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Assessment of Health-Enhancing Physical Activity at Population Level

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I rörelse

Den mätta dagen, den är aldrig störst.
Den bästa dagen är en dag av törst.

Nog finns det mål och mening i vår färd -
men det är vägen, som är mödan värd.

Det bästa målet är en nattlång rast,
där elden tänds och brödet bryts i hast.

På ställen, där man sover blott en gång,
blir sömnen trygg och drömmen full av sång.

Bryt upp, bryt upp! Den nya dagen gryr.
Oändligt är vårt stora äventyr.

Karin Boye

To my family

ABSTRACT

To assess the levels and patterns of health-enhancing physical activity in the population there is a real need for better instruments to be developed. The overall aims of this thesis were to test the International Physical Activity Questionnaire (IPAQ) and to study the level of health-enhancing physical activity in the Swedish adult population using both the IPAQ (a subjective method) and accelerometry (an objective method).

To validate the IPAQ, data was collected from a convenience sample of 46 adult men and women. In a second study data was collected from 980 men and women, aged 18 - 65, randomly chosen from a population register. The IPAQ data was compared against data from an accelerometer and a logbook for concurrent validity, and body composition and aerobic fitness for construct validity. For the population based studies two nationally representative samples of adult men and women were used (N = 1,470 and N = 1,114).

The validation studies showed significant correlations between the IPAQ and the accelerometer and logbook, although large intra-individual differences were found. Vigorous intensity activity and time spent in inactivity were systematically over-reported with IPAQ.

The IPAQ data showed that adults reported a median (25^{th} - 75^{th} percentile) of 1,699 (693 - 3,600) MET-min$\cdot$week^{-1}. This corresponds to about 60 (24 - 128) minutes of brisk walking per day. Men reported significantly more activity than women (1,836 vs. 1,554 MET-min$\cdot$week^{-1}, $P < 0.001$). A significant difference in total physical activity was found across age, BMI and self-rated health categories. For men, walking contributed 35 % (11 - 73 %) of the total physical activity, while for women, walking contributed 45 % (22 - 92 %).

The accelerometer data showed that men were significantly more active on moderate or higher intensity level than women. For total physical activity and time spent in inactivity, neither gender, age nor BMI could explain the variance. More than half (52 %) of the study population reached the “30 minutes per day” recommendation when every minute at moderate or higher intensity was counted. When activity bouts of 10 minutes or longer were considered, the prevalence estimates were only one percent.

This is the first time levels and patterns of physical activity have been assessed at population level, using objective methodology. Even though the absolute values between the instruments used differed, they both provided qualitatively consistent pictures. This thesis has shown a new and sobering picture of health-enhancing physical activity at population level. At the same time, the need to better understand the nature and measurement issues of health-enhancing physical activity has been highlighted.

Keywords: adults, behaviour, correlates, epidemiology, exercise, lifestyle, monitoring, physical activity recommendations, validity

SAMMANFATTNING

Bättre metoder behöver utvecklas för att bedöma arten och graden av hälsofrämjande fysisk aktivitet på befolkningsnivå. Syftet med denna avhandling var att dels metodpröva en enkät, the International Physical Activity Questionnaire (IPAQ), vidare att studera graden av hälsofrämjande fysisk aktivitet på befolkningsnivå med hjälp av IPAQ (subjektiv metod) och accelerometri (objektiv metod).

För att metodpröva IPAQ samlades data in från 46 frivilliga män och kvinnor. I en andra studie samlades data in från 980 män och kvinnor i åldrarna 18-65 år slumpmässigt utvalda ur ett befolkningsregister. Data från IPAQ jämfördes med data från en accelerometer och en dagbok för att utvärdera samtidig validitet och mot data från konditionstest och kroppsmått för begreppsvaliditet. För befolkningsstudierna har två nationellt representativa urval av män och kvinnor använts (N=1 470 och N=1114).

I valideringsstudierna kunde signifikanta korrelationer mellan IPAQ och accelerometern respektive dagboken visas. Stora individuella skillnader mellan metoderna hittades. Tid i mycket ansträngande fysisk aktivitet och tid i sittande var systematiskt överrapporterat i IPAQ.

IPAQ data visade att de vuxna rapporterade en median (25^e-75^e percentilen) av 1699 (693-3600) MET-min$\cdot$vecka^{-1}. Detta motsvarar ungefär 60 (24-128) minuter daglig rask promenad. Män rapporterade signifikant mer fysisk aktivitet än kvinnor (1836 resp. 1554 MET-min$\cdot$vecka^{-1}, $P<0.001$). En signifikant skillnad i total fysisk aktivitet kunde påvisas för ålder, BMI och självrapporterad hälsa. Av total fysisk aktivitet bidrog promenader med 35% (11-73%) för män och med 45% (22-92%) för kvinnor.

Accelerometerdata visade att män var signifikant mer fysiskt aktiva på minst måttlig intensitet än kvinnor. För total fysisk aktivitet eller i tid sittande kunde varken, kön, ålder eller BMI kunde förklara variationen. Mer än hälften (52%) av den studerade populationen uppnådde den rekommenderade nivån av 30 sammanlagda minuter daglig fysisk aktivitet på minst måttlig intensitet. Om man betraktar perioder om tio sammanhängande minuter eller mer uppnådde endast en procent av befolkningen rekommendationen.

Detta är första gången som arten och graden av fysisk aktivitet har uppmätts på befolkningsnivå med hjälp objektiva metoder. Även om de absoluta siffrorna mellan IPAQ och accelerometern skilde sig åt gav de båda ett liknande mönster. Denna avhandling har visat en utförligare bild av hälso-främjande fysisk aktivitet på befolkningsnivå. Samtidigt har behovet lyfts fram att ännu bättre förstå naturen och metodproblematiken kopplade till hälsofrämjande fysisk aktivitet.

Nyckelord: Bestämningsfaktorer, beteende, epidemiologi, livsstil, motion, mätsystem, rekommendationer, validitet, vuxna

LIST OF PUBLICATIONS

I. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutrition*. 2006;9:755-762

II. Hagströmer M, Bergman P, Bauman A, Sjöström M. The international prevalence study (IPS): health-enhancing physical activity in Sweden. *Journal of Public Health (Springer)*. 2006;14:310-308

III. Hagströmer M, Ainsworth B, Oja P, Sjöström M. Comparison of the long form of IPAQ with an accelerometer in a population sample. *Submitted*

IV. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc*. 2007; 39:1502 – 1508

CONTENTS

1 FOREWORD

I was brought up in a family where a morning walk around the lake, regular outdoor activities and manual chores were a natural part of life. I enjoyed and felt good being physically and socially active. This influenced my choice of occupation (health promotion and physiotherapy), hobbies and interests (I became a leader in Friskis & Svettis and Friluftsfrämjandet). It became evident to me early on in life that all would benefit from an active lifestyle but that not so many individuals in the population are interested in regular exercise or sports.

Who are these inactive or insufficiently active individuals and how can they be motivated to increase their activity?

The data available from Statistics Sweden presented data on participation in intentional physical activity exercise *("motion").* Individuals with sedentary jobs and who exercises only once or twice a week were classified as active enough, while individuals with no reported intentional exercise but a heavy manual work and may even have cycling to work were classified as insufficient active. I found this strange. The word for exercise was also poorly defined, and was left to the individual. The presented data were not very useful to me and I remained curious about this paradox.

When searching for a health-related topic for my master thesis in public health I came in contact with the Unit for Preventive Nutrition at Karolinska Institutet, and its head, Michael Sjöström. He was actively involved in the development and testing of a new questionnaire, the International Physical Activity Questionnaire (IPAQ), and he was looking for a project assistant. The questionnaire had been recently developed by him and a group of other outstanding scientist across the world, but required validation. A new method to assess physical activity objectively (accelerometry), was being validated, but needed to be tested in a full-scale study.

I accepted the invitation to become a member of the group, and later on registered as a PhD student. The work has been most stimulating. I became a member of the global core group as I also became responsible for the IPAQ web page (www.ipaq.ki.se). I hope that the results and the experiences gained, here summarised, will be useful in the future work of the public health in Sweden, to increase our knowledge about which groups in the population are most in need of support.

It is my sincere hope that this knowledge will ultimately lead to a more physically active and healthy population.

2 BACKGROUND

2.1 PHYSICAL ACTIVITY AND RELATED CONCEPTS

Physical activity is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen et al. 1985). This broad term means that physical activity includes almost everything a person does and that *inactivity* is time doing things that do not markedly increase energy expenditure. *Physical exercise* on the other hand is defined as a subset of physical activities that is “planned, structured and repetitive bodily movement done to improve or maintain one or more components of physical fitness” (Caspersen et al. 1985). *Physical fitness* is a set of attributes related to a person's ability to perform physical activities that require aerobic fitness, endurance, strength, or flexibility and is determined by a combination of regular activity and genetically inherited ability (Caspersen et al. 1985). *Health-enhancing physical activity* (HEPA) is defined as “any form of physical activity that benefits health and functional capacity without undue harm or risk” (Foster 2000; Oja and Borms 2004). Figure 1 is a graphically representation of theses concepts.

In epidemiological research being inactive or insufficiently activity is often defined as not reaching the current physical activity recommendations, i.e. not being active enough for health (Dishman et al. 2004).

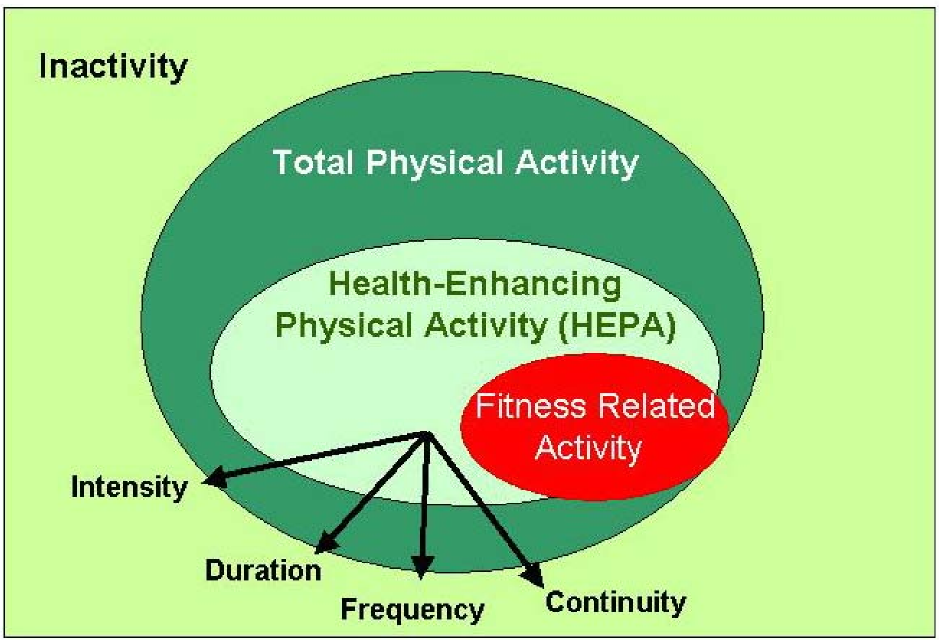

Figure 1. A graphical description of the definition of physical activity and related concepts. The figure represents time spent awake. The size of the different circles are not proportional to time spent at different levels.

As defined above, physical activity results in increased energy expenditure. Energy expenditure is usually expressed as the oxygen required per time unit based upon measurements of oxygen consumption ($l \cdot min^{-1}$ or $ml \cdot min^{-1} \cdot kg^{-1}$). From the oxygen consumption the energy expenditure ($kcal \cdot min^{-1}$) can be calculated. The energy expenditure can be expressed as a multiple of resting metabolic rate.

To account for differences in resting metabolic rates related to gender, age and body composition the Metabolic Equivalent (MET) classification has been developed. One MET corresponds to the mean resting oxygen uptake (i.e. resting metabolic rate) in the sitting position, which is roughly equivalent to 1 kcal per kilo body weight per hour or 3.5 ml oxygen per kg body weight and minute (Welk 2002a; McArdle et al. 2006). A comprehensive list (the Compendium of Physical Activities) of MET intensities for different physical activities performed has been developed (Ainsworth et al. 1993; Ainsworth et al. 2000b).

The dose of physical activity can be described by its intensity, duration, frequency, mode and continuity. *Intensity* is the rate of energy expenditure while an activity is performed. The intensity can be presented in absolute terms (METs), where 3 - 6 METs and > 6 METs correspond to moderate and vigorous intensity, respectively (ACSM 2006). Intensity can also be presented in relative terms, i.e. taking the aerobic fitness level into account, thus describing the activity as percentage of maximal aerobic capacity (% VO_2 max) for the specific activity or intensity, where 51 - 69 % and 70 - 85 % of VO_2 max corresponds to moderate and vigorous intensity, respectively (ACSM 2006). *Duration* is the length of time in hours or minutes an activity is performed. *Frequency* is usually given in number of times per week or month an activity is performed, but can be expressed as any time unit (e.g. three days per week). *Mode* refers to the type of specific activity that is performed and to the circumstances under which the activity is carried out (e.g. cycle to work). *Continuity* refers to the period of time during which the activity has been carried out (e.g. cycling to work, 3 days a week for 6 months).

2.2 HEALTH-ENHANCING PHYSICAL ACTIVITY

The concept of health-enhancing physical activity (HEPA) was developed in early 1990s, by Ilkka Vouri and Pekka Oja at the UKK institute, Finland, to highlight the fact that all activity during transportation, at work, household or leisure time on moderate intensity, or above, can confer health benefits (Bouchard et al. 1994). The concept also highlights that it is not all physical activity that is beneficial for health (Verhagen et al. 2007).

The seminal studies by Jeremy Morris in London, in the 1950s on bus-conductors and mailmen were among the first to show a link between habitual physical activity and coronary heart diseases (Morris et al. 1953; Morris et al. 1956). Research on health and the functional effects of physical activity has since then progressed along two principal themes. The two themes have developed independently, with different methods and traditions, but have generally complemented each other. One is rooted in epidemiology (population-based studies), in which Ralph Paffenbarger was a pioneer. The best known of his studies, the Harvard Alumni Health Study, clearly established that physical activity reduces the rate and risk of developing coronary heart disease in men (Paffenbarger et al. 1986; Bouchard et al. 2007).

The other theme is exercise science (experimental studies). The Scandinavian countries were very active early on this research. A key person in this research is Per-Olof Åstrand, exercise physiologist, Karolinska Institutet. His research in exercise physiology was outstanding, and he developed the concept "*motion*" (Swedish term), defined as planned and structured exercise that promotes health (Engström 1989).

