM) and maximal predictive cycle ergometer (CE) test [103]. The test was conducted on a Monark bike ergometer, model 839E (Monark Exercise, Vansbro, Sweden) shown in Figure 1. Monark bike was calibrated before each test session. Exclusion criteria for the CRF test was a self-reported history of taking medication that would alter the BP or heart rate response to exercise, prior diagnosis of ischemic heart disease, type 2 diabetes mellitus, and/or stroke. The participants were asked to abstain from smoking and eating 2 hours before testing. Prior to testing participants were fitted with a heart rate monitor (Polar Electro Inc, Lake Success, NY) that linked the heart rate response to the ergometer using a telemetry system. The participants also were given instructions for the cycle test, and explained how to report their perceived exertion using Borg’s Rating of Perceived Exertion (RPE) scale [147]. The RPE uses a 6–20 point scale that describes exertion from very, very light to very, very hard [147]. The cycle ergometer resistance was selected so participants would reach a steady-state heart rate of 120-150 beats per minute (equivalent to 50-85% of their heart rate reserve computed as 220 minus age). The pedal rate was set at 50-60 revolutions per minute (RPM) using a metronome set at 100 bpm and work rate at 50-75 Watts for untrained participants or up to 100 Watts for moderately trained participants. Untrained participants were described as performing moderate intensity activity for less than 3 days a week and/or ≤ 30 minutes per day. Trained participants were described as performing moderate-to-vigorous intensity activity 3 or more days per week and/or ≥ 30 minutes per day. The test was initiated at the established work rate and continued for 6 minutes to increase the heart rate to a target range of 125 beats per minute to 85% of age-predicted heart rate max. If the heart rate was lower or higher than the target range, the workload was adjusted to bring the heart rate into the desired range and an additional 6 minutes of cycling was performed. The test was terminated when the difference in the heart rate between the 5\textsuperscript{th} and 6\textsuperscript{th} minutes of exercise was 5 beats or less. If the difference in the heart rate values was greater than 5 beats, the test was continued until the heart rate between successive minutes was less than 5 beats or a maximum of 12 minutes of cycling was completed. The RPE was recorded during each minute of the tests. VO\textsubscript{2} max (l min\textsuperscript{-1}) was estimated using the Åstrand-Rhyming nomogram from the steady state heart rate and the work rate [148]. VO\textsubscript{2} max adjusted for body mass (ml.kg\textsuperscript{-1}. min\textsuperscript{-1}) was computed as (VO\textsubscript{2} max in l min\textsuperscript{-1} x 1000)/kg body mass. Maximal oxygen consumption (VO\textsubscript{2} max) is a generally accepted accurate index of CRF [149], also referred to as functional aerobic capacity. VO\textsubscript{2} max is defined as the maximum capacity of person’s body ability to transport and use oxygen to perform strenuous physical exercise [103]. VO\textsubscript{2} max can be expressed as an absolute rate (l/min), or as a rate relative to one’s body mass (ml/kg/min). The relative rate is often used for comparison of performance of endurance sports athletes. CRF data were used in paper III
Figure 11: Submaximal Cardiorespiratory fitness test conducted by use of Monark Electronic Ergometer 839E in ASUKI Step Study

3.4 Data treatment and statistical analyses

Questionnaire data and steps per day were recorded in an excel database. Physical fitness data were recorded onto forms used for direct data entry with the Cardiff TeleForm system (Vista, CA) and stored in an excel database. All statistical analyses were performed using SAS software version 9.2. The level of significance was set at \( p < 0.05 \) for all tests. The study data were examined for outliers and normality. Descriptive statistics including frequency, means, standard deviations (SD), and percentages were used to describe participant characteristics according to body fat categories and changes in activity classification over the intervention period (papers I-V). A multi-level growth modeling approach was used to show changes over time and predict changes over time by steps, age, gender, and body fat categories (papers II-V). To better understand significant continuous predictors, conditional regression lines and contrasts for the intercepts and slopes were constructed using Cohen & Cohen’s (1983) suggested values of one standard deviation above and one standard deviation below the mean for a continuous predictor (papers II-V). To predict changes over time for estimated VO\(_2\) max a mixed model ANOVA was used (paper III). Linear growth models were used to evaluate the impact of the intervention on pedometer steps and accelerometer-derived PA measures over time. To evaluate the proportion of individuals meeting the standard of 10,000 steps per day for 100 days, frequencies were calculated (paper II). Chi-Square tests of associations and bivariate logistic regression were used to evaluate bivariate associations with categorical socio-demographic characteristics and baseline physical activity levels (paper II). Multiple logistic regression was used to examine multivariate associations (Paper II). Analyses were performed using all available data, including participants who subsequently dropped out using Statistical intention to treat analyses (papers II-V).
4 RESULTS

4.1 RESPONSE RATE AND REPRESENTATIVENESS

Paper I describes the study design and methods used in a 6-month pedometer-based worksite intervention called “ASUKI Step” conducted at the KI in Stockholm, Sweden and ASU in the greater Phoenix area, Arizona [150]. “ASUKI Step Study” was based on the theory of social support and a quasi-experimental design was used for evaluation. Eligible participants included 2,118 faculty, staff, and graduate students from ASU (n = 712) and KI (n = 1,406) who participated in teams of 3–4 persons. The study was intended to increase the number of days employees walk 10,000 steps and to reduce the number of days employees spend being inactive, but due to the lack of pedometer baseline data and control group it is not possible to know with certainty whether the intervention lead to an increased number of steps/day, and if this influenced the other observables. The study also evaluates the intra- and interpersonal determinants for success in the intervention and in a sub-sample of the study, changes in physical fitness and body composition during the study.

A total of 2102 participants from ASU (712) and KI (1390) were included in the paper II. The mean age of the participants was 42.4 ± 12 years (ASU 41.4 ± 11.9 years; KI 42.9 ± 12.0 years). More women (79.2%) than men participated in the intervention. Participants completed the questionnaire one week before the starting of the pedometer intervention, and at months 3, 6, and 9.

For paper III a randomly selected sub-sample, including 355 individuals from two universities (141 ASU test group, 32 men and 110 women, and 214 KI test group, 38 men and 176 women) who were randomly selected from the teams that signed up for the pedometer project, attended to the fitness testing at week -1 prior to start the intervention (month one) and followed by 318 (ASU = 129, and KI = 189) at three month measurements, and at 6 month follow up, 251 participants received physiological testing (ASU = 99, and KI = 165) which reflects a total retention rate of 72.96%. Mean age was 42.98 ± 12.04 (ASU, 41.05 ± 11.39 and KI, 44.25 ± 12.30).

For paper IV, 214 Karolinska Institutet faculty, staff, and PhD students in the randomly selected subgroup completed the anthropometric measures at first month measurements (week -1) and 188, and 174 participants attended to month three and six measurements respectively with a total retention rate of 81.3%. Age ranged from 24 to 66 years (39 men, age = 36.9 ± 9.7 years, 175 women, age = 45.9 ± 12.3 years).

For paper V, the subgroup included 142 ASU faculty, staff, and students (32 men and 110 women) who were randomly selected from the teams that signed up for the pedometer project and completed first measurement. 130 and 99 participants completed the anthropometric measures at 3 and 6 months testing points respectively with a retention rate of 69.7%. Age ranged from 22 to 70 years (32 men, age = 38.9 (12.7), 110 women, age = 41.6 (11.1)).
4.2 REACHING 10,000 STEPS PER DAY

Paper II evaluated the average step counts over time, the proportion of individuals who accumulated at least 10,000 steps per day for a minimum of 100 days, and accelerometer-determined PA levels over time in a sub-set of individuals and examined the socio-demographic predictors of success. A total of 2102 participants from ASU (712) and KI (1390) are included in this study. Table 4 provides an overview of the demographic characteristics of the participants. Based on self-reported height and weight, more than 1/3 of the participants were overweight or obese (BMI >25 kg/m²). The majority of participants (87%) had 13 or more years of education and most were employed in non-managerial positions (76%). At the start of the intervention 15% of participants were classified as low active, 43% moderate and 42% high active based on their responses to the initial IPAQ survey.

There was a significant linear (t = -20.76, p = .001) and curvilinear change in steps over time (t = 7.65, p = 0.001) with steps decreasing from month 1 to month 6 when all participants were included in the model. Site and socio-demographic characteristics were predictive of initial step counts and changes in step counts over time. Age was associated with trajectory of change; as age increased the rate of decline in steps was slower (p < 0.001). Overall, 52.9% (n = 1105) of the participants accumulated 10,000 steps on at least 100 days of the study. More participants from the KI (59.1%) than ASU (39.8%) met this goal. Older age, being married, working in a non-managerial position, normal weight, and higher initial PA level were positively associated with meeting the step goal (p < 0.05). Finally, in the subset of individuals for whom we had accelerometer-derived physical activity levels, there were no changes over time in minutes of physical inactivity, light activity, moderate lifestyle or moderate activity.