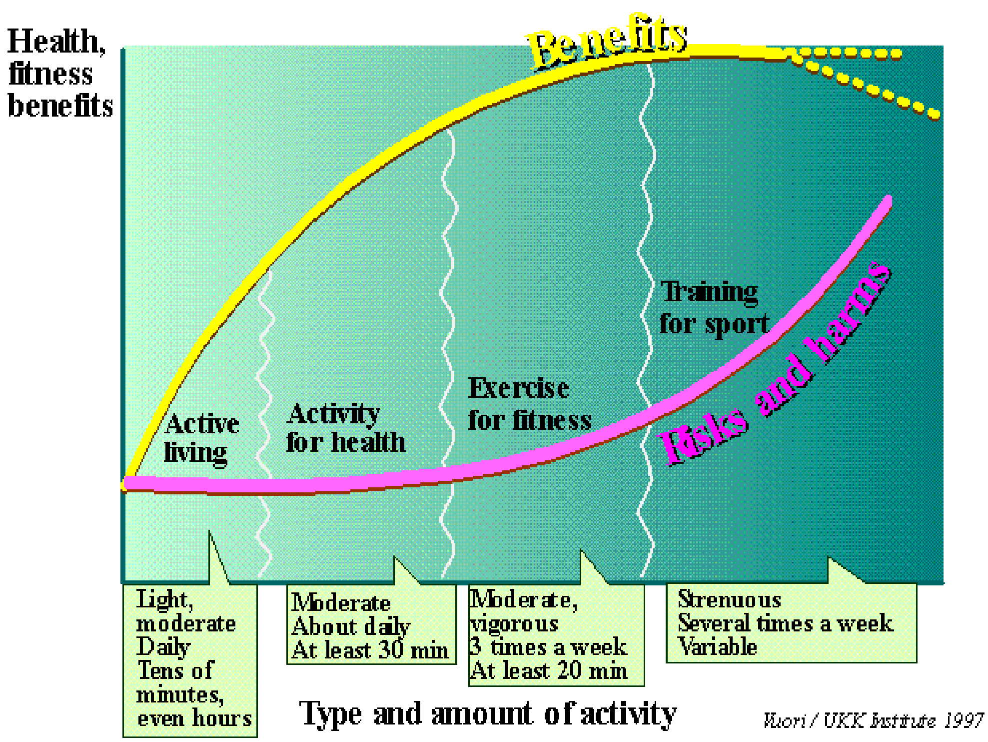

Figure 2. Graphical description of the curve-linear relationship between the dose of physical activity and health benefits (Vouri I and Oja P, 1997).

In order to get health benefits from physical activity, or exercise, a specific dose is needed (Haskell 1994; Haskell 2001). The principles of overload, progression and specificity are major determinants of how the body will respond to a dose of physical activity (McArdle et al. 2006). Recently, the terms activity profile, activity volume and accumulation have been included in these discussions and studies (Haskell 2007).

Depending on the aim, the dose can differ for general health and for different disabilities or diseases. For example, for health benefits, the lowest intensity dose required is activity of at least moderate intensity. The dose-response relationship between the dose of physical activity and mortality has a curve-linear relationship (Haskell 2001; Haskell 2007). This means that the greatest benefits will occur if inactive people will become somewhat active, which is important from a public health perspective (Figure 2).

The relationship between physical activity and health is complex (Bouchard et al. 1994; Bouchard et al. 2007) (Figure 3). On average, and in most people, regular physical activity at a certain dose will increase health-related fitness. Such improvements in fitness are likely to have favourable effects on overall health. A large amount of data shows that some health benefits are derived from being physically active even though there may be little or no associated gain in fitness.

Two paths potentially contribute to the reciprocal relationship between regular physical activity and health. Heredity and other factors such as lifestyle in general, personal attributes, social environment and physical environment play an important role in the relationship. These factors are often called correlates of physical activity and are also important to understand and identify in order to target the right group of populations for interventions (Sallis 1999; Trost et al. 2002).

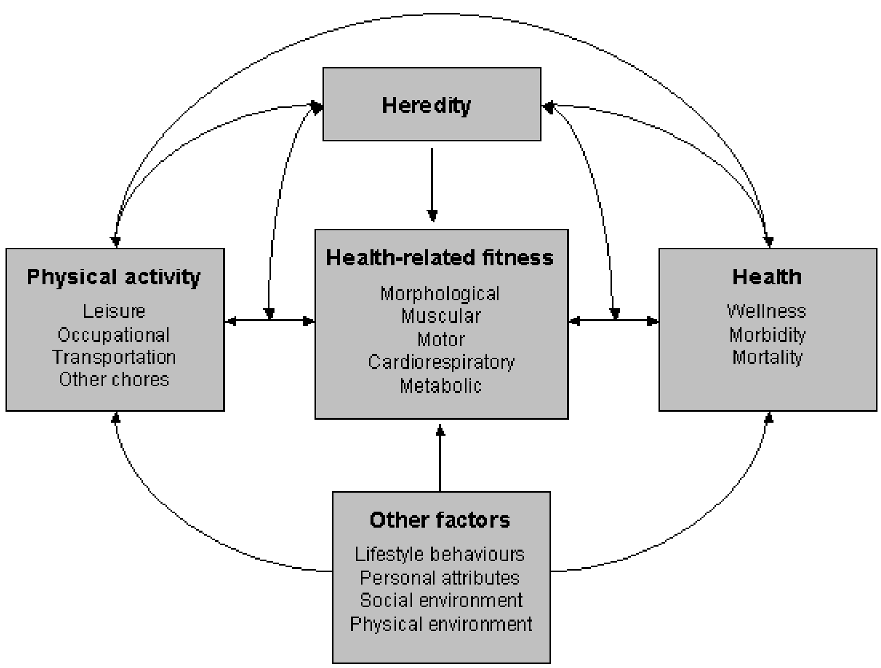

Figure 3. The complex relationship between physical activity and health (Bouchard el al. 1994).

2.3 PHYSICAL ACTIVITY RECOMMENDATIONS

Already in the early 1970s, Sweden provided guidelines on physical activity (*"motion"*) (Table 1). The National Board of Health and Welfare stated: "Do moderate physical activity daily, in combination with more intense exercise two to three times per week". Together with the advice on improving food habits, a sentence on physical activity was included; "Take every opportunity you have to increase lifestyle activities, such as walking, cycling, taking the stairs etc" (Socialstyrelsen 1971; Socialstyrelsen 1992). Public recommendations were developed in England in the early 1990s by the Health Education Authority (HEA). They stated "30 minutes of daily moderate intensity physical activity promotes health" (HEA 1994).

Two sets of physical activity and exercise recommendations are frequently referred to (Table 1). One is for cardiorespiratory fitness and strength training (ACSM 1978; 1990; 1998), sometimes referred to as the Scandinavian model, and is based mainly upon experimental studies. The other is for general health (Pate et al. 1995; CDC et al. 1996), which is mainly based upon reviews of clinical and epidemiological studies. It advises adults to do 30 minutes of at least moderate intensity physical activity on most, preferably all, days of the week. The 30 minutes can be accumulated in several bouts of at least 10-minutes duration (Pate et al. 1995).

This recommendation has recently (August 2007) been updated by the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) (Haskell et al. 2007). The update still emphasizes 30 minutes of moderate intensity physical activity to be regularly performed on at least five days per week (compared to"most, preferably all" days in the 1995 recommendation), but also that the 30 minutes of moderate intensity physical activity can be substituted by three occasions of 20 minutes of vigorous intensity activity per week. On top of these activities, ten strength-training exercises, eight to twelve repetitions of each exercise twice a week, is recommended. The recommendation also highlights that these activities are in addition to routines of daily living (such as self-care and cooking) or lasting less than 10 minutes (such as walking around home or office, walking from parking lot). Furthermore, the new recommendation has separated healthy adults and older adults (> 64 years) or adults (50 – 64 years) with chronic conditions.

The recommendations on health-enhancing physical activity seem straightforward: people are supposed to be more and more active. But, are they more and more active? For whom, and to what extent, are the recommendations valid? The recommendations are general and new evidence about the dose-response relationship between physical activity and different chronic diseases, suggests a need for them to be modified to suit individual circumstances (Suitor and Kraak 2007). For example, to prevent the transition from normal weight to overweight or obesity 45 to 60 minutes of moderate intensity daily is required and to prevent weight regain in formerly obese individuals 60 to 90 minutes of moderate intensity is required (Saris et al. 2003).

Certain groups of the population may be even more in need of encouragement, support and interventional efforts than others, if they are to increase their activity levels. At the same time, attempts to promote physically active lifestyles must be evaluated if their effectiveness is to be proven. The WHO, in its Global Strategy on Diet, Physical Activity and Health, has also recently stated that greater focus should be placed on national monitoring and surveillance of physical activity within and among countries (WHA 2004). Methods of accurately assessing physical activity at population level are urgently needed.

Table 1. Physical activity recommendations

Organisation	Year	Recommendation	Rational
National board of health and welfare, (Sweden)	1971	Be active on moderate intensity every day in combination with more intense exercise 2–3 times per week	Health and fitness
ACSM	1978	3-5 times per week, 15-60 min per occasion, 60-90% HRmax on aerobic exercise	Maintain and improve fitness
	1990	In 1990, strength training was added	
Health Education Authority, (England)	1994	30 minutes of daily moderate intensity physical activity	Health
Pate R. et al. and CDC, Surgeon General (US)	1995 1996	30 minutes of at least moderate intensity on most, preferably all, days of the week (150 kcal per day), accumulated in several bouts of at least 10-minutes duration (Pate, 1995)	Health
ACSM	1998	3-5 times per week, 15-60 min per occasion, 55-90% HRmax on aerobic exercise plus add strength and flexibility training	Maintain or improve fitness
IASO	2003	For prevention: 45-60 minutes per day of at least moderate intensity For maintenance: 60-90 min per day	Prevent obesity or maintain weight loss
ACSM, AHA	2007	30 minutes of at least moderate intensity daily *or* 20 minutes of vigorous 3 times per week. On top of these, strength training twice a week	Health and fitness

ACSM; American College of Sports Medicine (ACSM 1978; 1990; 1998; Haskell et al. 2007)
CDC; Centre for Disease Control and Prevention (CDC et al. 1996)
IASO; International Association for the Study of Obesity (Saris et al. 2003)
AHA; American Heart Association (Haskell et al. 2007)

2.4 ASSESSMENT OF PHYSICAL ACTIVITY

Assessment of physical activity at population level is difficult due to the complex nature of physical activity itself. It is difficult to find an accurate instrument for it. Feasibility must be balanced with measurement accuracy. One measure of accuracy (quality) of an instrument is validity. *Validity* has been defined as the extent to which an instrument assesses the true exposure of interest (Mahar and Rowe 2002; Morrow 2002). This definition is frequently referred to as internal validity and implies an absolute measure of the variable of interest. Indirect criteria of the exposure, such as data derived from an activity monitor and diaries can be used to assess *concurrent validity*. Another aspect of validity is *construct validity*, which indicates the consistency between the activity instrument and a physiological variable related to physical activity such as maximal aerobic capacity or body composition. For example, repeated episodes of vigorous physical activity should correlate with aerobic fitness (Morrow 2002). Other important properties for physical activity instruments are stability over time, i.e. reliability and different aspects of feasibility such as responsiveness, acceptability and costs.

The presence of bias in methods used could lead to erroneous conclusions from interventions and epidemiological trials (Welk 2002a; Ferrari et al. 2007; Lagerros and Lagiou 2007). This bias could also make it difficult to determine whether patients are compliant with therapeutic recommendations concerning health behaviour in clinical settings.

2.4.1 Principles

Physical activity is a construct of body movement and can be assessed either as the behaviour, or as the energy costs of the body movement (Figure 4). Regardless of the method used, a summary score can be computed to determine the association between physical activity and health. This has been described in a conceptual framework (Lamonte and Ainsworth 2001; Ainsworth and Levy 2004) (Figure 4).

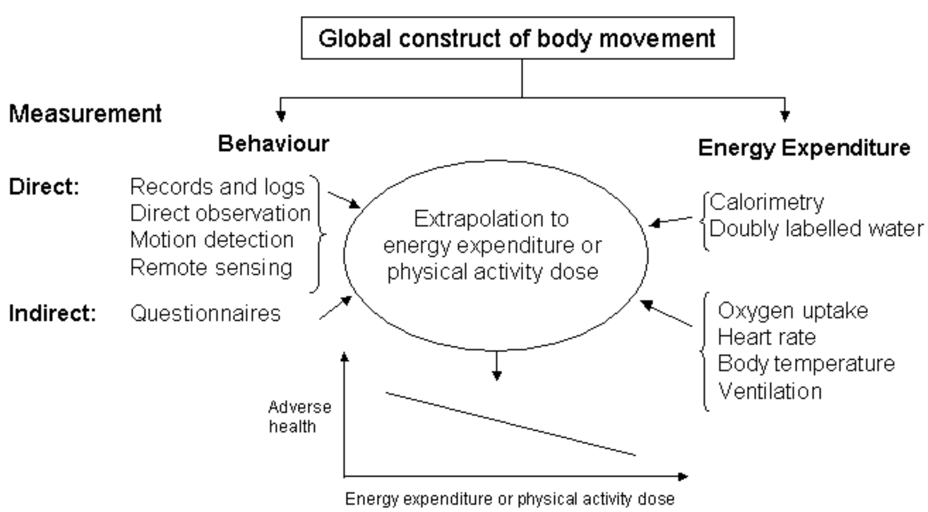

Figure 4. Principles of physical activity assessments (LaMonte, Ainsworth 2001).

2.4.2 Assessing physical activity as a behaviour

Physical activity as a behaviour can be assessed using indirect and direct measures (Figure 4). Direct methods include physical activity records and logs, direct observation, motion detectors and remote sensing systems. Indirect methods include 24-hour recalls, physical activity questionnaires and heart rate monitoring. The most common method used is self-reporting by questionnaires (“self-reports”).

2.4.2.1 Accuracy of self-reports

Self-reports are often used in epidemiological studies and have quite high feasibility. They are easy to administer and cost-effective, but they are hampered by low accuracy (Sallis and Saelens 2000; Ainsworth and Levy 2004).The low accuracy is related to reactivity, recall biases, differential biases and social desirability.

Reactivity refers to the extent to which requiring an individual to provide a verbal report influences the event reported or other measures associated with that event (Ainsworth and Levy 2004). Light and moderate activities, that are more habitual in nature, are more difficult to remember, leading to high *recall bias* (Ainsworth et al. 2000c). Vigorous and strenuous physical activities are often more intentional and structured, therefore generating more accurate recalls (Jacobs et al. 1993). *Differential bias* occurs when subgroups in the population, for example individuals with low education level do not understand the questions or concepts used and therefore report less well compared to those with a higher education (Timperio et al. 2003). *Social desirability* refers to respondents wishing to present themselves in a favourable light and may lead to over-reporting of physical activity level (Warnecke et al. 1997). All these errors or biases may result in diluted estimates of physical activity and outcomes.

If global questionnaires such as those which gather information on sports participation only are used, the risk of misclassification is high. For example, if an individual performs heavy manual work, but no leisure-time physical activity, he will be classified as inactive, while another individual with a sedentary occupation, who takes the car to work but who plays tennis once a week would be classified as active. The inclusion of physical activities involved in occupation, transport and housework has been shown to improve the accuracy of assessment of physical activity in particularly women, which has lead to more meaningful relationships with health outcomes being described (Ainsworth et al. 1999).

2.4.2.2 The International Physical Activity Questionnaire (IPAQ)

Different national and international studies on physical activity have used different methods of assessment, limiting the comparability of findings. Most existing questionnaires addresses leisure time physical activity (Kriska and Caspersen 1997), although, as previously mentioned, the current health-enhancing recommendations do not limit the activity to be performed to leisure time only.

To overcome this, in 1998, difficulty, researchers from CDC (Michael Pratt), University of Sydney (Michael Booth) and Karolinska Institutet (Michael Sjöström) invited a group of global researchers to a WHO meeting in Geneva, to develop a standardised questionnaire assessing all types of health-enhancing physical activity and not only intentional exercise, for use across many different cultural milieus. The group proposed and subsequently developed the International Physical Activity Questionnaire (IPAQ).

The IPAQ instrument assesses health-enhancing physical activity. As such, it measures time spent in walking and other moderate-to-vigorous intensity activities, in the seven days prior to IPAQ completion, counting only those sessions which lasted 10 minutes or more. The limit of 10 minutes was chosen as the recommendation for health-enhancing physical activity states that 30 minutes per day in at least moderate intensity is needed and that the 30 minutes can be split into 10 minute bouts (Pate et al. 1995; Haskell et al. 2007). All types of physical activity are included whether they are part of work, chores, transportation or leisure-time activity. The IPAQ also asks about time spent sitting, as an indicator of inactivity. This makes it possible to assess the amount of time spent at different intensity levels in a week, as well as the amount of total health-enhancing physical activity. The questionnaire is available in both a short ("IPAQ-short", 7 items) and long form ("IPAQ-long", 27 items), respectively, and in versions for use in telephone surveys or self-administration (www.ipaq.ki.se).

The short and long versions of the questionnaire have been piloted in twelve different countries in 14 sites to assess reliability and validity (Craig et al. 2003). The results suggested that the questionnaires had acceptable measurement properties for use in many settings and in different languages, and that the short version is suitable for national population-based prevalence studies. The testing performed only assessed the validity of total physical activity, not the validity of each domain and the different intensities asked for. The samples used in the different countries were mainly convenience samples.

The short version has since 2003 been further tested for validity, using convenience samples, in several countries/languages and settings (Ainsworth et al. 2000a; Hallal and Victora 2004; Ainsworth et al. 2006; Ekelund et al. 2006; Fogelholm et al. 2006; Kolbe-Alexander et al. 2006; Mader et al. 2006; Macfarlane et al. 2007). To date there has been limited evaluation of the long version of the IPAQ (Hallal et al. 2004; Graff-Iversen et al. 2007) and no evaluation in nationally representative samples.

2.4.2.3 Motion detectors

Motion detectors, such as pedometers and accelerometers, are direct measures of body movement.

Pedometers are simple motion detectors that measure body movement in terms of acceleration, but not the amplitude of the acceleration, using different techniques. Most new pedometers contain a horizontal spring-suspended lever arm and measure vertical body movement. They register force (*g*) above a model- and manufacturer-specific limit. For most pedometers, the accuracy decreases at very low walking speeds. In a step cycle (i.e. from right leg toe off until next right leg toe off) two steps are displayed.

Pedometers can only give a measure of the number of steps and some models calculate steps taken per minute. The most used outcome measure is number of steps per day. Different brands of pedometers have shown high validity with respect to number of steps taken, distance walked and also in relation to total energy expenditure (Basset and Strath 2002). Pedometers are convenient and simple to use but cannot give any information about intensity, duration or frequency of the activity. They are perfect tools for self-monitoring and for use during interventions, as understanding and interpreting the number of steps taken is relatively easy (Basset and Strath 2002).

Accelerometers are devices that measure body movement in terms of acceleration, which can be used to estimate the intensity of the physical activity over time (Chen and Bassett 2005). Acceleration is the change in speed in respect to time (e.g. change in position). Acceleration is usually measured in gravitational acceleration units (g, 1 g = 9.8 $m{\cdot}s^{-2}$). When acceleration is zero, the body of interest is no longer changing its speed, though it may still be moving if the body has a constant speed associated with it. To accurately assess the acceleration of the whole body the accelerometer is usually worn at the lower back with an elastic belt around the waist, which is close to centre of gravity (Figure 5).

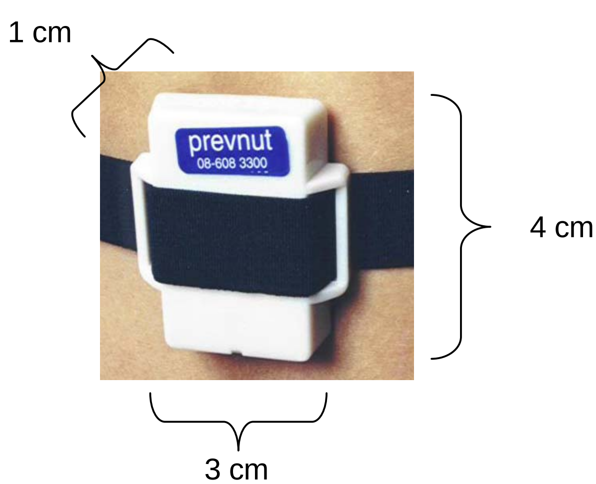

Figure 5. An example of an accelerometer, worn at the lower back.

Most accelerometers in current use are mechanical or digital piezoelectric sensors that detect acceleration(s) in one (vertical) or three (vertical plus anteroposterior and mediolateral) orthogonal planes. Mechanical accelerometers are sensitive to tension and digital accelerometers are sensitive to compression. Accelerometers measure ambulatory activities, which means that non-ambulatory and upper-body movement activities such as carrying heavy loads or riding a bike, etc, are not fully captured. While triaxial accelerometers provide slightly better estimates of total energy expenditure, they still do not capture non-ambulatory or upper-body movements and are in most cases bulkier and more expensive than uniaxial versions.

The uniaxial accelerometers have been extensively tested for validity, reliability and are also used in large studies. The most commonly used uniaxial accelerometer is the Actigraph® (Manufacturing Technology Inc, Fort Walton Beach, FL, USA), shown in Figure 5. Figure 6 illustrates the type of data that can be retrieved from an accelerometer.

Validation studies have been performed to establish cut-off limits for different intensities, which make it possible to estimate time spent at moderate and vigorous intensity activity (Freedson et al. 1998; Hendelman et al. 2000; Nichols et al. 2000; Matthew 2005). The Actigraph correlates significantly with activity energy expenditure ($r = 0.82 - 0.89$) when compared to walking and running on a treadmill (Welk 2005).

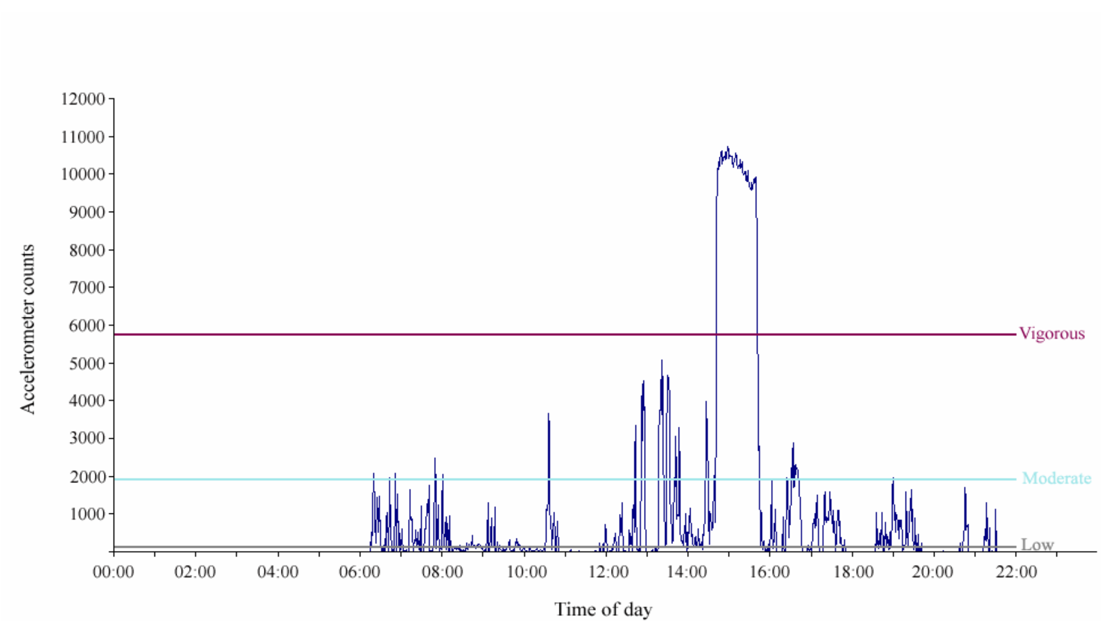

Figure 6. Sample output, provided by an accelerometer, showing physical activity over a day. Minutes between baseline and the grey line (Low) is time spent inactive, minutes above the blue line (Moderate) is time spent on moderate or vigorous intensity activities and minutes above the purple line (Vigorous) is time spent on vigorous intensity activities only. The subject whose data is shown on this graph accumulated about one hour of continuous, vigorous intensity physical activity and one hour of moderate intensity, dispersed over the day.

2.4.2.4 Heart rate monitoring

Monitoring the heart rate is an indirect measure of physical activity as the heart rate changes in response to body movement (Lamonte and Ainsworth 2001; Janz 2002). Heart rate monitors consist of a transmitter and a receiver. The transmitter, often placed with a belt around the chest or as an electrode on the left side of the chest, measures the change in voltage that is generated by the action potentials of the heart through the myocardium. The information used is the time interval between the complexes in the Electrocardiogram. For example if the interval is 1.0 second, the heart rate is 60; if it is 0.5 seconds the heart rate is 120. The monitor cannot indicate properties of heart rhythm other than frequency (e.g. origin of impulse or arrhythmias). The receiver can either be a wristwatch or a computer built into the electrode.

In order to get a picture of the intensity, duration and frequency of physical activity individual calibrations are needed. Heart rate increases in response to other physiological mechanism as well, for example heat and stress (McArdle et al. 2006). This leads to imprecise measures of, in particular low and moderate activities because of the relative influence these physiological mechanisms plays to heart rate (Janz 2002).

2.4.2.5 Combination methods

A new generation of objective instruments to measure physical activities are becoming available, which combine different techniques (Chen and Bassett 2005). For example, the ActiReg® (PreMed AS, Oslo, Norway) is an instrument that combines body posture and movement with heart rate. The instrument classifies the activity energy expenditure in three categories, light, moderate and high.

Another instrument, the ActiHeart® (Mini Mitter, Oregon, US), combines accelerometer registration and heart rate monitoring. With this method, accelerometer data are to a greater extent used for low intensities and heart rate for high intensities. Using this way of weighting different data, more precise estimates of activities will be given. New products combine accelerometer data and GPS (Global Positioning System) data. This makes it possible to account for the distance, altitude and speed. Until these new methods have shown to be valid, and the devices are small and cost-effective enough, the accelerometer remains the method of choice.

2.4.3 Assessing physical activity as energy expenditure

Doubly Labelled Water is seen as the golden standard for measuring energy expenditure in free-living conditions (Starling 2002). In principle, the method involves enriching the body water of a subject with an isotope of hydrogen and an isotope of oxygen, and then determining the washout of both isotopes as their concentrations decline exponentially toward natural levels. The difference between the declines of the isotopes represents the carbon dioxide production, i.e. energy expended. The method is very expensive and no information about the intensity, frequency or duration of the activity is obtained. It is mainly used for validation studies of dietary intake and assessment of physical activity.

Direct and indirect calorimetry is built upon the principle of heat production i.e. that heat is produced as a by-product of physical activity (Starling 2002). The word calorimetry is derived from the Greek word *calor*, i.e. heat. In direct calorimetry, heat production is measured using a calorimetric chamber. In indirect calorimetry, energy expenditure is calculated from the respiratory exchange ratio of carbon dioxide and oxygen (VO_2). Indirect calorimetry is usually measured using a portable, computerised device that captures gas exchange.

2.5 ASSESSMENT OF AEROBIC CAPACITY

Aerobic capacity can be seen as an indirect measure of physical activity, and is also one component of physical fitness (Caspersen et al. 1985; Ainsworth and Levy 2004). There are two ways to assess aerobic capacity: maximal tests or sub-maximal tests. In a maximal test, the subject runs or bikes until total exhaustion. Either gas exchange at the final stage or the heart rate alone is measured. Sub-maximal methods are based upon the linear relationship between workload and heart rate response.

Maximal tests are more precise compared to sub-maximal tests as sub-maximal tests are build on several assumptions, such as predicted maximal heart rate and that the relationship being linear even at the end, but sub-maximal test are safe and more acceptable to the participant (ACSM 2006). The measurement error in a sub-maximal test is the same for the one individual over time (if the procedures are standardised) leading to high reliability when paired comparisons are made. In adults, maximal tests are mainly used in the field of sports or in clinical laboratory settings (ACSM 2006).

2.6 ASSESSMENT OF BODY COMPOSITION

Body composition is one component of physical fitness (Caspersen et al. 1985) and can be assessed by advanced methods such as under-water weighing, Air-Displacement Phlethysmography (a device such as the BodPod®) and Dual X-ray Absorptiometry. Common field methods used include skinfold thickness measurement (Norton and Olds 1996), bio-electrical impedance (Ellis, 2001) or basic measurements of weight and height for calculation of the Body Mass Index (BMI) (Pietrobelli et al. 1998). Of these, BMI is the simplest, most convenient and frequently used method. BMI is a useful measure of the relative proportion of fat mass in groups (Norton and Olds 1996).

An estimation of body fat can be made by measuring skinfold thickness at three or more standard anatomical sites on the body. For consistency one side, of the body is measured (usually the right side). The tester pinches the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. The caliper is then applied one centimeter below, and at right angles to, the pinched tissue, and a reading is taken 2 seconds later. The mean of two measurements should be taken. If the two measurements differ greatly, a third should be done, and then the mean of the two closest values are taken. Either the total sum of the measurements or a conversion to percentage body fat can be used as outcome measures. When converting the sum of the measurements to percentage body fat, different algorithms can be used (Norton and Olds 1996).

2.7 PHYSICAL ACTIVITY IN SWEDEN

Physical activity in the form of intentional exercise is included in the national survey on living conditions that is measured by Statistics Sweden (SCB) and the National Board of Social Welfare since 1975, and data on exercise in some form, is available since 1980. The data is collected by researchers calling to the homes of randomly selected adults (18 - 84 years). The results are reported regularly in the national Public Health Reports (Socialstyrelsen 2005). The percentage of adults reporting exercise at least twice a week has increased from 31 % (34 % and 28 % in men and women, respectively), in 1988 to 46 % (45 % and 47 % for men and women, respectively) in 2005. The percentage of adults reporting no exercise has decreased from 14 % in 1980 to nine per cent in 2005. This change in exercise habits could be due to more people being more physically active during their leisure time, but it could also be due to reporting bias. The meaning of the terms used (*"motion"*) may have changed over this time frame. It is possible that people nowadays are reporting more types of activities as *"motion"*.

During the last five years different subgroups of the Swedish adult population have been studied with regard to physical activity, using different questionnaires. For example; Orsini et al. studied age and temporal trend of physical activity in women (2006), Fransson et al. studied the relationship between leisure time, household and occupational physical activity and cardiovascular diseases in working men and women (2003) and Norman et al. studied age and temporal trend of physical activity in men (2003). The outcomes of these studies are difficult to compare with the general physical activity recommendation and the national data on leisure time exercise.

2.8 RELEVANCE OF THIS THESIS

A strong body of evidence exist to support the importance of physical activity in promoting health, and preventing and treating diseases. As detailed above, in Sweden no solid data exists on the level and pattern of health-enhancing physical activity in the general population, so that, despite the existence of guidelines, no definitive method of measuring adherence to them exists.

The public health burden of inactivity is huge and it is important to target the right population when planning interventions. At the same time, the resources to promote more health-enhancing physical activity in the population are limited, and must be utilised effectively. To enable the formulation of better public health policies and health-care strategies, to be able to follow trends and evaluate interventions, valid and feasible instruments are needed to assess the level and pattern of health-enhancing physical activity in the population. The work included in this thesis aims to advance the field of physical activity assessment.