When dropouts were excluded from the analysis, there was no significant decrease in steps from month 1 to month 6. The effects of site and participant characteristics on steps were examined in all 2089 persons using individual growth models for the 3 measurement points, including step counts that were reported as zeros. To explore the possibility that the decline in steps was due to zeros in the data, for participants with four sequential weeks of zeros, the zeros were recorded to missing and the analysis for steps was redone with the missing values. Mean step counts for months 1, 3 and 6 using the two approaches are provided in Table 5. Changes in pedometer-determined step counts over time for all ASUKI participants and when the dropouts were excluded are shown in Figure 12.
Table 4. Baseline physical activity and sociodemographic characteristics of participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>ASU (n=712) Mean ± SD or N (%)</th>
<th>KI (n=1390) Mean ± SD or N (%)</th>
<th>All (n=2102) Mean ± SD or N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>41.4 ± 11.9</td>
<td>42.9 ± 12.0</td>
<td>42.4 ± 12.0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>124 (17.42)</td>
<td>309 (22.46)</td>
<td>433 (20.74)</td>
</tr>
<tr>
<td>Females</td>
<td>588 (82.58)</td>
<td>1067 (77.54)</td>
<td>1655 (79.26)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; High School (≤12 yrs)</td>
<td>47 (6.61)</td>
<td>208 (15.12)</td>
<td>255 (12.22)</td>
</tr>
<tr>
<td>College (≥13 years)</td>
<td>664 (93.39)</td>
<td>1168 (84.88)</td>
<td>1832 (87.78)</td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>267 (37.55)</td>
<td>406 (29.51)</td>
<td>673 (32.25)</td>
</tr>
<tr>
<td>Married or cohabiting</td>
<td>444 (62.45)</td>
<td>970 (70.49)</td>
<td>1414 (67.75)</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managerial</td>
<td>231 (32.49)</td>
<td>256 (18.60)</td>
<td>487 (23.33)</td>
</tr>
<tr>
<td>Non-managerial</td>
<td>480 (67.51)</td>
<td>1120 (81.40)</td>
<td>1600 (76.67)</td>
</tr>
<tr>
<td>BMI&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>20 (2.87)</td>
<td>41 (2.99)</td>
<td>61 (2.95)</td>
</tr>
<tr>
<td>Normal weight</td>
<td>299 (42.84)</td>
<td>912 (66.47)</td>
<td>1211 (58.5)</td>
</tr>
<tr>
<td>Overweight</td>
<td>202 (28.94)</td>
<td>338 (24.64)</td>
<td>540 (26.09)</td>
</tr>
<tr>
<td>Obese</td>
<td>177 (25.36)</td>
<td>81 (5.90)</td>
<td>258 (12.46)</td>
</tr>
<tr>
<td>Step Category&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>68 (9.55)</td>
<td>113 (8.13)</td>
<td>181 (8.61)</td>
</tr>
<tr>
<td>Low active</td>
<td>67 (9.41)</td>
<td>62 (4.46)</td>
<td>129 (6.14)</td>
</tr>
<tr>
<td>Somewhat active</td>
<td>138 (19.38)</td>
<td>163 (11.73)</td>
<td>301 (14.32)</td>
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<td>Active</td>
<td>264 (37.08)</td>
<td>441 (31.73)</td>
<td>705 (33.54)</td>
</tr>
<tr>
<td>Highly Active</td>
<td>175 (24.48)</td>
<td>611 (43.96)</td>
<td>786 (37.39)</td>
</tr>
<tr>
<td>IPAQ Category&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>132 (18.54)</td>
<td>186 (13.52)</td>
<td>318 (15.23)</td>
</tr>
<tr>
<td>Moderate</td>
<td>261 (36.66)</td>
<td>642 (46.66)</td>
<td>903 (43.25)</td>
</tr>
<tr>
<td>High</td>
<td>319 (44.80)</td>
<td>548 (39.83)</td>
<td>867 (41.52)</td>
</tr>
</tbody>
</table>

<sup>a</sup>BMI Categories: Underweight (<18.50), Normal (18.50 - 24.99), Overweight (25.00 - 29.99), Obese (≥30.00);<sup>b</sup>Step category is based on the average steps per day obtained from a pedometer and reported during the first week of the intervention;<sup>c</sup>Step categories were defined utilizing the cut points suggested by Tudor-Locke and colleagues [58];<sup>i</sup>IPAQ Categories: Low (some activities is reported but not enough to meet moderate or high categories), Moderate (5 or more days of any combination of walking, moderate- or vigorous-intensity activities achieving a minimum of at least 600 MET-min/week), High (7 or more days of any combination of walking, moderate- or vigorous-intensity activities accumulating at least 3000 MET-minutes/week)
Table 5. Descriptive Statistics for Physical Activity Outcomes

<table>
<thead>
<tr>
<th>Time Point</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedometer Step Counts (all participants)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Month</td>
<td>2089</td>
<td>11,063.26</td>
<td>4646.10</td>
<td>0-39,422</td>
</tr>
<tr>
<td>3 Month</td>
<td>2089</td>
<td>8514.34</td>
<td>6078.69</td>
<td>0-34,446</td>
</tr>
<tr>
<td>6 Month</td>
<td>2089</td>
<td>6998.24</td>
<td>6610.44</td>
<td>0-33,106</td>
</tr>
<tr>
<td>Pedometer Step Counts (dropouts excluded)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Month</td>
<td>1978</td>
<td>11,684.10</td>
<td>3942.16</td>
<td>206.0 - 39422</td>
</tr>
<tr>
<td>3 Month</td>
<td>1581</td>
<td>11250.12</td>
<td>4246.56</td>
<td>160.7 - 34,446</td>
</tr>
<tr>
<td>6 Month</td>
<td>1235</td>
<td>11837.51</td>
<td>4075.30</td>
<td>249.2 - 33106</td>
</tr>
</tbody>
</table>

Figure 12. Changes in ASUKI participants pedometer-determined step counts over time

35
Figure 13 shows changes in pedometer-determined step counts over time for ASUKI participants stratified by site when all participants were included in the model. KI participants had a higher initial step count and a slower rate of decline over time (p< 0.001). Age was associated with trajectory of change; as age increased the rate of decline in steps was slower (p< 0.001). The bivariate associations with meeting the study standard of 10,000 steps per day for at least 100 days are shown in Table 6.

![Figure 13. Changes in pedometer-determined step counts over time stratified by site (all participants included)](image-url)
Table 6. Bivariate Associations with meeting the study standard of 10,000 steps per day for at least 100 days

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample size</th>
<th>Met Standard N (%)</th>
<th>Odds Ratio Simple Logistic Regression [95% Confidence Intervals]</th>
<th>Beta Estimate</th>
<th>Wald Chi-Square</th>
<th>P-Value</th>
<th>Odds Ratio Multiple Logistic Regression [95% Confidence Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Met Standard N (%)</td>
<td>Beta Estimate</td>
<td>Wald Chi-Square</td>
<td>P-Value</td>
<td>Odds Ratio Multiple Logistic Regression [95% Confidence Interval]</td>
</tr>
<tr>
<td>All participants</td>
<td>2,102</td>
<td>1,105 (52.9)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASU</td>
<td>712</td>
<td>383 (59.8)</td>
<td>Ref</td>
<td>--</td>
<td>0.19</td>
<td>1.79</td>
<td>0.51 [0.42 – 0.63]</td>
</tr>
<tr>
<td>KI</td>
<td>1,390</td>
<td>821 (59.3)</td>
<td>Ref</td>
<td>--</td>
<td>0.55</td>
<td>14.44</td>
<td>1.74 [1.31 – 2.32]</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30</td>
<td>439</td>
<td>175 (44.4)</td>
<td>Ref</td>
<td>2.08</td>
<td>15.77</td>
<td>29.73</td>
<td>2.39 [1.75 – 3.27]</td>
</tr>
<tr>
<td>30 – 41</td>
<td>654</td>
<td>318 (48.6)</td>
<td>Ref</td>
<td>1.54 [1.19 – 1.98]**</td>
<td>14.44</td>
<td>29.73</td>
<td>2.39 [1.75 – 3.27]</td>
</tr>
<tr>
<td>42 – 54</td>
<td>628</td>
<td>346 (55.10)</td>
<td>Ref</td>
<td>1.18</td>
<td>1.92 – 1.52</td>
<td>1.79</td>
<td>0.51 [0.42 – 0.63]</td>
</tr>
<tr>
<td>&gt;55</td>
<td>426</td>
<td>266 (62.44)</td>
<td>Ref</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>1,655</td>
<td>215 (49.65)</td>
<td>Ref</td>
<td>0.16</td>
<td>1.85</td>
<td>0.17</td>
<td>1.17 [0.93 – 1.48]</td>
</tr>
<tr>
<td>Females</td>
<td>433</td>
<td>890 (53.78)</td>
<td>Ref</td>
<td>1.89</td>
<td>0.98</td>
<td>0.32</td>
<td>1.11 [0.90 – 1.35]</td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>673</td>
<td>335 (49.8)</td>
<td>Ref</td>
<td>0.10</td>
<td>1.00</td>
<td>0.32</td>
<td>0.81 [0.61 – 1.09]</td>
</tr>
<tr>
<td>Married</td>
<td>1,414</td>
<td>769 (54.4)</td>
<td>Ref</td>
<td>1.89</td>
<td>0.98</td>
<td>0.32</td>
<td>1.11 [0.90 – 1.35]</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;12th grade</td>
<td>285</td>
<td>139 (54.51)</td>
<td>Ref</td>
<td>0.10</td>
<td>1.00</td>
<td>0.32</td>
<td>1.11 [0.90 – 1.35]</td>
</tr>
<tr>
<td>College (≥13 years)</td>
<td>1,832</td>
<td>965 (52.67)</td>
<td>Ref</td>
<td>1.89</td>
<td>0.98</td>
<td>0.32</td>
<td>1.11 [0.90 – 1.35]</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managerial</td>
<td>285</td>
<td>139 (54.51)</td>
<td>Ref</td>
<td>-</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Non-managerial</td>
<td>1,600</td>
<td>836 (54.75)</td>
<td>Ref</td>
<td>1.89</td>
<td>0.98</td>
<td>0.32</td>
<td>1.11 [0.90 – 1.35]</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>61</td>
<td>23 (38.28)</td>
<td>Ref</td>
<td>-</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Normal weight</td>
<td>1,211</td>
<td>699 (57.7)</td>
<td>Ref</td>
<td>0.79 [0.64 – 0.97]**</td>
<td>15.28</td>
<td>0.15</td>
<td>0.63 [0.34 – 1.18]</td>
</tr>
<tr>
<td>Overweight</td>
<td>540</td>
<td>280 (51.9)</td>
<td>Ref</td>
<td>0.39 [0.30 – 0.43]**</td>
<td>15.28</td>
<td>0.15</td>
<td>0.63 [0.34 – 1.18]</td>
</tr>
<tr>
<td>Obese</td>
<td>258</td>
<td>90 (34.9)</td>
<td>Ref</td>
<td>-</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>IPAQ Category*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>338</td>
<td>127 (37.8)</td>
<td>Ref</td>
<td>-0.45</td>
<td>2.07</td>
<td>0.15</td>
<td>0.63 [0.34 – 1.18]</td>
</tr>
<tr>
<td>Moderate</td>
<td>908</td>
<td>456 (56.0)</td>
<td>Ref</td>
<td>15.28</td>
<td>0.15</td>
<td>0.63 [0.34 – 1.18]</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>867</td>
<td>522 (60.21)</td>
<td>Ref</td>
<td>-0.45</td>
<td>2.07</td>
<td>0.15</td>
<td>0.63 [0.34 – 1.18]</td>
</tr>
</tbody>
</table>
Workplace pedometer-determined physical activity intervention

*p <0.05, **p<0.001; ¹BMI Categories: Underweight (<18.50), Normal (18.50 - 24.99), Overweight (25.00 - 29.99), Obese (≥30.00); ²IPAQ Categories: IPAQ Categories: Low (some activities is reported but not enough to meet moderate or high categories), Moderate (5 or more days of any combination of walking, moderate- or vigorous-intensity activities achieving a minimum of at least 600 MET-min/week), High (7 or more days of any combination of walking, moderate- or vigorous-intensity activities accumulating at least 3000 MET-minutes/week); ³Step category is based on the average steps per day obtained from a pedometer and reported during the first week of the intervention. Step categories were defined utilizing the cut points suggested by Tudor-Locke and colleagues [58]. Only IPAQ Category was included in multiple logistic regression analysis due to collinearity with step category
To explore the predictors of dropping out at 6 month compared with reported baseline socio-demographic characteristics, a binary logistic regression model was used. Site (KI or ASU), gender, age categories, managerial position, initial IPAQ categories, and baseline BMI categories were used in the model as predictors. Site, age categories, managerial position, initial IPAQ categories, and baseline BMI categories were significant predictors for dropping out (all with p value < 0.05). To evaluate the proportion of individuals who dropped out, crosstab table was used. Being ASU staff, of younger age, working in a managerial position, being obese at baseline, being classified as low-to-moderately active at baseline (according to IPAQ) were positively associated with dropping out. Table 7 indicates the baseline sociodemographic characteristics and the proportion of dropouts during 6 month intervention.
Table 7. Baseline sociodemographic characteristics and proportion of dropouts during 6 months PA intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Proportion of participants at month 1</th>
<th>Proportion of dropouts At 6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASUKI Participants</td>
<td>2089 (100%)</td>
<td>767 (100%)</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASU</td>
<td>712 (34.1%)</td>
<td>326 (42.5%)</td>
</tr>
<tr>
<td>KI</td>
<td>1377 (65.9%)</td>
<td>441 (57.5%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>433 (20.7%)</td>
<td>181 (23.6%)</td>
</tr>
<tr>
<td>Female</td>
<td>1655 (79.3%)</td>
<td>586 (76.4%)</td>
</tr>
<tr>
<td>Age category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25 years</td>
<td>110 (5.3%)</td>
<td>62 (8.1%)</td>
</tr>
<tr>
<td>25-40</td>
<td>883 (42.3%)</td>
<td>401 (52.3%)</td>
</tr>
<tr>
<td>40-55</td>
<td>713 (34.2%)</td>
<td>213 (27.8%)</td>
</tr>
<tr>
<td>&gt;55</td>
<td>381 (18.3%)</td>
<td>90 (11.7%)</td>
</tr>
<tr>
<td>Managerial position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>487 (23.3%)</td>
<td>193 (25.2%)</td>
</tr>
<tr>
<td>Non-manager</td>
<td>1600 (76.7%)</td>
<td>574 (74.8%)</td>
</tr>
<tr>
<td>BMI category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>44 (2.1%)</td>
<td>24 (3.1%)</td>
</tr>
<tr>
<td>Normal weight</td>
<td>1237 (59.3%)</td>
<td>415 (54.2%)</td>
</tr>
<tr>
<td>Over weight</td>
<td>546 (26.2%)</td>
<td>197 (25.8%)</td>
</tr>
<tr>
<td>Obese</td>
<td>256 (12.4%)</td>
<td>129 (16.9%)</td>
</tr>
<tr>
<td>IPAQ category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>318 (15.2%)</td>
<td>135 (17.6%)</td>
</tr>
<tr>
<td>Moderate</td>
<td>903 (43.2%)</td>
<td>346 (45.1%)</td>
</tr>
<tr>
<td>High</td>
<td>867 (41.5%)</td>
<td>286 (37.3%)</td>
</tr>
</tbody>
</table>
4.3 ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND CRF AND BP

Paper III examined whether participating in a six-month pedometer-based PA intervention was associated with an improvement in CRF and systolic and diastolic BP on ASU and KI employees. Most of the participants were female. Steps/day averaged 12,256 (SD = 3,180) during month 1 and steadily decreased to month 6. The mean number of steps in month one exceeded the goal of 10,000 steps per day with KI participants recording more steps per day than ASU participants. Descriptive statistics (means and SD) at the beginning of the study are reported in Table 8.

Descriptive statistics (means and SD) at the beginning of the study are reported in Table 8.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All (N = 355)</th>
<th>ASU (n = 141)</th>
<th>KI (n = 214)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (% female)</td>
<td>80.3%</td>
<td>78.3%</td>
<td>81.8%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42.98 (12.04)</td>
<td>41.05 (11.39)*</td>
<td>44.25 (12.30)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.35 (5.50)</td>
<td>27.22 (7.14)*</td>
<td>24.12 (3.62)</td>
</tr>
<tr>
<td>Mean steps/day</td>
<td>11256 (3180)</td>
<td>10967 (3021)*</td>
<td>13105 (2998)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>118.14 (16.05)</td>
<td>113.72 (13.41)*</td>
<td>121.05 (16.99)</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>78.91 (10.10)</td>
<td>77.56 (9.27)</td>
<td>79.79 (10.53)</td>
</tr>
<tr>
<td>VO₂max (ml/kg/min)</td>
<td>36.57 (10.56)</td>
<td>34.16 (11.80)*</td>
<td>37.82 (10.24)</td>
</tr>
</tbody>
</table>

* Demonstrated a significant difference with p < 0.05 between ASU and KI participants. DBP: diastolic blood pressure; SBP: systolic blood pressure.

Changes in systolic and diastolic BP over time

There were significant linear and quadratic trends in systolic and diastolic BP over time. Age was positively related to initial starting values for systolic and diastolic BP, and approached significance for systolic BP changes over time. Steps/day approached significance for linear changes in systolic BP. The change over time for KI participants was U-shaped, concave upward, at first decreasing then increasing at the mid-study to the end of intervention. ASU, in contrast, has a lower starting value of the systolic BP and the change over time was inverted U-shaped, concave downward, with values at first increasing and then decreasing at the mid-study to the end of the study. The change over time for KI participants’ diastolic BP was also U-shaped, at first decreasing then increasing at the mid-study. ASU, in contrast, had a lower starting diastolic BP value and the change over time was inverted U-shaped, with values at first increasing and then decreasing at the mid study. Figures 14 and 15 show the changes in systolic and diastolic BP for ASUKI participants over time related to age.
Workplace pedometer-determined physical activity intervention

Figure 14. Changes in systolic BP (mmHg) for ASUKI participants over time by age groups
Changes in CRF over time

Means and SD of estimated VO2 max at baseline and six month are shown in Table 9. There was a significant change over time in the estimated VO2 max (F1, 244 = 7.61, p = .006). The time by site interaction was also significant, indicating that the change over time varied by site (F1, 244 = 4.25, p = .04), where VO2 max decreased for ASU participants, but stayed essentially the same for KI participants. The number of steps taken was significantly related to changes in estimated VO2 max over time (F1, 240 = 18.44, p = 0.001), as steps increased estimated VO2 max increased. Age was a significant predictor of changes in VO2 max over time (F1, 240 = 5.20, p = 0.02), where estimated VO2 max increased for older participants, and the increase was site specific (KI).
4.4 PA AND ANTHROPOMETRIC CHANGES IN THE SWEDISH GROUP

Papers IV examined the effects of a six-month pedometer-based PA intervention on KI employees’ body composition characteristics over time. In order to answer this scientific question, sample of KI employees were assessed and the results showed that a randomly selected subgroup from KI completed the anthropometric measures at all three testing points (month one = 214; month three = 188; month six = 174 ) with a total retention rate of 81.3% . The participants were 82% female. The Yamax SW-200 was used as main instrument to monitor steps taken. The participants’ mean number of steps by month during the PA intervention period are shown in the Figure 16.

![Figure 16](image)
According to the PA classification suggested by Tudor-Locke et al. [58], during the first month, only 0.5% of the participants were classified as sedentary (on average <5,000 steps per day) in comparison with 3.5% during month six. The majority of the KI participants (88.7%) were active or highly active during month one, compared to 78.3% at month six. Results showed that 8.8% of the participants had a positive improvement in activity category over the intervention period, 76.6% did not change activity classification level and 14.6% dropped in activity classification over time. Based on the BMI results, 2.8% of KI participants were underweight, 63.5% were normal weight, 28.4% were overweight, and 5.2% were obese at baseline measures. On average, women had a lower WC, BMI, SAD, higher body fat percentage, and older age compared with male participants (Table 10).