3 AIMS

The overall aims of this thesis were to further test the measurement properties of the International Physical Activity Questionnaire (IPAQ) in Sweden and to investigate the level and pattern of health-enhancing physical activity in the Swedish adult population.

3.1 RESEARCH QUESTIONS

- How does data on physical activity measured by the IPAQ compare with that measured directly by accelerometry and activity logbooks and indirectly by aerobic capacity and body composition? (Papers I and III)

- Does the validity of the IPAQ differ between genders and can age, BMI and education affect the qualitative consistency between the IPAQ and accelerometer data? (Paper III)

- What is the level and pattern of physical activity and inactivity at population level, and how does it vary with regard to demographic factors? (Papers II and IV)

- What percentage of the population is reaching the physical activity recommendation of 30 minutes of at least moderate intensity per day? (Paper IV)

4 METHODS

4.1 STUDY DESIGN

The papers included in the thesis are of cross-sectional design. Paper I is based on a convenience sample of adult men and women and Papers II, III and IV are based upon two national samples from the Swedish adult population. Data for Papers I and II were collected during the autumn. In order to avoid the effect of seasonal variation in activity the data for Papers III and IV were collected throughout a calendar year.

4.2 STUDY POPULATION, PARTICIPATION RATES AND DROPOUT

4.2.1 Paper I

The participants were recruited via work places around the Karolinska Institutet, southern campus, in reply to advertisements placed in the nearby buildings. In total, 50 participants accepted to participate. Four subjects (2 men) were excluded from the analyses due to incomplete logbook recordings or failure to complete aerobic fitness testing. The remaining 46 participants (22 men, aged 19 - 63 years, mean BMI 24 ± 2 $kg{\cdot}m^{-2}$) had a higher education than the average Swedish population, as indicated by the high percentage of participants with a university degree.

4.2.2 Paper II

A total of 2,500 adults aged 18 - 74 were selected from the official Swedish population register, using stratified sampling procedure with random sampling from each strata of age, gender and region of residency. The study protocol was approved by Huddinge University Hospital ethical board (Dnr: 432/03).

In total 1,470 subjects (59 %) produced all the data required. The mean age was 46 ± 16 years and self-reported BMI was 25.5 ± 3 $kg{\cdot}m^{-2}$, 34 % of the sample was classified as overweight and 8 % obese. The demographic characteristics of the sample are close to those of the Swedish adult population. The responders and non-responders were evenly distributed all over Sweden.

4.2.3 Papers III and IV

A telemarketing company (Markör Ltd, Örebro, Sweden) recruited the subjects. They randomly selected 3,300 adults (52 % women) between 18 and 69 years of age from the official Swedish population register. During 2001, about 40 were contacted by phone every week, over the whole year. The adults were informed about the study and invited to participate. The study protocol was approved by the Huddinge University Hospital ethical board (Dnr: 378/02).

In total, the telemarketing company reached 2,262 (54 % women) of the subjects (Figure 6). A number of subjects, 884, did not have publicly listed telephone numbers and 154 did not speak Swedish or were not currently living in Sweden. Among the remaining 2,262 eligible subjects, 1,556 (54 % women and 68 % of eligible subjects) accepted to participate while 706 declined to participate. A total of 442 participants were excluded due to technical errors such as accelerometers lost in the mail, or not returned (N = 108), and due to insufficient wearing time (N = 334).

In Paper III, only participants of working age (18 - 65 years) with eligible data from the IPAQ and the accelerometer were used. Therefore, an additional 134 participants were excluded. In total N = 980 (537 women) participated in the study reflecting a completion rate of 62 % of participants who agreed to participate in the study.

In Paper IV, the final sample consisted of 1,114 participants (623 women, 45 ± 15 years, BMI 25.0 ± 3.8 $kg{\cdot}m^{-2}$) (Figure 7). Of these, 36 % were classified as overweight and 7 % as obese. The final sample was compared to the Swedish adult population. The proportion of women (56 %) was significantly higher ($P < 0.001$) than in the Swedish population but similar to the proportion among the eligible subjects. The age groups 18 - 24 years and > 65 years were under represented ($P < 0.001$) in the study sample compared to the Swedish population, and to the eligible subjects. The proportion of participants from other counties outside the large cities were under represented ($P < 0.001$) in the final sample and in the eligible subjects.

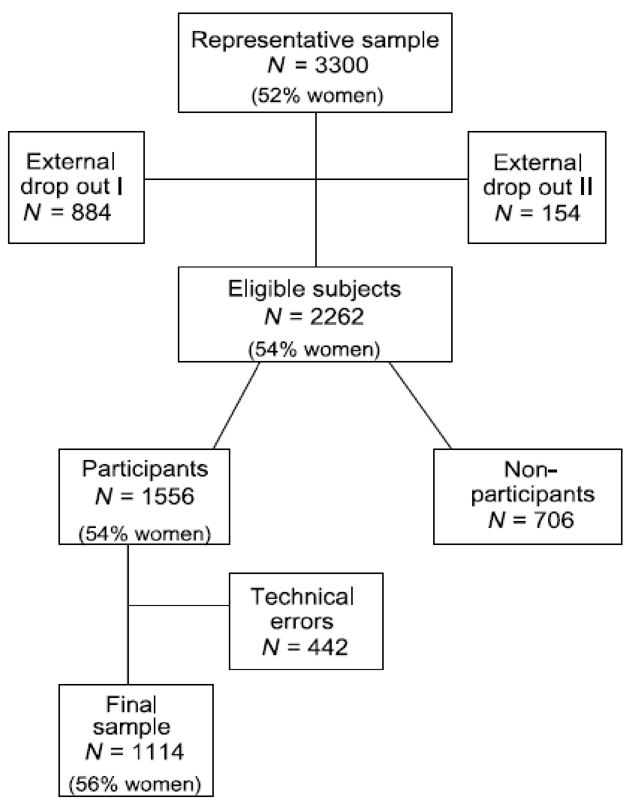

Figure 7. Flowchart of the study population for Paper IV.

4.3 PROCEDURES

4.3.1 Paper I

On day one, the participants were invited to the study centre at Karolinska Institutet and were provided with detailed instructions on how to use the accelerometer and how to fill in the activity logbook. Data on anthropometric and demographic characteristics were collected. Starting on day two the participants wore the accelerometer for seven consecutive days and filled in the logbook at the end of each day. On day eight, the participants returned to the study centre, filled in the IPAQ and performed an aerobic fitness test.

4.3.2 Paper II

The self-administered IPAQ-short and a demographic questionnaire were sent out by post. Participants were asked to send the questionnaire back in a prepaid envelope. After two weeks a reminder was sent out to those who had not returned the questionnaire.

4.3.3 Papers III and IV

Following agreement to participate in the study, the self-administered IPAQ-long, a demographic questionnaire, and an Actigraph accelerometer were mailed to each participant by post. Prior to mailing the materials, the accelerometer was initialised as described by the manufacturer using a 60-second epoch for recoding movement (Computer Science Application 1995). Participants were instructed to wear the accelerometer from when they woke up until going to bed during seven consecutive days, except when in water, starting on the Monday morning following the receipt of the study materials. Participants were given instructions to wear the accelerometer attached to a belt and secured directly next to their skin at their lower back, close to the centre of gravity.

On the eighth day, participants were instructed to complete the demographic questionnaire and the IPAQ-long self-administered questionnaire and return the questionnaires and the accelerometer to the study centre in a pre-paid mailing envelope. Participants failing to return the materials within one week of completing the data collection were called to return the materials. Upon receipt of the materials at the study centre, the accelerometer and the questionnaire data were downloaded into a Microsoft Access database for later scoring and data analysis.

4.4 MEASUREMENTS

4.4.1 IPAQ

The self-administered IPAQ-short was used in Paper I and the self-administered IPAQ-long were used in Papers I and III. The short and long versions of IPAQ, formulated by the IPAQ development group, and available in English, were translated to Swedish and back translated to English using the guidelines provided at the IPAQ homepage (www.ipaq.ki.se). For each question, respondents were given culturally relevant examples of moderate and vigorous intensity activities and physiological cues (i.e. breathing rate) to help them recall activities with an appropriate intensity level.

The IPAQ-short consists of seven items that identify frequency and time spent in walking and other moderate-vigorous intensity physical activities, during the seven days prior to the questionnaires administration, and counts only those sessions that lasted 10 minutes or more. All types of physical activities are included whether they are part of occupation, transportation, household chores or leisure time activity. It also asks about the time spent sitting, as an indicator of inactivity. Swedish translation´s of the short version have been tested for reliability and validity in the so-called 12-country validation study (Craig et al. 2003) and by Ekelund et al. (2006). The correlation coefficient between total physical activity from the IPAQ-short and an accelerometer was $r = 0.34$, which is similar to other physical activity questionnaires.

The IPAQ-long consists of 27 items that identify the frequency (times per week) and duration (minutes or hours per day) of physical activity performed in the activity domains of occupation (7 items), transportation (7 items), housework, house maintenance, and family care (6 items), recreation, sport and leisure (6 items), and time spent sitting (minutes or hours per day) in a weekday and in a weekend day (2 items), during the seven days prior to the questionnaires administration, again, counting only those sessions lasting 10 minutes or more. For all physical activity domains, participation in vigorous and moderate intensity physical activity is obtained.

The data were treated according to the IPAQ scoring protocol, version 2.0, which guides cleaning, presentation and interpretation of IPAQ data (www.ipaq.ki.se). The protocol was followed, with one exception: if only days per week were reported without accompanying minutes per day, the days per week and minutes per week were truncated to zero, not excluded as suggested in the protocol. This was done to avoid excluding more than half of the participants, due to missing data in one of the 27 items. In the IPAQ-short a maximum of 240 $min \cdot day^{-1}$ was allowed for vigorous, moderate and walking activities, respectively. Any higher values reported were truncated to 240 minutes. In the IPAQ-long, a maximum of 180 $min \cdot day^{-1}$ in any of the three intensities in the four domains was allowed. Any higher values reported were truncated to 180 minutes. The minutes were multiplied by the number of days and then multiplied by the appropriated metabolic equivalent value (MET) (Ainsworth et al. 1993; Ainsworth et al. 2000b). Vigorous intensity at work and during leisure time was assigned 8 METs, vigorous intensity during yard work (garden) 5.5 METs, cycling for transportation 6 METs, moderate intensity at work, yard chores and leisure time 4 METs, moderate household chores 3 METs and all domains of walking in all domains, 3.3 METs.

Outcome measures from the IPAQ-short (Paper II) were MET-minutes per week in total health-enhancing physical activity, vigorous, moderate intensity activity and time in minutes per day reported sitting. Outcome measures from the IPAQ-long (Papers I and III) were total health-enhancing physical activity in MET-minutes per day and minutes per day reported in vigorous, moderate and walking activities, as well as sitting.

4.4.2 Accelerometer

An accelerometer, the Actigraph MTI model 7164 (Manufacturing Technology Inc, Fort Walton Beach, FL, USA) was used for concurrent validity (Papers I and III) and to provide objective measures of physical activity at population level (Paper IV). The Actigraph measures accelerations (*g)* from 0.05 to 2.1 g in the vertical axis. It is equipped with a frequency-dependent band pass filter, which aims at discriminating human movements from vibrations. The output from the accelerometer is sampled 10 times per second and summed over a selected time interval or epoch.

Figure 8. Accelerometer placement.

The accelerometer was calibrated and initialised as described by the manufacturer and the 60-second epoch was used (Computer Science Application 1995). It was secured directly against the skin using an elastic belt around the waist (Figure 8).

The subjects were instructed on how to handle the accelerometer, verbally (Paper I) and in writing (Papers I, III and IV). The subjects were asked to wear the accelerometer during waking hours, except during water activities, for seven consecutive days.

The accelerometer data were uploaded onto a computer and analysed by software based on Microsoft Access. Data with periods of zero values for more than 20 minutes were excluded from the analysis. Accelerometer malfunction was identified as having counts per minute greater than 20,000.

Data were deemed complete if participants had recorded accelerometer data for at least 10 hours per day, for at least four days, including at least one weekend day. A minimum of four recording days is recommended to reflect one-week's worth of physical activity in children and adults (Trost 2001; Trost et al. 2005). The threshold criteria used in this study for the time required for wearing the Actigraph is consistent with the procedures used in the international IPAQ validity study described by Craig et al. 2003 and in other studies using the Actigraph as an objective measure of physical activity (Ward et al. 2005).

Based on the intensity (counts per minute) of the epochs, time spent in different intensities could be calculated. In Papers I and IV, cut-points for moderate (1952 - 5724 counts), and vigorous (> 5724 counts) were used (Freedson et al. 1998). The cut-points are derived from ambulatory activities, such as walking and running. In Paper III minutes per day of moderate (761-5724 counts), and vigorous (> 5724 counts) physical activity were used (Matthew 2005). The Matthews cut-points for moderate intensity are derived from both ambulatory and non-ambulatory activities, which the IPAQ also asks for. Counts per minute reflecting inactivity were set at < 100, which is consistent with methods reported by others (Craig et al. 2003; Yngve et al. 2003). The average intensity was calculated by taking the total counts divided by the recorded time ($counts \cdot min^{-1}$) and this was considered as a weighted measure of total physical activity.

4.4.3 Logbook

The logbook, used in Paper I, consisted of one page for each day of the 7-day period of the study, and the subject filled out the type of and time spent in physical activity. Each page had separate sections for the four different domains; physical activity at work, during transportation, household activity and leisure-time activity. The participants were also asked to report the amount of time they spent sitting.

Data from the logbook were given a MET value derived from the Compendium of Physical Activities by Ainsworth et al. and transformed into MET-hours per week ($MET\text{-}h \cdot week^{-1}$), as described for the IPAQ (Ainsworth et al. 1993; Ainsworth et al. 2000a). Reported time spent in moderate and vigorous intensity physical activity for each domain was also calculated.

4.4.4 Aerobic fitness test

Aerobic fitness (VO_2 max, ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) was estimated in Paper I using a 15-min sub-maximal treadmill walking test (Figure 9). The test began at a speed of 4.8 $km \cdot h^{-1}$ at zero gradient. The gradient was raised by 3 % every third minute up to a 15 % gradient. The heart rate was measured throughout the test, using a Polar Vantage NV monitor (Polar Electro OY, Kempele, Finland). During the last minute of each stage rating of perceived exertion (RPE) was assessed using the Borg RPE 6-20 scale (Borg, 1998). The maximal aerobic power was calculated from the last heart rate at the final stage using a modified Balke formula (ACSM 2006).

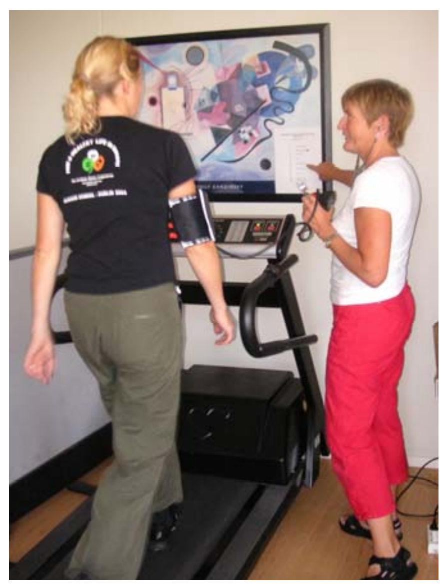

Figure 9. Sub-maximal fitness test in progress.