Table 10. Descriptive statistics in the KI subgroup participants at baseline

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (SD)</th>
<th>Male (N = 39)</th>
<th>Female (N = 175)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
<td>44.3 (12.3)</td>
<td>36.9 (9.7) *</td>
<td>45.9 (12.3)</td>
</tr>
<tr>
<td>**Steps/day</td>
<td>13105 (2998)</td>
<td>13776 (3710)</td>
<td>12956 (2806)</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>24.1 (3.6)</td>
<td>25.2 (3.5)</td>
<td>23.9 (3.6)</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>86.6 (10.4)</td>
<td>91.2 (10.0) *</td>
<td>85.5 (10.3)</td>
</tr>
<tr>
<td>Sagittal Abdominal Diameter</td>
<td>19.3 (2.5)</td>
<td>20.8 (2.3) *</td>
<td>19.0 (2.4)</td>
</tr>
<tr>
<td>Percent Body Fat</td>
<td>27.9 (8.2)</td>
<td>18.9 (6.0) *</td>
<td>29.9 (7.2)</td>
</tr>
</tbody>
</table>

* Demonstrated a significant gender differences with p < 0.05  
** Mean steps per day for month 1

The average BMI was 24.1 (SD = 3.6) and this remained relatively stable over the three time points. The average WC was 86.6 (SD = 10.4) and it declined significantly over time. The average SAD was 19.3 (SD = 2.5) and it declined significantly at three months (p = .001) and then showed a tendency towards an increase at six months (p = .068). The average body fat percentage was 27.9 (SD = 8.2) and it showed a tendency towards an increase at three months (p = .537) and was relatively stable at six months. A multi-level growth modeling approach showed that there was a significant change over time with significant individual differences in initial starting values and linear slopes. There was a significant reduction in BMI over time for older participants (51 – 66 yrs; t = -3.48, p = 0.0006) (Figure 17), and there was a significant decline in waist circumference (WC) for middle age (36-51 yrs; t = -5.97, p <.0001) and older participants (t = -7.38, p <.0001) (Figure18). There was also a significant reduction in WC over time in the subgroup of females (t = - 4.55, p <.0001). Figure 19 shows curvilinear changes in SAD over time for the three age groups.
No other changes were statistically significant. The Table 11 indicates the changes in anthropometric measures in relation to time, steps taken, age, gender, and weight status over time. No associations were observed between steps taken and initial values or changes in BMI, WC, SAD, and body fat percentage over time.

<table>
<thead>
<tr>
<th>Effect</th>
<th>BMI</th>
<th>BFP</th>
<th>WC</th>
<th>SAD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff</td>
<td>SE</td>
<td>P</td>
<td>Coeff</td>
</tr>
<tr>
<td>Intercept</td>
<td>27.17</td>
<td>0.50</td>
<td>&lt;.000</td>
<td>23.50</td>
</tr>
<tr>
<td>Time</td>
<td>-0.24</td>
<td>0.12</td>
<td>0.05</td>
<td>-0.24</td>
</tr>
<tr>
<td>Steps</td>
<td>0.00</td>
<td>0.00</td>
<td>0.30</td>
<td>0.00</td>
</tr>
<tr>
<td>Cage</td>
<td>0.03</td>
<td>0.02</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>Female</td>
<td>-0.76</td>
<td>0.51</td>
<td>0.14</td>
<td>11.49</td>
</tr>
<tr>
<td>Normal/OverFatCat</td>
<td>-4.49</td>
<td>0.39</td>
<td>&lt;.000</td>
<td>-9.58</td>
</tr>
<tr>
<td>Time*steps</td>
<td>0.00</td>
<td>0.00</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td>Time*Cage</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>Time*Female</td>
<td>0.01</td>
<td>0.08</td>
<td>0.88</td>
<td>0.04</td>
</tr>
<tr>
<td>Time*Normal/OverFatCat</td>
<td>0.14</td>
<td>0.06</td>
<td>0.03</td>
<td>0.29</td>
</tr>
<tr>
<td>Time*2</td>
<td></td>
<td></td>
<td></td>
<td>-0.28</td>
</tr>
<tr>
<td>Time<em>2</em>Steps</td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Time<em>2</em>Cage</td>
<td></td>
<td></td>
<td></td>
<td>-0.01</td>
</tr>
<tr>
<td>Time<em>2</em>Female</td>
<td></td>
<td></td>
<td></td>
<td>0.18</td>
</tr>
<tr>
<td>Time<em>2</em>Normal/OverFatCat</td>
<td></td>
<td></td>
<td></td>
<td>0.18</td>
</tr>
</tbody>
</table>

Abbreviations: BFP, Body Fat Percentage; BMI, Body Mass Index; CAge, Centered Age; Coeff, Coefficient; Normal/OverFatCat, Normal/Over Fat Categories; P, P-value; SAD, Sagittal Abdominal Diameter; SE, Standard Error
Ali Soroush

Figure 17. Growth trajectories for BMI (kg.m$^{-2}$) index by age for KI participants during the intervention period (time $0 = 1$, $1 = 3$, and $2 = 6$ months)

Figure 18. Growth trajectories for WC (cm) by age for KI participants during the intervention period (time $0 = 1$, $1 = 3$, and $2 = 6$ months)
Figure 19. Growth trajectories for SAD (cm) by age for KI participants during the intervention period (time 0 = 1, 1 = 3, and 2 = 6 months)
4.5 PA AND CHANGES OF BODY COMPOSITION IN THE U.S. GROUP

Paper V examined whether attending a six-month pedometer-based PA intervention was associated with changes on body composition characteristics in ASU employees over time. A total of 142 ASU faculty, staff, and PhD students participated in the anthropometric measures (First measurement = 142; month three = 130; month six = 99) with a total retention rate of 69.7%. The unique aspect of the ASUKI Step sub-sample were the differences in initial body composition values between the US (BMI = 27.2 ±7.2 kg m$^{-2}$) and Swedish (BMI = 24.1 ± 3.6 kg m$^{-2}$) cohorts [151]. This allowed us to compare changes in body composition measures in two cohorts who completed the same study protocol but with different initial body composition values. To examine changes in pedometer steps taken each month and assess the relationship between average number of steps per day and body composition outcomes in the US cohort, we used the same analytic procedures described for the Swedish cohort [151]. We hypothesized that the US cohort would show larger decreases in body composition variables, than reported for the Swedish cohort, and specific predictor variables (age, gender, steps taken, fat category) would predict the changes in the body composition outcomes.

The participants were 77.5% female. The Yamax pedometer SW-200 was used to monitor steps. During the first month, 4.3% of the participants were classified as sedentary, which increased to 5.5% by month six. In the first month a 9% were categorized as low active, but by time three, 16.7% were classified in the low active group. The percentage for the somewhat active group also increased from 18.7% to 23.3% over the three time periods. Those in the active classification slightly increased from 36% - 36.7%. However the percentage of participants in the highly active group decreased from 30.9% to 17.8%. The descriptive statistics for ASU participants are shown in Table 12. For analysis age groups were separated in to three groups (Mean age ± SD) (18-34 years, 35-55 years and > 55 years). Significant individual differences in linear slopes and change over time was observed only for WC (t = -0.67, p = 0.016). No significant changes in other body composition measures were observed over time when predictors were included in the model. No associations were observed between steps taken and initial body composition values or change in body composition over time. The changes in anthropometric measures in relation to time, steps taken, age, gender, and weight status (conditional mixed model) can be seen in Table 13.
### Table 12. Body composition measures and steps for ASU participants from baseline to month 6

<table>
<thead>
<tr>
<th>Mean (SD)</th>
<th>Month 1</th>
<th>Month 3</th>
<th>Month 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (N = 110)</td>
<td>Female (N = 99)</td>
<td>Female (N = 77)</td>
</tr>
<tr>
<td></td>
<td>Male (N = 32)</td>
<td>Male (N = 28)</td>
<td>Male (N = 20)</td>
</tr>
<tr>
<td></td>
<td>Total (N = 142)</td>
<td>Total (N = 127)</td>
<td>Total (N = 97)</td>
</tr>
<tr>
<td><strong>Steps/day</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10,514 (3,258)</td>
<td>8,485 (4,831)</td>
<td>6,192 (5,420)</td>
</tr>
<tr>
<td></td>
<td>11,462 (3,665)</td>
<td>9,040 (5,454)</td>
<td>6,857 (6,013)</td>
</tr>
<tr>
<td></td>
<td>10,714 (3,357)</td>
<td>8,602 (4954)</td>
<td>6,332 (5535)</td>
</tr>
<tr>
<td><strong>BMI (kg.m(^{-2}))</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>26.4 (6.4)</td>
<td>26.8 (7.9)</td>
<td>25.1 (5.0)</td>
</tr>
<tr>
<td></td>
<td>29.9 (9.2)</td>
<td>29.4 (9.7)</td>
<td>29.6 (10.8)</td>
</tr>
<tr>
<td></td>
<td>27.2 (7.2)</td>
<td>27.4 (8.3)</td>
<td>26.0 (6.8)</td>
</tr>
<tr>
<td><strong>WC (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>87.5 (15.4)</td>
<td>85.9 (14.9)</td>
<td>83.9 (12.2)</td>
</tr>
<tr>
<td></td>
<td>100.2 (25.1)</td>
<td>99.1 (21.9)</td>
<td>100.7 (25.8)</td>
</tr>
<tr>
<td></td>
<td>90.2 (18.7)</td>
<td>88.5 (17.4)</td>
<td>87.2 (17.2)</td>
</tr>
<tr>
<td><strong>SAD (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19.5 (3.9)</td>
<td>19.6 (3.9)</td>
<td>18.8 (3.4)</td>
</tr>
<tr>
<td></td>
<td>22.3 (5.3)</td>
<td>22.6 (5.4)</td>
<td>22.3 (6.8)</td>
</tr>
<tr>
<td></td>
<td>20.1 (4.4)</td>
<td>20.1 (4.4)</td>
<td>19.5 (4.5)</td>
</tr>
<tr>
<td><strong>Percent Body Fat</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33 (8.37)</td>
<td>32.4 (7.9)</td>
<td>31.7 (7.5)</td>
</tr>
<tr>
<td></td>
<td>26.4 (12.7)</td>
<td>25.7 (13.1)</td>
<td>24.8 (13.0)</td>
</tr>
<tr>
<td></td>
<td>31.5 (9.9)</td>
<td>30.9 (9.7)</td>
<td>30.3 (9.3)</td>
</tr>
</tbody>
</table>
### Table 13. Changes in anthropometric measures in relation to time, steps taken, age, gender and weight using the Conditional Mixed Model for ASU participants

<table>
<thead>
<tr>
<th>Effect</th>
<th>BMI</th>
<th>WC</th>
<th>BF</th>
<th>SAD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>SE</td>
<td>P</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Intercept</td>
<td>32.1</td>
<td>1.45</td>
<td>0.0001*</td>
<td>102.8</td>
</tr>
<tr>
<td>Time</td>
<td>-0.31</td>
<td>0.66</td>
<td>0.64</td>
<td>-0.48</td>
</tr>
<tr>
<td>Steps</td>
<td>0.00</td>
<td>0.00</td>
<td>0.38</td>
<td>0.00</td>
</tr>
<tr>
<td>Cage</td>
<td>0.03</td>
<td>0.04</td>
<td>0.45</td>
<td>0.18</td>
</tr>
<tr>
<td>Female</td>
<td>-1.77</td>
<td>1.28</td>
<td>0.17</td>
<td>-7.67</td>
</tr>
<tr>
<td>Normal/OverFatCat</td>
<td>-7.53</td>
<td>1.12</td>
<td>0.0001*</td>
<td>-20.23</td>
</tr>
<tr>
<td>Time-steps</td>
<td>0.00</td>
<td>0.00</td>
<td>0.41</td>
<td>0.00</td>
</tr>
<tr>
<td>Time-Cage</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.73</td>
<td>-0.08</td>
</tr>
<tr>
<td>Time-Female</td>
<td>-0.18</td>
<td>0.49</td>
<td>0.71</td>
<td>-0.63</td>
</tr>
<tr>
<td>Time-Normal/OverFatCat</td>
<td>-0.07</td>
<td>0.43</td>
<td>0.86</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Abbreviations: BFP, Body Fat Percentage; BMI, Body Mass Index; Cage, Centered age; Normal/OverFatCat, Normal/Over Fat Categories; P, P-value; SAD, Sagittal Abdominal Diameter; SE, Standard Error

*Statistical intent to treat analyses using all available data were performed using SAS software version 9.2. The level of significance was set at p<0.05 for all tests.
5 DISCUSSION

5.1 DISCUSSION ON MAIN FINDINGS

This thesis was a part of an international collaborative 6-month pedometer-determined workplace PA intervention called “ASUKI Step Study”[150] conducted at the KI in Stockholm, Sweden and ASU in the greater Phoenix area, Arizona. “ASUKI Step” was a single group quasi-experimental, workplace pedometer-determined PA intervention designed to increase the number of days employees walk 10,000 steps and to reduce the number of days employees spend being inactive, defined as taking less than 3,000 steps per day. The study results should be considered in the light of the context of the strengths and limitations of the methods used in the study.

The primary aim of paper II was to examine the changes in daily steps during the intervention period among participants in the ASUKI step program and to describe the socio-demographic predictors of month one step counts and changes in steps over the six month intervention. We hypothesized that participants who were male, not in a managerial position, older or reported a higher PA level at baseline would be more successful in obtaining 10,000 steps per day for at least 100 days.

The data show that there was a significant linear and curvilinear change in steps over time with steps decreasing from month 1 to month 6 when all participants were included in the model. When dropouts were excluded from the analysis, there was no significant decrease in steps from month 1 to month 6. This trend was observed at both ASU and KI. Participants at the KI had a higher initial step count and a slower rate of decline over time. It is plausible that this finding could be partially attributed to seasonality.

Site and socio-demographic characteristics were predictive of initial step counts and changes in step counts over time. Age was associated with trajectory of change; as age increased the rate of decline in steps was slower. The average step count over time was over 11,000 steps per day which is much higher than the average 4000-6000 steps per day for the typical office worker [58]. Additionally, socio-demographic characteristics were predictive of changes in step counts. Men had a greater rate of decline than women, which was an unanticipated finding. Age was also associated with trajectory of change; as age increased the rate of decline in steps was slower. We hypothesized that initial PA level would be associated with changes in step count over time. However, this was not the case. People who were classified as low active or moderately active based on IPAQ responses had lower initial step counts but activity levels were not associated with the trajectory of change. Likewise, BMI was only associated with initial step counts, not the trajectory of change. Individuals who were obese had significantly lower initial step counts relative to normal weight individuals.

Overall, more than half (52.9%) of the participants accumulated at least 10,000 steps per day on 100 days or more. These results varied by site and participant characteristics. Participants at the KI were more likely to meet this step count goal, with nearly 60% of the study participants at KI met this goal. In contrast, at ASU, only 40% met the goal. Similar to the predictors for changes in step counts, individuals who were older were more likely to meet the study goal. Obesity was also indicative of likelihood of meeting the step goal; obese individuals were 60% less likely to meet
the goal. While self-reported PA level at the beginning of the study was not associated with changes in step counts over time, it was predictive of meeting the study step goal. Individuals who were moderately or low active were 55% and 60%, respectively, less likely to meet the step standard. Sociodemographic predictors of meeting the step standard were similar across sites. Gender and employment type were significant predictors at KI only. Interestingly, women at KI were 50% more likely than men to reach 10,000 steps on 100 days.

Our findings for gender were different by site. Gender was only associated with meeting the step goal at the KI. At this site, women were 50% more likely to meet the goal. Several previous PA studies found that men took significantly more steps than women [152-156]. In contrast, Hirvensalo et al. showed that Finnish women took significantly more steps than Finnish men [157]. It is plausible that similarities in work culture in Sweden and Finland may explain why women were more likely to be active in the present study and the one by Hirvensalo et al. Similar to a previous PA study [158], we found no association between education level and meeting the step goal.

Our findings also suggested a negative association with BMI and successful attainment of the step goal. Individuals who were overweight or obese were less likely to meet the goal. Baseline level of PA, as indicated on the IPAQ and by initial pedometer measured PA level, was a predictor of success. Compared to highly active individuals, low active individuals were 40-60% less likely to meet the goal. This finding is in line with other studies of worksite wellness programs. De Cocker et al. found that individuals who are already active are more successful in worksite PA interventions [121]. The results of this walking study may be useful in helping setting steps per day targets for segments of the general population.

Similarly, in analyses with missing data excluded, older age, male gender, a higher baseline level of activity and a lower BMI were predictive of initial step counts but only age was associated with changes in step counts over time. Younger individuals had a sharper decline in steps over time. Finally, in the subset of individuals for whom we had accelerometer-derived physical activity levels, there were no changes over time in minutes of physical inactivity, light activity, moderate lifestyle or moderate activity suggesting that the intervention did not improve PA levels.

The average dropout rate for the study II was 36.7%, which is similar to other community-based PA interventions ranging from 20%-44% [159-163]. Associations found between socio-demographic characteristics and dropouts were in line with earlier studies [157, 159, 163]. Participants who dropped out were more likely to be of younger age, being categorized as low-to-moderately active in the initial IPAQ, and being obese at baseline using reported BMI. A low level of PA is a risk factor for obesity and participants who were obese were more likely to dropout from the study [164]. However, participants at ASU had a higher dropout rate than KI participants. The explanation for higher dropout rate observed in ASU could be related to the seasonal difference (hot weather in Arizona) that may limit opportunities for walking or outdoor PA during the summer or differences in PA and sports culture that reflects the lifestyle of Americans. The participants who work in managerial position have been found to dropout more than those who working in non-managerial position. This could possibly be explained by work overload among those employed in managerial positions, creating lack of time and energy for engaging in PA, or for engaging in the surrounding activities, which in this case were reporting and responding to
questionnaires. The dropout rate for men was higher than for women. However, we found that when the models included all predictors the differences between men and women disappeared. While the majority of the results remained similar between the analyses with zeros and dropouts, there were a few differences as mentioned in the results.

The major purpose of the study III was to investigate the changes in resting BP and estimated VO2 max as determined by an ergometer submaximal exercise test during a six-month pedometer-determined PA intervention. We hypothesized that a six-month pedometer-based PA would be positively associated with decrease in resting BP and improvement in CRF. The results indicate significant improvements in both systolic and diastolic BP, and estimated VO2 max increased only for older KI participants during the intervention period. The goal of 10,000 steps per day was reached by the subgroup of participants during a larger number of days than the other ASUKI participants. This shows the importance of a thorough follow-up and continuous support in PA interventions. The main results presented in this study were observations of significant linear and quadratic decreases in both systolic and diastolic BP, while no significant improvements in estimated VO2 max in the ASUKI subgroup participants were observed. This is similar to earlier pedometer interventions where decreases in systolic and diastolic BP have been reported, particularly when a specific target is set (e.g., 10,000 steps/day) [159, 162, 165, 166]. However, another interesting finding was that individuals with higher CRF levels at the start of the study on average reported more steps per day than participants with lower initial CRF levels.

The data from this study also suggest that reported number of steps was significantly related to both the linear and quadratic changes in diastolic BP over time. The differences in starting values of BP between ASU and KI participants correlates with the general differences in blood pressure demonstrated between US and European countries [167]. The differences in BP change over time in ASU and KI participants indicated in Figures 1 and 2 in paper III may be related to variations in the environmental temperature (heat in Arizona and cold in Stockholm), financial stress, work related stress, alcohol intake during vacation, just to mention a few. Generally, BP is higher in the winter and lower in the summer [168]. Our results indicate that BP showed a tendency towards an increase in KI participants during the end of the intervention, but it decreased in ASU participants. The explanations for these changes could be that the end of the study at KI coincides with going back to work, possibly adding some work related stress. The vacation in Sweden also means substantially increased alcohol consumption [169], even if we have no data regarding this in the ASUKI group. The US situation was such, that the ASU had severe cuts of staff and funding in the wake of the financial crisis coinciding with the start of the study which may have been a factor contributing to the higher BP during the first month.

We saw no change in CRF over time for the KI participants in total or by gender. There was, however, a decline in estimated VO2 max for ASU participants during the intervention period. One explanation for the significant decline in ASU participants’ estimated VO2 max can be related to a greater decrease in their reported daily average number of steps compared to KI participants who kept the goal of walking 10,000 steps per day over time. Also, estimated VO2 max increased for older KI participants during the intervention period. Interestingly, the older participants who had significantly greater increase in estimated VO2 max had a higher compliance to daily walking. The number of steps taken was significantly related to changes in
estimated VO₂ max over time, as steps increased estimated VO₂ max increased. A meta-analysis of randomized, controlled trials that yielded over 40 studies using walking as an intervention, indicated significant decreases in diastolic BP, and significant increases in CRF [89].