4.4.5 Body composition

In Paper I, body weight and height were measured using standard equipment, while the subject wore light clothing. In Papers II, III and IV, body weight and height was self-reported. BMI ($kg \cdot m^{-2}$) was then calculated.

In Paper I four skinfold measurements (biceps, triceps, sub scapular and supra iliac) were taken using a Harpenden calliper (Figure 10) and percent body fat (% BF) was calculated according to Durnin & Womersley formula {1974}. The inter-tester reliability was assessed by calculation of the technical error of measurements (TEM). Ten participants were measured twice with at least three days between each measurement. The following TEM was achieved: biceps = 6.7 %, triceps = 2.7 %, sub scapular = 2.5 % and supra iliac = 3.8 %. A TEM < 10 % was considered to indicate acceptable inter-tester reliability (Norton and Olds 1996).

Figure 10. Skinfold thickness measurement.

4.4.6 Demographics

The demographic data used in Papers II, III and IV was obtained from a questionnaire, and included gender, age, height, weight, education, income, city of residence (location), marital status and self-rated health. Age and BMI were categorised into three levels; (Age: 18 - 34, 35 - 50, 51 - 65 years; BMI: < 25, 25 - 30, > 30). Education was classified as compulsory, high school and university level. Income was recoded into four groups: < 100,000, 100,000 - 200,000, 200,000 - 300,000 and > 300,000 SEK per year. Employment status was classified as employed, student, retired and unemployed. Residential was classified as four groups: village, small town, medium town or large town. Marital status was recoded to married or living with a partner, and single. The options for self-rated health were: excellent, very good, good, satisfactory and poor. The two lowest levels were combined due to low absolute numbers.

4.5 STATISTICS

All statistical analyses were performed using the Statistical Package for Social Sciences for Windows, version 10.0 (Paper I), 13.0 (Paper II) and 15.0 (Paper III, IV). (SPSS, Inc, Chigago, IL). The level of significance was set at 95 %.

In all studies the continuous data were checked for normality using the Kolmogorov-Smirnov test. In most cases the distribution of physical activity data was considerably skewed to the right. The characteristics of the participants and outcomes were described as mean and standard deviation (SD) and the range if methods based upon mean values were used (i.e. the Bland-Altman method). In all other cases the median and 25th and 75th percentile was used (Bland JM 1986; Altman 1991). Table 2 describes the different statistical methods applied in the different studies. The strength of the agreement between different methods (correlation coefficient) was valued according to Domholdt (Table 3) (Domholdt 2000).

Table 2. Statistical methods applied in the different papers.

	Paper I	Paper II	Paper III	Paper IV
Spearman rank correlation	X		X	
Bland and Altman method	X		X	
Students paired T-test	X			
Kruskal-Wallis test		X		
Wilcoxon signed rank test			X	
Kendall's tau-b			X	
One-way ANOVA				X
Three-way ANOVA				X
Post-hoc analysis, Tukey Simultaneous				X
Chi-square test for homogeneity				X

Table 3. The strength of agreement (Domholdt, 2000).

Correlation coefficient (r)	Strength of agreement
0.00 – 0.25	Little, if any (poor)
0.26 – 0.49	Low (fair)
0.50 – 0.69	Moderate
0.70 – 0.89	High
0.90 – 1.00	Very high

5 RESULTS

5.1 VALIDATION OF THE IPAQ (PAPERS I AND III)

5.1.1 Concurrent validity

Concurrent validity of the IPAQ was tested both in a small convenience sample (Paper I) and a relatively large representative sample of the Swedish adult population (Paper III).

5.1.1.1 The IPAQ versus the accelerometer

Table 4 describes the absolute time reported from the IPAQ and derived from the accelerometer and the Spearman correlation coefficient between the instruments using data from Paper I and III. In order to make the data comparable, the hours per week from Paper I have been transformed to minutes per day. In Paper I the Spearman rank correlation coefficients (Rs) between the IPAQ and Actigraph scores ranged from 0.12 to 0.63, indicating little to moderate correlation between the instruments. In Paper III the Spearman rank correlation coefficients (Rs) between the IPAQ and Actigraph scores ranged from 0.07 to 0.36, indicating little to low correlation between the two instruments. Women had lower correlations for all comparisons than men, except for sitting and walking.

Table 4. Descriptive physical activity data from the IPAQ and the accelerometer. Mean (SD) and spearman rank correlation coefficient (Rs) between the IPAQ and accelerometer are given.

	Paper I (N = 46)			Paper III (N = 980)		
	IPAQ $min \cdot day^{-1}$	Accelerometer $min \cdot day^{-1}$	Correlation Rs	IPAQ $min \cdot day^{-1}$	Accelerometer $min \cdot day^{-1}$	Correlation Rs
Vigorous	20 (37)	14 (9)	0.63***	18 (33)	5 (15)	0.31**
Moderate [a]	44 (59)	78 (22)	0.12	106 (71)	133 (58)	0.29**
Total PA[b]	429 (429)	591 (219)	0.55***	648 (629)	382 (141)	0.30**
Sitting	446 (138)	472 (78)	0.17	590 (208)	466 (87)	0.23**

** P < 0.01, *** < 0.001
[a] Moderate intensity includes moderate and walking from the IPAQ
[b] For total physical activity the unit is MET-minutes per day for the IPAQ and counts per minute for the accelerometer

In the convenience sample (Paper I), no significant differences between the absolute values in hours per week from the IPAQ and the accelerometer were found. However, the 95 % limits of agreement were wide (Figure 11). High correlations were found between both instruments for vigorous intensity and total physical activity, respectively. For moderate intensity activity and sitting, moderate to weak correlations were found.

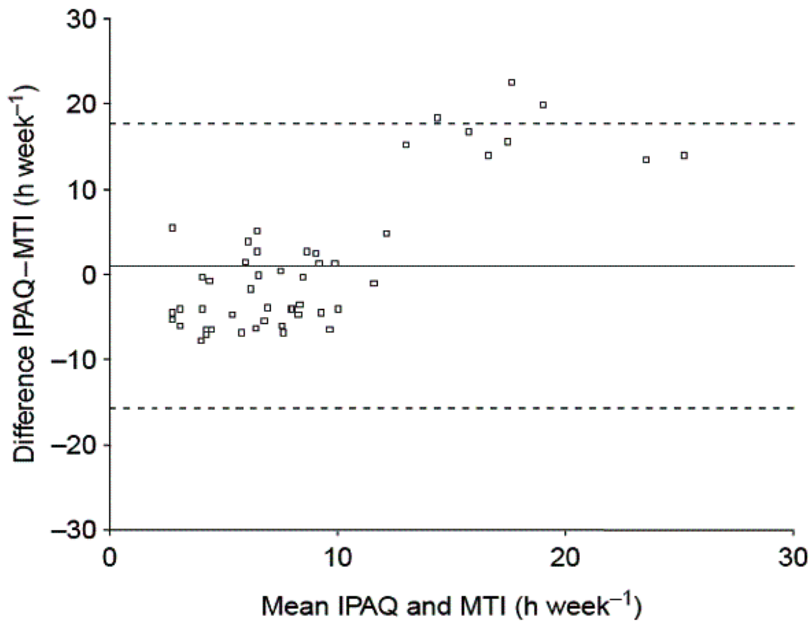

Figure 11. A Bland-Altman plot for hours·week^{-1} reported at moderate intensity physical activity or higher from the IPAQ and the accelerometer. The mean difference (SD) for the total sample was 1 (8) hours per week (not significant).

In the nationally representative sample (Paper III), the IPAQ showed, across all stratified variables, significantly higher minutes per day spent in vigorous intensity activities and in sitting compared to the accelerometer ($P < 0.001$). Men, adults age 18-34 and those with the highest education spent most time in vigorous physical activity according to both the IPAQ and the accelerometer data. Moderate intensity activity from the accelerometer showed significantly higher minutes per day compared to the sum of walking and moderate intensity activity from the IPAQ ($P < 0.001$). For both vigorous and moderate intensity activities the 95 % limits of agreement were wide (Figure 12). Modest, but significant correlations between the instruments were observed for vigorous, moderate and walking minutes per day. Significant correlations were also found between the MET-minutes per day of IPAQ and total counts per minute of the accelerometer.

Figure 13 shows the concordance in tertiles of total physical activity scores between the IPAQ MET min·day^{-1} and the Actigraph counts per minute. A significant, but weak, (Kendall´s tau-b, 0.210, $P < 0.001$) overall association was found between the instruments. The figure shows consistent associations between the two methods at low and high tertiles of physical activity. However, half of the Actigraph counts were correctly classified within each IPAQ tertile.

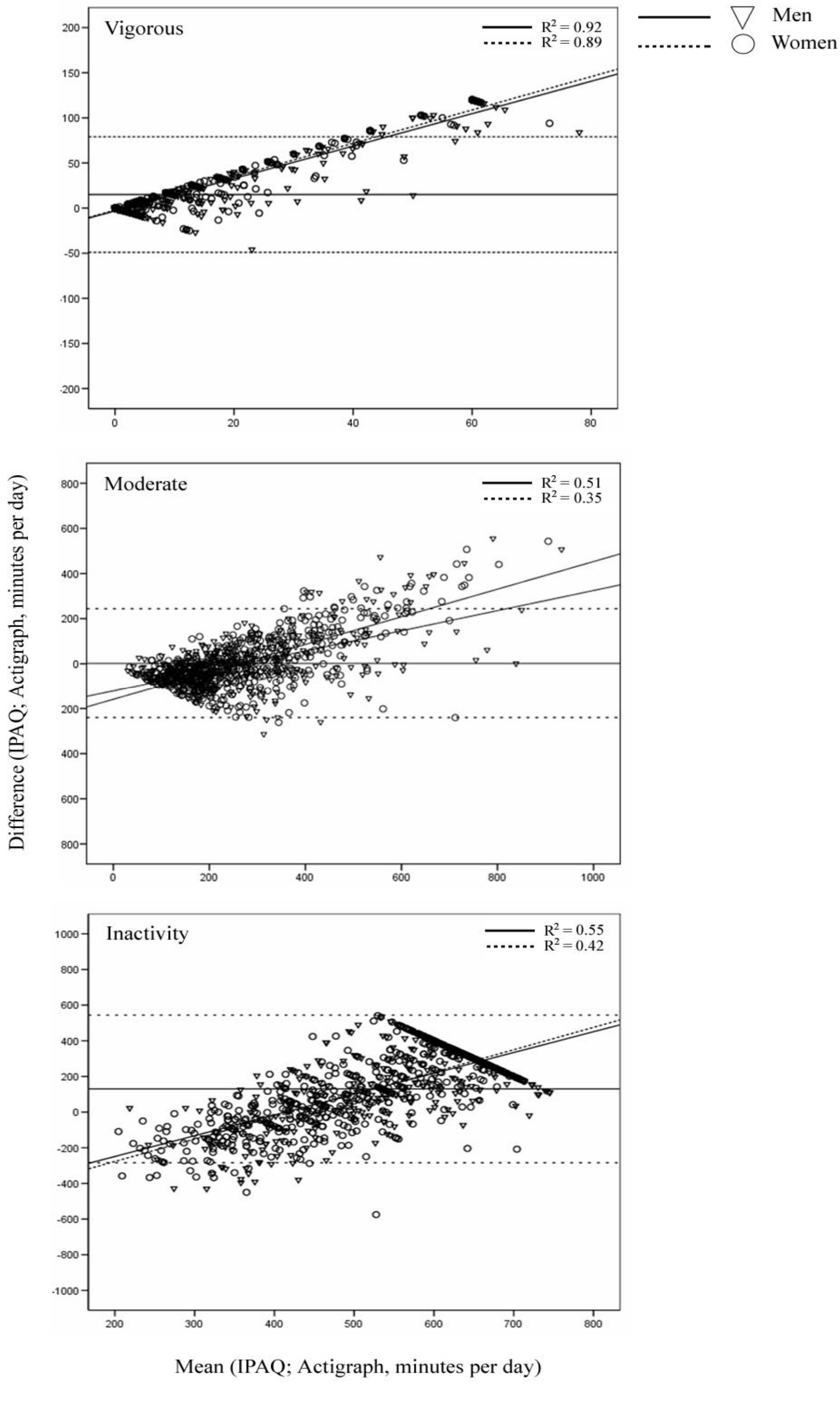

Figure 12. Bland-Altman plots for minutes per day reported in vigorous, moderate intensity physical activity and inactivity, from the IPAQ and the accelerometer. The mean differences (SD) for the total sample were 15 (32), 2 (121) and 130 (207) minutes per day, respectively.

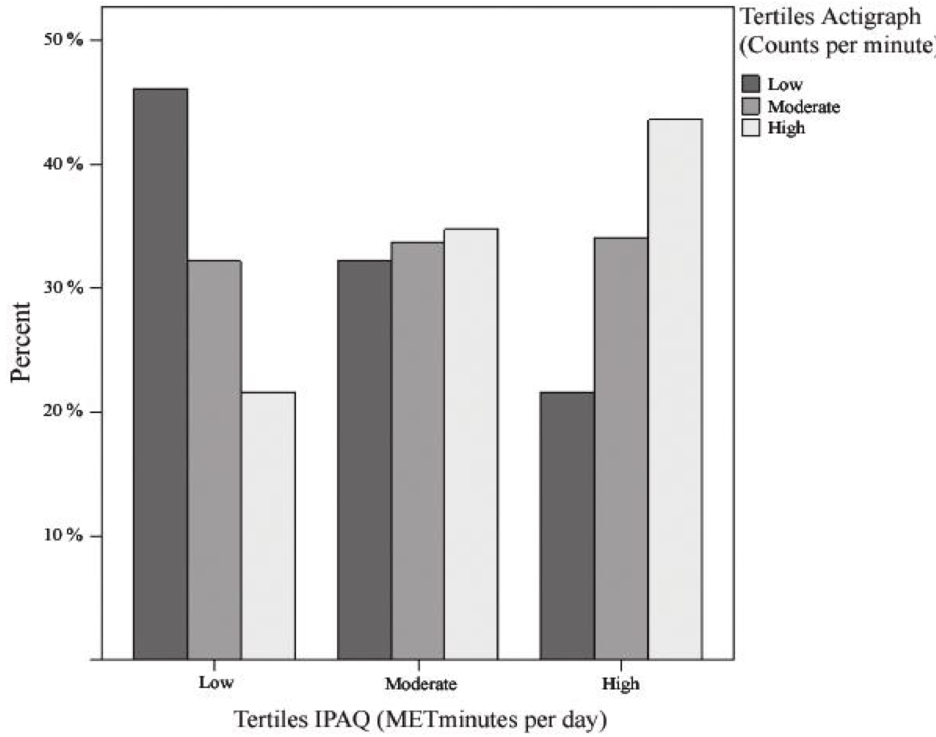

Figure 13. Tertiles of total physical activity scores as calculated from the IPAQ and the Actigraph, showing the percent of subjects classified in the same tertile by both measures.