The major purpose of the study IV was to investigate the association of improvement in BMI, WC, SAD, and body fat percentage with the pedometer-determined PA intervention. We hypothesized that participants who complied with the six month pedometer-determined PA intervention would show weight maintenance or improvements in body weight, BMI, WC, SAD, and body fat percentage at the end of the intervention. The results indicate that small improvements in anthropometric characteristics can occur by use of a pedometer-determined PA intervention during six months. These changes were observed in the older age group, who had the best compliance of walking 10 000 steps/day. Interestingly, those with higher BMI, WC, and SAD values had the greatest reductions during the intervention.

The data presented in the study IV suggested that the intervention period started with a mean of more than 13,000 (SD = 3,117) reported steps per day and decreased to just below 10,000 (SD = 5,947) steps per day after six months, and the goal of 10,000 steps per day was reached by the KI subgroup during a larger number of days than the other ASUKI participants. This indicates the importance of a thorough follow-up in PA interventions. By contrast, evidence from previous worksite studies demonstrate that office employees generally accumulate about 4000-6000 steps per day [58]. A systematic review investigating the health effects of pedometer interventions found that people who wear a pedometer demonstrated a significant decrease in BMI, and other anthropometric and biological health indicators [159, 170] but our data showed that there was a significant reduction in BMI over time for older participants, and there was a significant decline in WC for middle age, and older participants, and there was also a significant reduction in WC over time in the subgroup of females for the KI subgroup over the six-month intervention period. Those with higher BMI, WC, and SAD values had the greatest reductions over time. A meta-analysis of randomized, controlled trials that yielded over 40 studies using walking as an intervention, showed significant decreases in body weight, BMI, and percent body fat [89]. The results suggest that the KI subgroup participants overall were relatively healthy and many of them were within the normal category for each anthropometric variable and thus large reductions were not likely to be seen.

The older participants who had significantly greater body fatness and a higher compliance to daily walking also decreased both body fat percentage and WC, but the weight maintenance was reached for several individuals. Thus, a pedometer intervention with a goal of 10,000 steps/day, as required by the ASUKI Step study, may introduce a sufficient dose to promote small decreases in the WC and body fat percentage. We have no information regarding diet and unhealthy lifestyle choices during vacation months such as alcohol consumption and a more energy dense diet. There was no correlation between the reported number of steps in the competition and the change in any of the anthropometric variables which might be due to the small changes in each anthropometric variable and the relatively similar amount of steps among the participants. An additional reason for the small changes in the anthropometric variables during the intervention might be as previous studies suggest [121, 159, 161], that large improvements cannot be made in healthy employees that take part in PA interventions. And likewise, another suggestion could be that the less healthy employees dropped out of the study at an earlier stage.
The study V evaluated the effects of a 6-month, pedometer-based walking intervention on body composition measures in the US cohort of the ASUKI Step study. In study V we hypothesized that we would observe significant decreases in body composition measures among the US cohort and that the changes would be larger than those observed in the leaner Swedish ASUKI Step cohort who had lower BMI, WC, BF and SAD measures than the US cohort at the start of the study [151]. The secondary hypothesis was that specific predictor variables (age, gender, steps taken, fat category) would predict the changes in the body composition outcomes.

Contrary to our hypothesis, only minimal changes were observed in the body composition measures among the US cohort over the 6-month intervention period, and the changes in body composition measures among the US cohort were smaller than those observed in the Swedish cohort. Significant changes were observed among the US participants for WC on the order of -3 cm over the 6 month study. Female gender and higher levels of BF at baseline predicted greater changes in WC by end of the study. Even this small decrease in BC measures among the US cohort has clinical implications. WC is an indirect indicator of central obesity. Central obesity is a strong predictor of visceral adiposity and an independent risk factor for various metabolic diseases, including type 2-diabetes [171-173]. In a meta-analysis by Ohkawara and colleagues, brisk walking for 300 minutes per week had a positive impact on reducing visceral fat and improving health [173].

We observed that the amount of steps taken over the six month period did not significantly affect changes in body composition in the ASU sub-sample of adult men and women enrolled in the ASUKI Step Study similar to previous pedometer-determined interventions which have showed decrease or no change in BC [121, 159, 161, 162]. While there were no changes due to steps there are some important characteristics of the BC to note. BMI did not show significant changes. Significantly large changes in BMI groups are rare in low-to-moderate intensity walking in pedometer studies [121, 159]. Change in anthropometric measures may be related to health but other clinical health characteristics such as blood pressure, may be more representative measures of health outcomes as shown in paper III in this thesis or in other pedometer studies [121, 159]. On average, the Swedish cohort took more steps per day than the US cohort (13,105 ± 2,998 vs. 10,514 ± 3259). The lack of relationship between changes in BMI (reflecting body weight) and the steps taken in the US cohort may reflect a steady decline in average steps taken from the start of the study to the end [174]. De Cocker et al., also showed non-significant changes in BMI with steps decreasing throughout a 20-week study [121]. In our study, with a goal of taking 10,000 steps per day, the percentage of people in each step activity classification level changed such that overall activity levels decreased over six months. Overall, participants went from ‘active’ at month one [10,714 (3,357) steps/day] to ‘somewhat active’ by month three [8,602 (4,954) steps/day], and to ‘low active’ by the sixth month [6,332 (5,535) steps/day]. The reason for participants walked less as the study progress is unknown but expected due to the length of the intervention. However, the impact of the increasing summer heat in Arizona may be related to the declining levels of PA. Pedometer studies have shown that seasons may be a factor in participation and have a modest effect on PA [121, 175, 176].

The weather may be a barrier to PA but objective assessment of this hypothesis is limited [175]. Chan CB et al. showed that weather had modest effects on PA of participants in an intervention to improve their activity. These effects may be different for more or less motivated individuals [175]. The weather has been indicated as an environmental factor affecting PA [177-180]. Humpel et al. showed that weather was least inhibiting for people who were "high neighborhood walkers" or
who walked specifically for exercise [181]. Time of year or weather apparently impacts all socioeconomic groups as a barrier to PA [182]. However, several studies using self-report of PA found associations with weather [176]. The relationship between weather as a barrier to PA was indicated to be similar in men and women [181]. There have been only limited reports of the effects of weather on PA where physical activity was assessed objectively [176, 183]. In one case, steps per day recorded by pedometer in 23 participants over a one-year period were showed to vary with the season (summer more than winter) for individuals in Tennessee and South Carolina [176], and Togo F et al. found an exponential decrease in PA with increasing precipitation (rain) in 41 elderly Japanese [183]. In a 20-week pedometer based PA program that was built on the Social Ecological Model [184], a decrease in the number of steps taken from baseline to the end of the intervention was observed and the authors of this study postulated that the observed decline in step counts was attributable to seasonality as the baseline step counts were recorded in late summer and post-test steps were recorded in winter. Additionally, participants who were active at baseline (> 10,000 steps per day) at the intervention worksite saw a smaller decline in steps taken per day compared to active participants at the comparison worksite. Kang M et al. showed that targeting the data collection during certain months (eg, May) may provide more accurate estimates of year-round averages and reduce pedometer measurement error [185]. Understanding the environmental factors that impact on PA is important for policy makers and program coordinators. To date, there have been only a few studies that address these factors, including weather, and utilized an objective measure of PA in a longitudinal design [176, 183]. Chan CB et al. have shown for the first time the potential for variables such as rain and snow, temperature, and wind speed to alter daily PA. Further study should be aimed at examining PA among the general population correlated with weather variables [175].
5.2 METHODOLOGICAL CONSIDERATIONS

5.2.1 Study design

ASUKI Step study was a workplace pedometer-determined PA intervention. The study also examines the intra- and interpersonal determinants for success in the intervention and in a sub-sample of the participants, changes in physical fitness and body composition during the study. To the best of our knowledge, this is the first workplace pedometer-determined PA intervention in Sweden, as well as in collaboration with the ASU to measure subjectively total PA using IPAQ and to objectively measure PA using pedometers and accelerometers in a randomly selected sub-sample of participants. The study used a pre-post test, non-randomized, experimental group only quasi-experimental design. This was an unusually long intervention on healthy volunteers. Most pedometer interventions run for 1-3 months. We have done a literature review regarding workplace pedometer-determined PA intervention before starting the study, most workplace pedometer-based intervention run for less than 6 month (3-4 month) [184, 186-193].

The limitations of the study design

Due to logistical reasons of enrolling more than 2,000 participants from two universities, each with two to three campuses, and because just giving pedometers to people and asking them to report their PA is an intervention in itself, we were unable to collect pedometer-determined steps data before the start of the study. Hence, “ASUKI Step study” does not have a true baseline of the usual steps per day walked before the study began. However, the pedometer study is able to show individual changes in steps taken during the study and concomitant changes in correlates of walking behaviors during the 6 month study. Baseline data are available for laboratory assessments with accelerometry, body composition, and cardiorespiratory fitness. The questionnaire data, including IPAQ for assessing PA level were collected prior to the participants starting the walking intervention.

Although experimental studies are considered as the “gold standard” to assess the effectiveness of an intervention in changing outcomes, in some cases, a quasi-experimental study may be more appropriate or feasible [194, 195]. Quasi-experimental study, often described as nonrandomized, pre-post intervention studies, is common in research area, and it often is used to evaluate the benefits of specific interventions. In the literature quasi-experimental studies are divided into four study design groups, and quasi-experimental design without control group (pre-post test) is a commonly used design [196], and the social sciences literature is replete with examples of ways to improve and implement quasi-experimental designs [196]. While a true experimental study includes (1) random assignment of study participants, (2) a treatment group and a control group, and (3) pre-post test design, a quasi-experimental study lacks one or more of these design elements [195, 197]. This design is frequently used when it is not logistically feasible or not ethical to conduct a randomized, controlled trial of causal research design [194, 196].