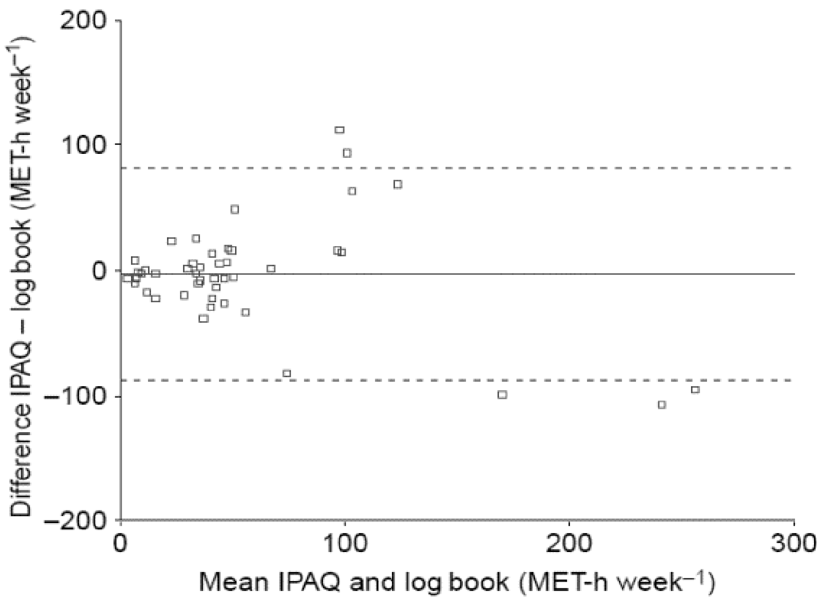

Figure 14. A Bland-Altman plot for MET-hours per week reported with the IPAQ and the logbook. The mean difference (SD) for the total sample was -2.9 (44) MET-hours per week (not significant).

5.1.1.2 *The IPAQ versus the logbook*

Table 5 and Figure 14 describe physical activity data from the IPAQ and the logbook. The Spearman rank correlation coefficients (Rs) between the IPAQ and the logbook scores ranged from 0.18 to 0.75, indicating little to high correlation between the instruments. The absolute difference between reported total activity energy expenditure from the IPAQ and reported total physical activity from the logbook was a mean (SD) of -2.9 (44) MET-h·week^{-1} (N.S.). Calculated MET-h·week^{-1} from the physical activity logbook was significantly correlated with MET-h·week^{-1} from the IPAQ (Rs = 0.67, P < 0.001).

Table 5. Descriptive data from the different domains of the IPAQ and the logbook. Mean (SD) and Spearman Rank Correlation coefficient (Rs) between the IPAQ and logbook.

	IPAQ	Logbook	Rs
Work related PA (MET-h·week^{-1})	15 (30)	16 (4)	0.64***
Transport related PA (MET-h·week^{-1})	5 (4)	16 (14)	0.18
Housing or gardening (MET-h·week^{-1})	15 (13)	7 (12)	0.47**
Leisure-time related PA (MET-h·week^{-1})	14 (13)	15 (20)	0.58***
Sitting (h·week^{-1})	52 (16)	45 (16)	0.75***

** P < 0.01, *** P < 0.001

5.1.2 Construct validity

The construct validity of the IPAQ was tested using aerobic capacity (VO_2 ml·kg^{-1}·min^{-1}) and body composition (BMI and % BF) as a construct of activity.

Aerobic fitness showed a weak positive correlation with the total amount of physical activity (MET h·week^{-1}) and with time spent in moderate intensity physical activity (hour per week) from the IPAQ (Rs = 0.21, P < 0.05). There was no significant relationship between aerobic fitness and time spent in vigorous activity (h·week^{-1}) from the IPAQ (Rs = 0.14). There was a low positive correlation between BMI and total amount of physical activity (MET h·week^{-1}) and time (h·week^{-1}) spent in moderate (Rs = 0.27, P < 0.01) and vigorous activity (Rs = 0.17, P < 0.05) from the IPAQ. There was no significant relationship between % BF and any of the variables from the IPAQ (Table 6).

Table 6. Spearman rank correlation coefficient (Rs) for reported time of different intensities of physical activity (PA) from the IPAQ and measures of construct validity.

IPAQ measure	Construct measure	Rs
Total PA (MET-h·week^{-1})	Aerobic fitness (ml O_2·kg^{-1}·min^{-1})	0.21*
Moderate PA (h·week^{-1})	Aerobic fitness (ml O_2·kg^{-1}·min^{-1})	0.21*
Vigorous (h·week^{-1})	Aerobic fitness (ml O_2·kg^{-1}·min^{-1})	0.14
Total PA (MET-h·week^{-1})	BMI (kg·m^{-2})	0.25**
Moderate PA (h·week^{-1})	BMI (kg·m^{-2})	0.27**
Vigorous (h·week^{-1})	BMI (kg·m^{-2})	0.17*
Total PA (MET-h·week^{-1})	BF (%)	0.11
Moderate PA (h·week^{-1})	BF (%)	0.12
Vigorous (h·week^{-1})	BF (%)	0.09

BMI body mass index; BF body fat
* P < 0.05, ** P < 0.01

5.2 PHYSICAL ACTIVITY AND INACTIVITY (PAPERS II AND IV)

5.2.1 Total health-enhancing physical activity

Using the IPAQ as an instrument to study total health-enhancing physical activity (Paper II), the subjects reported a median (25^{th} - 75^{th} percentile) of 1,699 (693 - 3,600) MET-min·week^{-1}. This corresponds to about 60 (24 - 128) minutes of brisk walking per day. Men reported significantly more total health-enhancing physical activity than women (median 1,836 and 1,554 MET-min·week^{-1}, respectively, $P < 0.001$). A significant difference in total health-enhancing physical activity was found across BMI and self-rated health categories (Figure 15). No significant differences were found across age, education, income, employment status, location, income and marital status categories in the total sample.

Total physical activity as average intensity, derived from accelerometer data (Paper IV) showed a mean (SD) of 376 (141) counts per minute. No significant gender difference was found. Figure 16 describes the bivariate relationships between average intensity and age (R^2 = 5 %) and BMI (R^2 = 4 %).

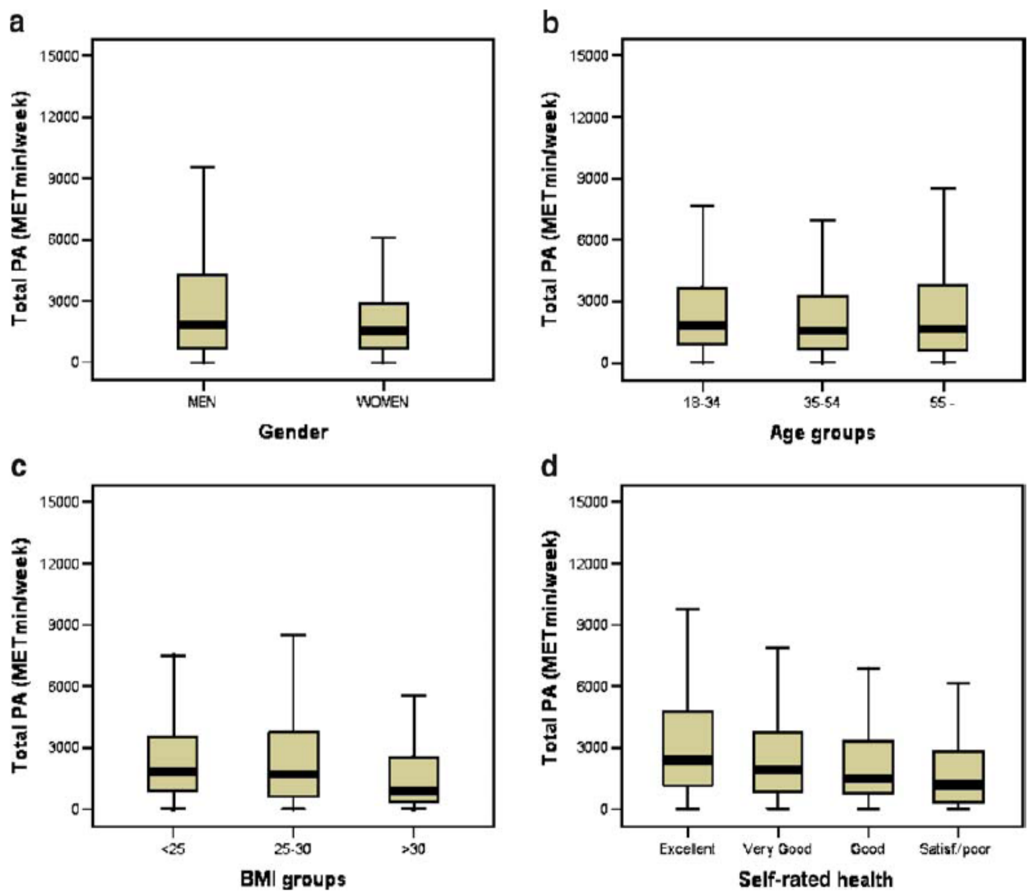

Figure 15. Box-plot of total health-enhancing physical activity by a) gender, b) age, c) BMI and d) self-rated health.

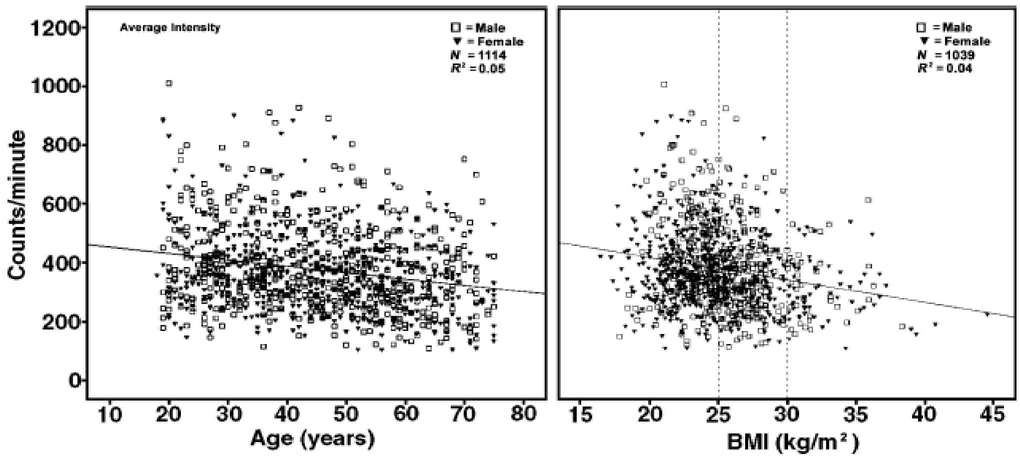

Figure 16. Total physical activity as total counts per minute, by age and BMI.

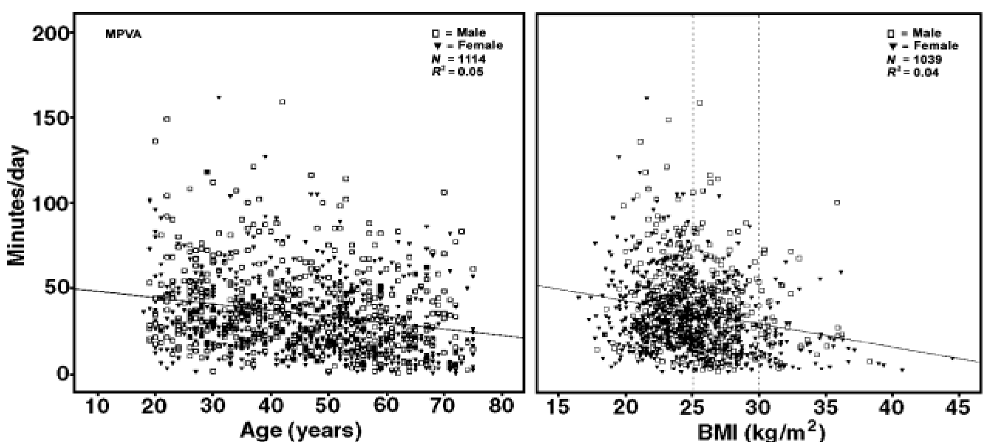

Figure 17. Time spent in at least moderate intensity, by age and BMI.

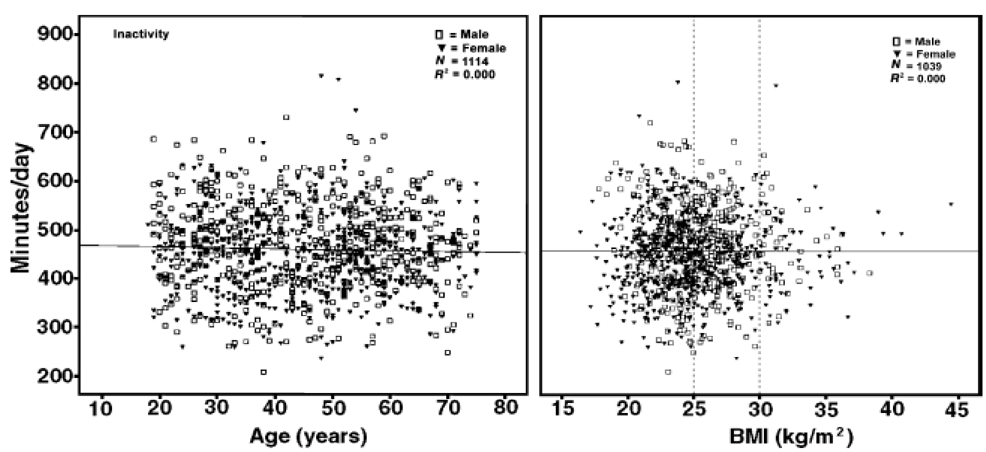

Figure 18. Time spent in inactivity, by age and BMI.

5.2.2 Patterns of health-enhancing physical activity

Results from Paper II (IPAQ) showed that, in the total sample, the subjects reported physical activity at vigorous intensity, moderate intensity and walking with a median (25^{th} - 75^{th} percentile) of 0 (0 - 1,200), 240 (0 - 960) and 495 (148 - 1,386) MET-min·week^{-1}, respectively. Absolute amounts and associations with socio-demographic factors differed by gender.

Men reported vigorous intensity, moderate intensity and walking for a median (25^{th} - 75^{th} percentile) of 240 (0 - 1,600), 240 (0 - 960), 462 (0 - 1,386) MET-min·week^{-1}, respectively. Significant differences in reported vigorous intensity activity were seen across age, BMI, education, employment and self-rated health categories. For moderate intensity, significant differences were seen across education, income, location, marital status and self-rated health categories. For walking, significant differences were seen across age and BMI categories.

Women reported vigorous intensity, moderate intensity and walking for a median (25^{th} - 75^{th} percentile) of 0 (0 - 960), 240 (0 - 720) and 594 (198 - 1,386) MET-min·week^{-1}, respectively. Significant differences in reported vigorous intensity activity were seen across age, BMI, employment status, marital status and self-rated health. For moderate intensity, significant differences were seen across BMI and self-rated health categories. For walking, significant differences were seen only across self-rated health categories.

Table 7 shows the contribution of walking to the total health-enhancing physical activity by demographic variables in men and women. For men, walking contributed for a median (25^{th} - 75^{th} percentile) of 35 % (11 - 73 %) of the total health-enhancing physical activity. Significant differences across age, education, employment, location and self-rated health categories were found. For women, walking contributed 45 % (22 – 92 %) of total health-enhancing physical activity. Significant differences across age, BMI, employment, marital status and self-rated health categories were found.

The results from Paper IV (accelerometer) gave a slightly different picture of the pattern of physical activity. The subjects were active at moderate intensity or higher for a median (25^{th} - 75^{th} percentile) of 31 (18 - 47) min·day^{-1} and accumulated 0 (0 – 2) minutes of vigorous intensity activity daily. Men were significantly more active at moderate or higher intensity level than women. The scattergram in Figure 17 describes the bivariate relationships between time spent at moderate or higher intensity physical activity and age (R^2 = 5 %) and BMI (R^2 = 4 %).

Three-way ANOVA showed that for vigorous intensity activity a small (R^2 = 13.9 %) but significant gender, age and BMI effects was seen. Post-hoc analysis showed that time spent in vigorous intensity activity was lower in older groups, after 45 years and with increasing BMI. Men spent significantly more time in vigorous intensities than women. For moderate intensity activity a small (R^2 = 9.3 %) but significant gender, age and BMI effect was seen. Post-hoc analysis showed that time spent in moderate intensity activity was lower with higher age after 25 years and with higher BMI. Men were significantly ($P < 0.01$) more active at moderate intensity level than women.

Table 7. The contribution of walking to the total amount of health-enhancing physical activity by socio-demographic variables in men and women (as percent of total physical activity, %).

	Men [a] Median (25th-75th percentile)	P	Women [a] Median (25th-75th percentile)	P
Age		<0.001		<0.001
18 - 34	21.6 (5.0-54.7)		39.1 (17.1-78.0)	
35 - 54	35.5 (13.8-75.5)		42.3 (20.5-81.2)	
55 - 74	41.3 (14.3-100.0)		64.2 (27.9-100.0)	
BMI		0.172		0.004
< 25	35.7 (10.3-78.3)		43.3 (20.3-82.7)	
25 - 29.9	29.2 (10.4-69.2)		45.2 (21.6-100.0)	
> 30	45.2 (18.3-100.0)		78.1 (35.5-100.0)	
Education level		<0.001		0.915
Compulsory	36.1 (10.0-100.0)		73.3 (22.7-100.0)	
High School	25.4 (7.2-55.3)		45.2 (21.6-89.7)	
College/University	45.2 (20.4-100.0)		41.7 (20.4-80.2)	
Other	45.2 (7.0-88.5)		42.5 (24.1-72.5)	
Income		0.078		0.239
< 100.000	28.9 (7.3-80.6)		36.6 (17.1-80.7)	
100.000 - 200.000	40.7 (14.7-100.0)		41.9 (19.1-92.0)	
200.000 - 300.000	30.7 (10.2-69.2)		49.0 (23.6-100.0)	
> 300.000	34.7 (11.0-58.8)		45.2 (26.1-90.8)	
Employment status		<0.001		<0.001
Employed	31.5 (8.4-67.6)		42.9 (23.0-82.2)	
Student	19.8 (3.0-60.1)		31.4 (13.4-57.8)	
Retired	52.4 (20.3-100.0)		78.8 (28.7-100.0)	
Unemployed	38.2 (17.1-100.0)		45.2 (18.4-100.0)	
Location		<0.001		0.324
Village	20.5 (5.3-52.2)		42.1 (22.3-87.0)	
Small city	37.9 (13.8-67.3)		49.8 (21.6-100.0)	
Medium city	40.0 (17.1-74.3)		40.5 (17.1-84.5)	
Large city	38.2 (14.4-100.0)		49.1 (25.6-100.0)	
Marital status		0.126		0.004
Married/partner	31.4 (10.0-69.8)		50.8 (23.1-100.0)	
Single	39.9 (13.5-94.7)		38.2 (16.3-78.6)	
Self-rated health		0.010		<0.001
Excellent	22.8 (7.2-53.6)		38.7 (17.1-68.4)	
Very good	29.9 (12.6-65.8)		36.6 (17.1-74.3)	
Good	38.7 (11.8-74.3)		55.3 (25.3-100.0)	
Satisfactory/poor	45.2 (11.6-100.0)		62.3 (22.3-100.0)	

a) Walking contributed to a larger percent in the total HEPA in women (median 45.2 %) than in men (median 34.8 %), p < 0.001

5.2.3 Inactivity

Using self-reported time spent sitting, derived from the IPAQ (Paper II) as an indicator of inactivity, the results showed a median (25^{th} - 75^{th} percentile) of 300 (180 - 480) min·day^{-1}, which equals 5 (3 - 8) h·day^{-1}. No differences between genders could be found.

Using objectively measured time spent sitting (Paper IV), the results showed a mean (SD) of 459 (86) min·day^{-1}, which equals 8 (1) h·day^{-1}. The scattergram in Figure 18 shows the bivariate relationships between time spent in inactivity and age and BMI. For inactivity neither gender, age nor BMI (R^2 = 0 %) could explain the variation in inactivity.

5.2.4 Adherence to the physical activity recommendation

Figure 19 describes the adherence estimates. Fifty-two percent of the subjects accumulated at least 30 minutes per day of separate minutes of moderate intensity physical activity or higher, with significantly more men than women accumulating this amount. Thirty-seven percent of the population achieved at least one 10-minute continuous bout in these 30 minutes. Seven percent accumulated at least 30 minutes per day of moderate intensity physical activity or higher, by bouts of two or more minutes including one bout of at least 10 minutes and only one percent achieved those minutes of moderate intensity physical activity or higher by three or more 10-minutes bouts per day.

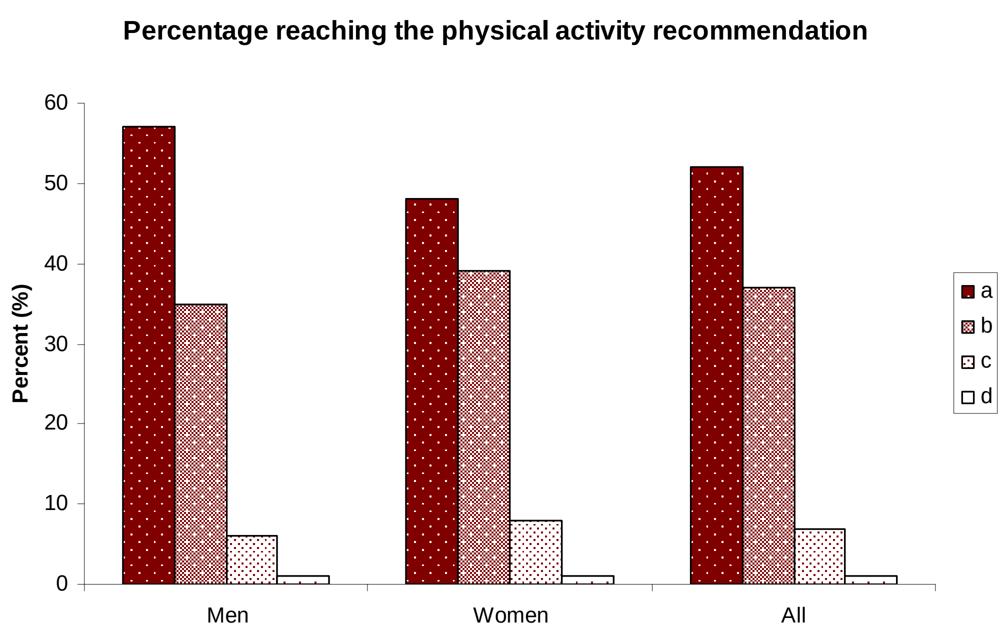

Figure 19. The percentage of men, women and in total reaching the health-enhancing physical activity recommendation, of 30 minutes at least moderate intensity physical activity, interpreted in different ways:
a) accumulating at least 30 minutes per day;
b) accumulating at least 30 minutes, of which at least ten are continuous;
c) accumulating at least 30 minutes, of which at least ten are continuous and all others are from bouts of two minutes or more;
d) accumulating at least 30 minutes, of which all are from bouts of ten minutes or more.

6 DISCUSSION

6.1 MAIN FINDINGS

This is the first population-based study in Sweden (and to the best of our knowledge in the world) to objectively measure physical activity and also to subjectively measure total physical activity, as distinct from leisure time exercise or occupational physical activity only. A new and sobering picture of health-enhancing physical activity at population level has been shown.

The objectively (accelerometry) obtained data suggested less physical activity and a different activity pattern compared to those obtained by self-reports (the IPAQ). The data were to some extent qualitatively consistent with the data based upon a self-report. Data from both instruments suggested that males were generally more active at moderate or higher intensity than females, but no differences could be found for total physical activity. The level of health-enhancing physical activity appeared to decline slightly with age. The low level of adherence to current physical activity recommendations was particularly evident when bouts of activity (from the accelerometer data) were considered. Before discussing the outcomes, interpretation and implication of this thesis some methodological issues must be addressed.

6.2 METHODOLOGICAL ISSUES

6.2.1 Study design and samples

The analyses (Papers II, III and IV) were based upon representative and relatively large samples of the Swedish adult population. Analysis of non-participants and comparison with the general Swedish population showed no evidence of selection bias. However, more women than men participated and participants living outside of big cities where under-represented. Data for Papers III and IV was collected throughout the calendar year, which reduces the effect of seasonal variation in physical activity levels. To be able to give guidelines when (during a year) physical activity should be assessed for best interpretation, further analysis on seasonal variation of our data and in other studies are recommended.

The cross-sectional design of the papers is a limitation. To be able to draw any causal relationships, longitudinal studies using both subjective and objective measures of total health-enhancing physical activity, together with health outcomes, are needed. This should lead to a better understanding of the dose-response relationship from the perspective of more novel methodologies.

6.2.2 Methods

The methods used in this thesis have both strengths and limitations. The use of an objective measure of physical activity that has been extensively validated is one strength, as is the fact that the validation of the IPAQ was performed against several measures.

One particular issue for the validation of physical activity questionnaires is the choice of an appropriate criterion measure against which to compare to, as no golden standard for the validation of physical activity questionnaires exist. For example, the use of the golden standard for measuring energy expenditure, doubly labelled water (DLW), would only give a picture of the total energy expenditure and not the intensity or pattern of the activity, which in the IPAQ instrument are key components.

Accelerometers have been suggested as one of the best criterion measures of self-report instruments of physical activity (Welk 2002b; Esliger et al. 2005). Accelerometers and self-reports measure different things (Ham et al. 2007). An accelerometer measures body movement while a questionnaire often ask for respondents to rate activities according to effort (absolute versus relative measures are thus compared). Furthermore, activities reported in IPAQ such as heavy manual work, cycling and weight lifting are not possible to capture with the accelerometer. Still it is the best criterion method available. To enhance the assessment of various physical activities with the accelerometer for the validation study, we chose the cut-points recommended by Matthew et al. (2005) that are derived from both ambulatory and non-ambulatory activities.

The accelerometer measurements in the validation studies were performed for the same period as the IPAQ asks for. It is therefore no reason to believe that the respondents did not refer to the same days when answering the IPAQ as was measured by the accelerometer.

The use of an uniaxial accelerometer, such as the Actigraph, with cut-points based upon experimental studies on walking and running (Paper I and IV), misses physical activities that involve upper-body movement or the additional costs of load-carrying (as discussed in the background and above). However, walking is the most prevalent form of leisure-time activity and also occurs in occupational and transportation activities (Paper II).

When interpreting the results from the objectively measured physical activity data (Paper IV) one must bear in mind that, even though an objective measure of activity has been used, accelerometers are not a panacea for physical activity assessment, but they still provide better data than subjective measures and are more feasible than more advanced equipment (Esliger et al. 2005).

One limitation with the use of self-report instruments for physical activity, such as the IPAQ, is the complex nature of physical activity behaviour (as discussed in the background) and that it is potentially liable to differential measurement biases – one is recall, which may differ among individuals, and another is the individual perceptions of what physical activities comprise (Sallis and Saelens 2000; Shephard 2002; Ainsworth and Levy 2004). Possible differential bias can be if, for example, obese subjects or subjects with low education over-report physical activity to a greater extent than normal weight or highly educated subjects. If this is true for the IPAQ instrument findings here would underestimate the real differences between groups observed here. For example, in Paper II, older subjects and subjects with poor health reported less sitting, and this could also reflect differential biases compared to younger people. All these hypotheses on differential biases have to be further tested for in the IPAQ instrument.

In Paper I, height and weight were measured using standardised equipment. In Papers II, III, IV, height and weight were self-reported. The use of self-reported height and weight leads to underestimation of body weight and overestimation of height (John et al. 2006). On the other hand, earlier studies showing that physical activity decreases with higher BMI also used self-reported data.

6.3 OUTCOMES, INTERPRETATION AND IMPLICATIONS

6.3.1 Validation of the IPAQ

The validation study of the IPAQ was first performed on a convenience sample (Paper I). The findings from that study showed a) that correlations between the IPAQ and the accelerometer were low to moderate but similar to other validation studies on physical activity questionnaires, and b) that there is a large inter-individual difference between the IPAQ and the accelerometer and activity logbook, but no systematic biases were found. This led us to believe that the IPAQ can be used for population-based studies in Sweden. When searching for literature on validity on self-reports of physical activity no studies were found that show a higher validity on this type of questionnaire or studies done on randomly selected individuals.

In Paper III, a nationally representative sample was used together with both a subjective (the IPAQ) and an objective measure of activity (accelerometry). The findings from Paper III showed even larger inter-individual differences between the IPAQ and the accelerometer. Systematically higher values were found for vigorous physical activity from the IPAQ, and the differences between the instruments were larger as reported physical activity increased. This is a problem for the IPAQ, but as no other physical activity instruments have been validated using population samples, this error might occur in them as well.

The difference in minutes of daily physical activity minutes reported on the IPAQ and recorded on the accelerometer increased with higher IPAQ scores. This may reflect over-reporting, failure to recall time well, or rounding up of time for the IPAQ. The long form of the IPAQ consists of 27 items, if each of them are rounded up just a little, it will still yield a large over-estimation. In questionnaires, when a person reports different tasks such as cleaning, she/he might report one hour, but it is unlikely that the whole hour was cleaning at moderate intensity. The same is true for structured training such as aerobic, gym classes in which a warm up and stretching is included. Therefore, in these cases the IPAQ would yield higher values compared to an accelerometer.

Furthermore, the IPAQ asks for time and frequency spent in moderate and vigorous intensity physical activities, which is a subjective rating of intensity. This perception of intensity may be higher for a person with a higher body weight and/or low aerobic capacity. Alternatively, the accelerometer may classify physical activity performed by not measuring non-ambulatory activity. However, it is unlikely this would account for the large differences noted.

Studies have shown that the item order in physical activity questionnaires can influence the outcome (Ainsworth and Levy 2004). The relevance of this to the IPAQ has been discussed. A study by Barnett et al. showed less over-reporting and higher correlations coefficient between the IPAQ and data derived from an accelerometer when the order of questions was changed, i.e. walking reported first, than moderate and vigorous intensity physical activity (Barnett et al. 2007). This might influence the Swedish translation as well and needs to be further tested.

Given that the IPAQ apparently leads to higher estimates of physical activity, it may be that participants have difficulties understanding the concepts used in the IPAQ. For example, in a validation study on IPAQ in Finland it was found that over-reporters have lower education (Fogelholm et al. 2006). A qualitative study, using focus groups, on how Swedish women understand the concepts used in the IPAQ have been performed as a Master project (Johnson, 2006). The findings showed that the women did not fully understand the intensity examples for moderate and vigorous physical activity used in the IPAQ (e.g. breathing much harder than usual). Physical activity and exercise was similar words for them. The findings from the master project are in line with a study in US (Tudor-Locke et al. 2003). Further investigations on the understanding of physical activity concepts will likely help us to increase the validity of IPAQ.