Quasi-experimental design could be implemented either with the same units or different units receiving both pre-test and post-test. When the same units are used this is often called a within-subjects design. By contrast, an experiment having multiple conditions and different units in each condition is often called a between subjects design [198]. The main difference between a quasi-experimental study and an experimental study is that in a true experimental study, the individuals are assigned to a control group or a treatment group by random assignment [194], that will allow you to get the best evidence of whether or not that the intervention had the intended causal effect.
But, random assignment is not always a practical step in the research area [197, 199], and often it may not be practical to divide up study participants into both a treatment and control group at all.

It is believed that the workplace is a good setting for conducting of interventions, but is a difficult setting for delivering high quality research according to clinical tradition [199], and quasi-experimental studies are often more feasible in workplace settings. For example, in our study dividing up the participants into two test and control groups may be impractical in the workplace settings. For some interventions such as our workplace PA intervention, it may not be possible to keep employees in the control group from being affected by the intervention. For example, as suggested by the ‘lunchroom effect’, participants in the test group may talk to individuals in the control group about the intervention during lunch or other times, so the control group is also being influenced by the intervention (Contamination effect or also known as diffusion threat to internal validity) [195, 197]. The major drawback with quasi-experimental study is that, compared to experimental research, it has a weakness in that is not possible to deliver cause and effect results and you cannot be completely sure that changes in the dependent variables were caused by the manipulation of the independent variable, and it is possible that something other than the independent variable might have occurred between the pre and the post intervention that influenced the participants [200], and you may then “speculate” about the role of the intervention.

The pre-post test design allows you to make inference on the effect of your intervention by looking at the difference in the pre-test and post-test results [201]. However, interpreting the pre- and post-intervention differences should be done with caution [197, 202], thus in the ASUKI Step Study and in our statistical methods we tried to describes what occurs during the 6 month intervention. A systematic review including fifteen randomized, controlled trials, and eleven nonrandomized, controlled trials conducted to critically review the literature with respect to the effectiveness of workplace PA interventions on PA, physical fitness, and health indicate that the majority of the studies had methodological shortcomings [203]. A meta-analysis of twenty-six worksite PA studies [199] indicates that a few studies that used an exemplary research design, sample, and measures have also yielded small effects. The poor scientific quality of the literature on worksite PA interventions precludes judgment that worksite PA intervention cannot improve PA, physical fitness, or health, but such as increase needs to be demonstrated by interventions using valid study designs and measures [199]. Nonetheless, since the majority of the population in the societies is currently in the workforce, the public health effect of PA interventions having even small to moderate health impact would be substantial [199, 203].

**Internal validity of the study**

Internal validity is the approximate truth about inferences regarding cause-effect or causal relationships. It occurs when the experimenter tries to control all variables that could affect the results in the experiment. Regression to the mean, history and the participants are all possible threats to internal validity. The question you would want to ask while trying to keep internal validity, is "Is there any other possible reasons for the outcome besides the reason we want it to be?" If so, then internal validity might not be as strong.
The lack of random assignment and control group (and lack of baseline pedometer data) in the current study as a quasi-experimental design study create multiple threats to internal validity [196], and these make the interpretation of the findings of the study problematic.

In quasi-experimental studies the methodological principles that most often result in alternative explanations for the apparent causal effect include (a) difficulty in measuring or controlling for important confounding variables, particularly unmeasured confounding variables, and (b) results being explained by the statistical principle of regression to the mean [196]. An inability to sufficiently control for important confounding variables arises from the lack of randomization. A variable is a confounding variable if it is associated with the exposure of interest and is also associated with the outcome of interest; the confounding variable leads to a situation where a causal association between a given exposure and an outcome is observed as a result of the influence of the confounding variable. Potential confounding variables that are unmeasured or immeasurable cannot be controlled for in nonrandomized quasi-experimental study designs. Another important threat to establishing causality is regression to the mean. This widespread statistical phenomenon can result in wrongly concluding that an effect is due to the intervention when in reality it is due to chance [196, 204, 205].

The lack of random assignment and control group in the quasi-experimental design method may allow studies to be more feasible, but these also pose many challenges for the investigator in terms of internal validity. Randomness and having control group bring a lot of useful information to a study because they broaden results and therefore give a better representation of the population as a whole. In ASUKI Step Study as a whole, because randomization and control group are absent, some knowledge about the data can be approximated, but conclusions of causal relationships are difficult to determine due to a variety of extraneous and confounding variables that exist in a social environment.

### 5.2.2 Pedometer-determined PA

In this study we used pedometer SW-200 as main tool to measure PA. This pedometer is a valid and reliable tool for counting steps in healthy adults [60, 127]. The SW-200 pedometer is valid within ± 3% of actual steps taken during a self-paced walk on an individual and within 1% of actual steps for a group mean [206]. This accuracy is similar in normal weight, overweight, and moderately obese adults [207]. Pedometers provide information on ambulatory activity (e.g. walking). These devices record steps taken and can estimate distance walked if stride length is known. The high quality pedometers have been proven as a valid and reliable method to measure ambulatory movement [61]. Generally, pedometers are most accurate for assessing steps, less accurate for assessing distance, and even less accurate for assessing energy expenditure or kilocalories [60]. They can also be used to estimate PA energy expenditure by estimating the energy cost associated with walking. The main advantages of pedometers are the low cost and ease to use, potential for use in a variety of settings including schools and workplaces, easy to administer to large groups, potential to promote behavior change. On the other hand some limitations must be considered in any study involving pedometers including loss of accuracy when jogging or running, possibility of participants tampering [43]. Likewise, swimming is not usually assessed by pedometer due to practical problems. Pedometer has been suggested as an accurate and reliable tool to record steps taken in studies with a diversity of participants, yet there is the potential that placement of wearing this device on the body may alter the accuracy of the
monitored steps [207, 208]. Previous studies discuss conflicting results regarding the impact of body size on the accuracy of the pedometer [184, 207, 208]. A study recommended that participants in the pedometer study be individually assessed regarding effective pedometer placement on the body [208] which in many pedometer-determined PA studies as well as in the current study was not feasible.

It must be restated that the study pedometer and questionnaire data were self-reported. Thus, there may have been over- or under-reporting of step data.

5.2.3 Walking 10,000 steps per day

Physical activity guidelines suggest that healthy adults should achieve at least 30 min of daily moderate to vigorous intensity PA or walking a minimum of 10,000 steps per day to improve health and well-being [36, 209], and the most frequently used pedometer-determined PA level recommendation is to achieve 10,000 steps per day [157]. One of the main goals of ASUKI Step Study was to examine whether a six-month, web-based pedometer intervention in a workplace could promote walking 10,000 steps per day for at least 100 days among participants, and the socio-demographic characteristics that were associated with successfully meeting the goal of 10,000 steps for at least 100 days. The results indicate that slightly more than half of the ASUKI participants achieved the goal of the study. However, certain segments of the target population were less likely to meet these goals suggesting that a low-intensity intervention such as ASUKI step might not work. Individuals who are overweight or obese or very inactive may need additional intervention strategies to be successful. Intervention participants were asked to achieve 10,000 steps per day. This approach could be counterproductive if people are unable to make such a big improvement in a reasonable period of time and become discouraged. Interventions may be much more successful if they promote small increases in walking during the intervention, gradually building up to a PA level of 10,000 steps per day. Using adaptive goal setting has been shown to be a more effective strategy than a blanket 10,000 steps per day goal. In adaptive goal setting, the goal is based on the participants’ current level of physical activity and may be more manageable and reasonable.

5.2.4 Anthropometric measures

Simple, noninvasive, and accurate methods for measuring body composition are needed in many research, clinical, and community settings. Many reference methods are useful to accurately estimate body composition at the individual level. Multicompartiment models, air displacement plethysmography, underwater weighing, double labeled water, and dual-energy X-ray absorptiometry (DXA) techniques are the most reliable techniques to assess accurate measures of body composition [210]. Anthropometry is the most widely used method when the sample to be measured is large, when economic resources are limited or when a quick measure is required [211]. The reference techniques are not always feasible for research and clinical use. In this study we measured body weight, BMI, WC, body fat percentage, and SAD. As main outcomes for assessing the effects of PA intervention on BC characteristics body weight (kg), BMI, body fat percentage were determined by BIA with the Tanita TBF-300A scale. The foot-to-foot BIA system could be one method of addressing those needs (simple, noninvasive, and accurate) [130]. The Tanita BIA system provides a valid measure of percent body fat in older adults, and could be a convenient and
practical approach for assessment in public health settings [130]. BIA derived BC values were highly correlated with DXA values [212].

BMI is a simple index of weight-for-height that is commonly used to classify underweight, normal weight, overweight and obesity in adults. BMI is probably most common anthropometric index that is used in the literature. It remains as a useful technique for obesity screening, although it has been criticized. The use of BMI as the only measure of BC does not seem a good choice, because the main drawback of BMI is that it does not differentiate between lean mass and fat [213]. SAD and WC also were measured in the current study. Abdominal obesity (estimated by abdominal WC) cutoff criteria (WC ≥102 cm for men and WC ≥88 cm for women) is a surrogate for abdominal subcutaneous and visceral fat stores [214]. It has been shown previously that WC is correlated with measures of total abdominal adipose tissue. Similarly, WC has been shown to be correlated, but less strongly so, with visceral adipose tissue, particularly in obese subjects. WC has been used widely in observational studies, and shown to be a stronger and indeed independent, predictor of health risks over BMI [215]. SAD is a novel anthropometric measure of visceral obesity [216, 217]. And SAD has also been proposed as an estimate of visceral adipose tissue. SAD showed the strongest correlation to visceral adipose tissue irrespective of age, sex, and degree of obesity compared with other anthropometric measures, whereas WC may have a stronger correlation to subcutaneous adipose tissue than to visceral adipose tissue [218]. several reports have suggested that the anteroposterior diameter of the abdomen, the sagittal abdominal diameter (SAD), is a superior correlate of metabolic syndrome criteria and insulin resistance than WC [219]. Some documents showed that SAD also reflects abdominal obesity [132].

5.2.5 Objective assessment of PA - accelerometry

In this study accelerometry was measured with the ActiGraph GT1M accelerometer (ActiGraph, Pensacola, FL) to provide an objective measure of PA during a one week period in each measurement time point. The ActiGraph provides information about the frequency, intensity, and duration of PA by utilizing a built-in single axis accelerometer which measures vertical accelerations at the hip. The ActiGraph was worn by a randomly selected subgroup for 7 days on a waist belt during all waking hours, except while in water. Based on guidelines for using accelerometers in a field setting, a minimum of three days during the week with 10 h.d⁻¹ of wear time was required for data to be included in the analysis [220]. The effects of site and participant characteristics on minutes of inactivity, light, lifestyle and moderate to vigorous PA were examined in 226 people using individual growth models for the 3 measurement points. In the subgroup of individuals for whom we had accelerometer-derived PA levels, there were no changes over time in minutes of physical inactivity, light activity, moderate lifestyle or moderate activity. These findings suggest that a more intensive approach may be required for particular segments of the population.

5.2.6 Sub-maximal VO2 max

Despite the advantages of submaximal fitness tests with adults, laboratory measurements that examine actual individual’s aerobic capacity are considered the gold standard for predicting CRF [100, 221]. VO2 max could be estimated using maximal or sub-maximal tests, by direct and indirect methods. The most common tests are cycling, walking/running tests [149]. Maximal oxygen consumption (VO2 max) is a generally accepted accurate index of CRF [149]. We
conducted Åstrand-Rhyming cycle ergometer test using Monark Electronic Ergometer 839E to predict estimated sub-maximal VO2 max at baseline and after 6 month [103, 142]. The results indicate no improvement in participants’ VO2 max. In contrast, a meta-analysis of randomized, controlled trials that yielded over 40 studies using walking as an intervention, showed significant increases in CRF [89]. The obvious advantages of Åstrand-Rhyming sub-maximal VO2 max test are: (1) sedentary or older participants can be tested without the potential hazards and discomfort attendant with a maximal exercise test and, (2) it can be administered to a large number of individuals in a short time period. The VO2 max predicted from the Astrand-Rhyming test correlated significantly with VO2 max measured by maximal predictive cycle ergometer test and direct measure of VO2 max using treadmill [103]. A study showed that Åstrand-Rhyming test protocol is feasible in healthy participants, and has strong relationship to actual VO2 consumption, and Criterion validity and retest reliability of test data were excellent [145]. Furthermore, there are several limitations for Åstrand-Rhyming nomogram to predict VO2 max [222, 223]. The differences in individual maximal heart rate may be the most important. Previous studies have indicated that the nomogram may underestimate VO2 max. It is assumed that the nomogram is sub-optimal to compare between individuals but may have indications on a group level [222]. Direct methods to measure estimated VO2 max are superior in validity in comparison with other methods, but they may be less than optimal to use in a large samples of adults [222].

5.2.7 Resting systolic and diastolic blood pressure

Using pedometers to track walking, Awain et al. showed that walking at least 10,000 steps per day resulted in reductions in elevated BP and an improved exercise capacity in hypertensive adults and prevent cardiovascular disease [60, 85, 224]. Evidence showed that walking programs of moderate-high intensity may be more useful than walking at low-intensity on lowering BP [225]. Fagard RH et al. showed that regular PA is a cornerstone therapy for the prevention, treatment and control of hypertension [117]. In this study we measured resting BP using an Omron automated BP cuff [134, 135]. The participants were asked to abstain from smoking, eating, exercising, and drinking alcohol 2 hours before testing. The main results in our study were observations of significant decreases in resting systolic and diastolic BP. The main advantages of the Omron automated device are accuracy comparable to manual mercury sphygmomanometry, with reduced potential for observer biases and less demand on research assistants in terms of training and effort in data collection [137, 139]. Omron automated device was accepted according to the European Society of Hypertension International Validation protocol [138]. The sensitivity and specificity of the Omron to detect hypertension were 88.2% and 98.6%, respectively. Data showed that the Omron BP device could be used for measuring BP in large epidemiology studies without compromising study validity or precision [137]. The Omron BP device overestimated systolic BP by 1.8 mmHg and underestimated diastolic BP by 1.6 mmHg, which is acceptable according to the European Society of Hypertension guidelines [136, 137]. To define categories of blood pressure and recommended follow-up the seventh report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) was used [146].
6 PUBLIC HEALTH IMPLICATIONS, AND CLINICAL IMPORTANCE OF THE STUDY

The data presented in this thesis showed that the subgroup participants reported more steps than their no-test group team members in both ASU and KI workplaces. The results from paper II have shown that accumulating 10,000 steps per day is feasible for healthy individuals and pedometer along with the goal of 10,000 steps per day could be a considerable recommendation with the beneficial health effects in the research and practice areas.

Results from paper III also suggest that walking with a goal of 10,000 steps/day can be effective in reducing resting systolic and diastolic BP on participants. It should be noted that BP is an indicator that can be improved rather quickly with exercise by adding daily moderate PA. As would be expected, individuals with higher CRF levels at the start of the study on average reported more steps per day than participants with lower initial CRF levels. Estimated VO2 max increased for older KI participants during the intervention period. Interestingly, the older participants who had significantly greater increase in estimated VO2 max had a higher compliance to daily walking. Nevertheless, data from epidemiological studies using objective methods for measuring PA, and results from randomized controlled trials, support the idea that high intensity PA will be associated with improvement of CRF level [89].

Having three testing sessions may have served as a motivational follow-up which aided their participation. According to results presented in paper IV, nearly all Swedish employees involved in this study were relatively healthy and many of them were within normal category for each body composition variable and thus small reductions in anthropometric variables were likely to be seen. Previous studies [121, 159, 161] indicate that small improvements in anthropometric variables can be made in healthy employees that took part in PA interventions. A better improvement in body composition variables was observed in the older participants, who had the best compliance of walking 10,000 steps per day. While anthropometric measures such as BMI, WC, BF, and SAD may be related to health, other clinical health indices (e.g. blood profile), which were not included in this study, may be more sensitive measures of health outcomes. Further studies are needed to determine the association between reported steps/day and other clinical health indicators such as blood lipid profile, as well as the association with diet.

It is also important to assess the likely biological and clinical importance of results that are statistically significant. Our results indicate that this 6-month pedometer-determined PA intervention had a statistically significant association with reducing systolic and diastolic BP over time in relatively healthy volunteers, ASUKI participants. We observed significant reductions in some body composition variables, and a significant improvement in estimated VO2 max only for older KI participants. However, the initial mean systolic BP was 118.14 mm Hg (SD = 16.05) and we achieved a rather substantial decrease in systolic BP by 5.57 mm Hg over time. According to the WHO publication cardiovascular risk factor trends and potential for reducing coronary heart disease mortality in the United State of America [226], a reduction corresponding to 5 mm Hg would correspond to a reduction in cardiovascular death of 48,000 deaths in CVD-where the average number of deaths per year is 450,000 per year in the US. This is compared to the
NHANES data—where the mean for men was 119.4 mm Hg and 118.9 mmHg for women. This suggests that our intervention is likely to play an important biological role in determining systolic and diastolic BP and certainly it seems as this change in BP is clinically relevant, and in our study we found only minor clinical importance in regards to changes in body composition and VO2 max in healthy adults.

Also, there is a growing recognition that assessing an intervention’s effect should not only focus at the statistical significances in health outcome, but should also focus at the relevance or importance of these outcomes. According to Middel B. et al., the estimated amount change measured by the effect size (ES) index can be denoted as clinically importance change [202]. According to the above mentioned paper, in health-related functional status or quality of life in pre post designs substantial effects can be detected with an estimate of ES. Of course the interpretation should be done by using p-value and ES index together. The ES tells us something different from p-value. ES statistics should be provided to supplement statistical testing (not as a substitute for it), and only when the outcome is sufficiently extreme from what would have been expected on the basis of chance (p<α). On the measurement of health-related quality of life and Health-Related Functional Status (HRFS), ES has been used as surrogates for clinical relevant change when change over time in outcome was substantial. Our data show that the ES index is large for systolic and diastolic blood pressure and small for VO2 max and anthropometric variables.
7 CONCLUSION

The ASUKI Step is one of the first long-term workplace pedometer-based PA interventions performed using objective (pedometer and accelerometer) and subjective (IPAQ) methods to assess PA in university staff, and the data provide a new and sobering picture of PA in university employees in the U.S. and Sweden. The data show that it was difficult to keep employees in the study for 6 months, as could be expected, and that there were significant linear and curvilinear changes in steps over time with steps decreasing from month 1 to month 6 when all participants were included in the model. When dropouts were excluded from the analysis, there was no significant decrease in steps from month 1 to month 6. Site and socio-demographic characteristics were predictive of initial step counts and changes in step counts over time. Overall, 52.9% of the participants accumulated 10,000 steps on at least 100 days of the study. Older age, being married, working in a non-managerial position, normal weight, and higher initial PA level were positively associated with meeting the step goal. The results indicate significant improvements in both systolic and diastolic BP, and estimated VO2 max increased only for older KI participants during the intervention period. The results indicate that small improvements in anthropometric characteristics can occur by use of a pedometer-determined PA intervention during six months. These findings were observed in the older age group, who had the best compliance of walking 10,000 steps/day. Only minimal changes were observed in the body composition measures among the US cohort over the 6-month intervention period, and the changes in body composition measures among the US cohort were smaller than those observed in the Swedish cohort.

The results of the study indicate that generally healthy individuals who took part in a workplace intervention using pedometers improved several cardiovascular risk factors, and walking 10,000 steps/day may be effective in reducing resting blood pressure among participants and improving CRF, particularly within the older age group who had the best compliance to walk 10,000 steps/day. Furthermore, the data indicate that small improvements in anthropometric characteristics can occur by use of a pedometer-based intervention over a six-month period. More than half of our participants were able to sustain 10,000 steps per day for 100 days of the study. Findings suggest that a low-intensity, pedometer based intervention grounded in social support can work with some segments of the population but a more intensive intervention may be needed for individuals who are sedentary or overweight.
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