The results from this thesis raises the concern that, by attempting to get a more detailed picture of the different dimensions of health-enhancing physical activity, one may increase the risk of misclassification due to misinterpretation of the questions.

6.3.2 Levels and patterns of physical activity

Both a subjective and an objective measure of health-enhancing physical activity were used to study the levels and patterns in Swedish adults. The absolute figures differ, however, the findings from the objectively measured accelerometer data are to some extent qualitatively consistent with findings based upon the self-reported data (the IPAQ).

When studying time spent at moderate intensity physical activity or higher and total physical activity by age and BMI using an accelerometer some unexpected results emerged. A large inter-individual difference was found and only very small correlations with age or BMI were seen. Time spent in inactivity could not, in this study, be explained by gender, age or BMI. A recently published study by Levine et al. showed that obese subjects spent more time sitting and time in low intensity activities than subjects of normal weight (Levine 2004). Another Swedish study has reported weak associations between time spent sitting and BMI in subjects with a BMI < 35, using accelerometry. In severely obese subjects the association was strong (Hemmingsson and Ekelund 2007). In our study there were only 80 subjects who reported a BMI ≥ 30 of which 19 subjects reported a BMI ≥ 35 and this small sub-sample size could explain the lack of association.

Another example is the previously demonstrated differences between men and women, i.e. that men are more active than women (Trost et al. 2002; Socialstyrelsen 2005). This could only be partly confirmed by the data presented here. On high intensity physical activity, a gender difference was found but when taking total physical activity into account (average intensity) no significant difference between men and women was found.

The prevalence estimates in this study, based upon the accelerometer data, indicate that 52 % of the adult population reaches the health-enhancing physical activity recommendation if every minute above the threshold was included. When the number of people achieving 30 minutes in bouts of at least 10 minutes duration the prevalence estimates were only one percent among the adults. These findings are in contrast with adherence estimates based upon self-reported data from national surveys that indicate 65 % of the population that perform exercise at least once a week and about 9 % that never perform any intentional exercise (Socialstyrelsen 2005). Estimates based upon the Eurobarometer study, using the IPAQ indicate that 23 % are sufficiently active and 35 % are walking for 30 minutes at least five times per week, in Sweden (Sjostrom et al. 2006).

This thesis has shown that the large-scale application of accelerometry in population studies is feasible. At the same time new questions about recommended duration, intensities and needs of bouts of physical activity are raised (Troiano 2007). It is also important to recognise that the current recommendation to accumulate 30 minutes of moderate intensity physical activity or higher on most days is based on epidemiological associations between self-reported physical activity and health outcomes. Epidemiological relationships based on objective measures might have resulted in different recommendations for physical activity levels. Less than 30 minutes per day of physical activity as measured by accelerometer may provide significant health benefits because lower levels of objectively measured physical activity corresponds to higher levels of self-reported physical activity.

7 SUMMARY

- The validation of the IPAQ-long in a convenience sample showed that the correlations between the IPAQ and the accelerometer were low to moderate, which is similar to those found in validation studies of other physical activity questionnaires. Large inter-individual differences between the IPAQ and both the accelerometers and the logbooks were found, but there was no evidence of a systematic bias. In the validation of IPAQ-long in a population sample, even larger inter-individual differences between the IPAQ and the accelerometers were found. Systematically higher values were found for vigorous physical activity from the IPAQ and that the difference between the instruments increased with increasing physical activity as reported in the IPAQ.

- Correlations between the IPAQ-long and the accelerometer were lower in women than in men, but the IPAQ and the accelerometer yielded similar patterns of activity for both women and men. The inter-individual differences between the instruments did not differ between the genders. The findings from the objectively measured accelerometer data are with regard to gender, age, BMI and education to some extent qualitatively consistent with findings based upon the IPAQ.

- The IPAQ data showed that adults reported a median (25^{th} - 75^{th} percentile) of 1,699 (693 - 3,600) MET-min·week^{-1}. This corresponds to about 60 (24 - 128) minutes of brisk walking per day. Men reported significantly more activity than women (1,836 vs.1,554 MET-min·week^{-1}). A significant difference in total physical activity was found across age, BMI and self-rated health categories. For men, walking contributed to 35 % (11 - 73 %) of the total physical activity, while for women, walking contributed to 45 % (22 - 92 %). The accelerometer data showed that men were significantly more active on moderate or higher intensity level than women. For total physical activity and time spent in inactivity neither gender, age nor BMI could explain the variance.

- The prevalence estimates in this study, based upon the accelerometer data, indicate that 52 % of the adult population reaches the health-enhancing physical activity recommendation if every minute above the threshold was included. However, when activity bouts of 10 minutes or longer were considered, the prevalence estimates were only one percent. The adherence results from the accelerometer data provide a new and sobering picture of physical activity levels in the Swedish population. The low levels of activity are particularly evident when bouts of activity are considered.

8 CONCLUSION

This is the first time levels and patterns of health-enhancing physical activity have been assessed at population level, using novel objective (accelerometry) methodology. Together with the use of a subjective method (the IPAQ), the data provides a new and sobering picture of health-enhancing physical activity in Sweden. They also raise new questions about recommended duration, intensity and needs for bouts of physical activity. Even though the absolute values between the instruments used differ, they both provide qualitatively consistent pictures of health-enhancing physical activity at population level. This thesis has shown that the large-scale application of accelerometry in population studies is feasible.

9 ACKNOWLEDGEMENTS

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10 REFERENCES

ACSM. "American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults." Med Sci Sports Exerc. 1978;10:vii-x.

ACSM. "American College of Sports Medicine. Position stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults." Med Sci Sports Exerc. 1990;22:265-274.

ACSM. "American College of Sports Medicine. Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults." Med Sci Sports Exerc. 1998;30:975-91.

ACSM. Resource manual for guidelines for exercise testing and prescription. Baltimore, MD, Lippincott Williams & Wilkins. 2006.

Ainsworth, B. E., Bassett, D. R., Jr., Strath, S. J., et al. "Comparison of three methods for measuring the time spent in physical activity." Med Sci Sports Exerc. 2000a;32:S457-64.

Ainsworth, B. E., Haskell, W. L., Leon, A. S., et al. "Compendium of physical activities: classification of energy costs of human physical activities." Med Sci Sports Exerc. 1993;25:71-80.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., et al. "Compendium of physical activities: an update of activity codes and MET intensities." Med Sci Sports Exerc. 2000b;32:S498-504.

Ainsworth, B. E. and Levy, S. Assessment of health-enhancing physical activity: Methodological issues. Health enhancing physical activity. Oja, P. B., J. Oxford, UK, Meyer & Meyer Sport. 2004: 239-270.

Ainsworth, B. E., Macera, C. A., Jones, D. A., et al. "Comparison of the 2001 BRFSS and the IPAQ Physical Activity Questionnaires." Med Sci Sports Exerc. 2006;38:1584-92.

Ainsworth, B. E., Richardson, M. T., Jacobs, D. R., Jr., Leon, A. S. and Sternfeld, B. "Accuracy of recall of occupational physical activity by questionnaire." J Clin Epidemiol. 1999;52:219-27.

Ainsworth, B. E., Sternfeld, B., Richardson, M. T. and Jackson, K. "Evaluation of the kaiser physical activity survey in women." Med Sci Sports Exerc. 2000c;32:1327-38.

Altman, D. Practical statistics for medical research. London, Chapman & Hall. 1991.

Barnett, J., Nigg, C., De Bourdeaudhuij, I., Maglione, C. and Maddock, J. "The effect of item order on physical activity estimates using the IPAQ." Californian Journal of Health Promotion. 2007;5:23-29.

Basset, D. R. and Strath, S. J. Use of pedometers to assess physical activity. Physical activity assessment in health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002: 163-178.

Bland, JM and Altman, DG. "Statistical methods for assessing agreement between two methods of clinical measurement." The Lancet. 1986;8:307-310.

Bouchard, C., Blair, S. N. and Haskell, W. L. Physical activity and health. Leeds, UK, Human Kinetics. 2007.

Bouchard, C., Shephard, R. J. and Stephens, T. Physical activity, fitness and health. Consensus statement. Leeds, UK, Human Kinetics. 1994.

Caspersen, C. J., Powell, K. E. and Christenson, G. M. "Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research." Public Health Rep. 1985;100:126-31.

CDC, USDHHS and NCCDH. Physical Activity and Health. A report from the Surgeon General. Atlanta, GA, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, National Center for Chronic Disease Prevention and Health Promotion. 1996.

Chen, K. Y. and Bassett, D. R., Jr. "The technology of accelerometry-based activity monitors: current and future." Med Sci Sports Exerc. 2005;37:S490-500.
Computer Science Application. Activity Monitor Operator´s Manual. Shallimar FL. 1995.
Craig, C., Marshall, A. L., Sjostrom, M., et al. "International physical activity questionnaire: 12-country reliability and validity." Med Sci Sports Exerc. 2003;35:1381-95.
Dishman, R. K., Washburn, R. A. and Heath, G. W. Physical activity epidemiology. Leeds, UK, Human Kinetics. 2004.
Domholdt, E. A. Physical therapy research, 2nd ed. Philadelphia, Saunders. 2000.
Durnin, J. V. and Womersley, J. "Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years." Br J Nutr. 1974;32:77-97.
Ekelund, U., Sepp, H., Brage, S., et al. "Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults." Public Health Nutr. 2006;9:258-65.
Engström, L. M. Idrottsvanor i förändring (in Swedish). Stockholm, HSL Förlag. 1989.
Esliger, D. W., Copeland, J. L., Barnes, J. D. and Tremblay, M. S. "Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring." JPAH. 2005;2:366-383.
Ferrari, P., Friedenreich, C. and Matthews, C. E. "The Role of Measurement Error in Estimating Levels of Physical Activity." Am J Epidemiol. 2007.
Fogelholm, M., Malmberg, J., Suni, J., et al. "International Physical Activity Questionnaire: Validity against fitness." Med Sci Sports Exerc. 2006;38:753-60.
Foster, C. Guidelines for health-enhancing physical activity promotion programmes. the UKK Institute for Health Promotion Research, Tampere, Finland. 2000.
Fransson, E. I., Alfredsson, L. S., de Faire, U. H., Knutsson, A. and Westerholm, P. J. "Leisure time, occupational and household physical activity, and risk factors for cardiovascular disease in working men and women: the WOLF study." Scand J Public Health. 2003;31:324-33.
Freedson, P., Melanson, E. and Sirard, J. "Calibration of the Computer Science and Applications, Inc. accelerometer." Med Sci Sports Exerc. 1998;30:777-81.
Graff-Iversen, S., Anderssen, S. A., Holme, I. M., Jenum, A. K. and Raastad, T. "An adapted version of the long International Physical Activity Questionnaire (IPAQ-L): construct validity in a low-income, multiethnic population study from Oslo, Norway." Int J Behav Nutr Phys Act. 2007;4:13 -.
Hallal, P. C. and Victora, C. G. "Reliability and validity of the International Physical Activity Questionnaire (IPAQ)." Med Sci Sports Exerc. 2004;36:556.
Hallal, P. C., Victora, C. G., Kingdon-Wells, J. C., Lima, R. C. and Valle, N. J. "Comparison of short and full-length International Physcial Activity Questionnaire." JPAH. 2004;1:227-234.
Ham, S. A., Reis, J. P., Strath, S. J., Dubose, K. D. and Ainsworth, B. E. "Discrepancies between Methods of Identifying Objectively Determined Physical Activity." Med Sci Sports Exerc. 2007;39:52-8.
Haskell, W. L. "Health consequences of physical activity: understanding and challanges regarding dose-respone. J.B Wolffe Memorial Lecture." Med Sci Sports Exerc. 1994;26:649-660.
Haskell, W. L. "What to look for in assessing responsiveness to exercise in a health context." Med Sci Sports Exerc. 2001;33:S454-8; discussion S493-4.
Haskell, W. L. Dose-response issues in physical activity, fitnsee and health. Physical activity and health. Bouchard, C., Blair, S. N. and Haskell, W. L. Leeds, UK, Human Kinetics. 2007: 303-318.
Haskell, W. L., Lee, I. M., Pate, R. R., et al. "Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association." Circulation. 2007;116:1081-93.
HEA. Moving on, International perspecitve on promotion physical activity. London, UK, Health education authority. 1994.
Hemmingsson, E. and Ekelund, U. "Is the association between physical activity and body mass index obesity dependent?" Int J Obes (Lond). 2007;31:663-8.

Hendelman, D., Miller, K., Baggett, C., Debold, E. and Freedson, P. "Validity of accelerometry for the assessment of moderate intensity physical activity in the field." Med Sci Sports Exerc. 2000;32:S442-9.
IPAQ. The International Physical Activity Questionnaire, http://www.ipaq.ki.se/.
Jacobs, D. R., Jr., Ainsworth, B. E., Hartman, T. J. and Leon, A. S. "A simultaneous evaluation of 10 commonly used physical activity questionnaires." Med Sci Sports Exerc. 1993;25:81-91.
Janz, F. K. Use of heart rate moniotrs to assess physical activity. Physical activity assessment in health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002: 143-162.
John, U., Hanke, M., Grothues, J. and Thyrian, J. R. "Validity of overweight and obesity in a nation based on self-report versus measurement device data." Eur J Clin Nutr. 2006;60:372-7.
Kolbe-Alexander, T. L., Lambert, E. V., Harkins, J. B. and Ekelund, U. "Comparison of two methods of measuring physical activity in South African older adults." J Aging Phys Act. 2006;14:98-114.
Kriska, A. and Caspersen, C. "Introduction to a collection of physical activity questionnaire." Med Sci Sports Exerc. 1997;Supplement:S5 - S205.
Lagerros, Y. T. and Lagiou, P. "Assessment of physical activity and energy expenditure in epidemiological research of chronic diseases." Eur J Epidemiol. 2007;22:353-62.
Lamonte, M. J. and Ainsworth, B. E. "Quantifying energy expenditure and physical activity in the context of dose response." Med Sci Sports Exerc. 2001;33:S370-8; discussion S419-20.
Levine, J. A. "Non-exercise activity thermogenesis (NEAT)." Nutr Rev. 2004;62:S82-97.
Macfarlane, D. J., Lee, C. C., Ho, E. Y., Chan, K. L. and Chan, D. T. "Reliability and validity of the Chinese version of IPAQ (short, last 7 days)." J Sci Med Sport. 2007;10:45-51.
Mader, U., Martin, B. W., Schutz, Y. and Marti, B. "Validity of four short physical activity questionnaires in middle-aged persons." Med Sci Sports Exerc. 2006;38:1255-66.
Mahar, M. T. and Rowe, D. A. Construct validity in physical activity research. Physical activity assessments for health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002.
Matthew, C. E. "Calibration of accelerometer output for adults." Med Sci Sports Exerc. 2005;37:Suppl 512-22.
McArdle, W. D., Katch, F. I. and V.L., K. Exercise Physiology; energy, nutrition and human performance. Baltimore, Maryland, Lippincott Williams & Wilkins. 2006.
Morris, J. N., Heady, J. A. and Raffle, P. A. "Physique of London busmen." Lancet. 1956;271:569-570.
Morris, J. N., Heady, J. A., Raffle, P. A., Roberts, C. G. and Parks, J. W. "Coronary heart-disease and physical activity of work." Lancet. 1953;265:1053-7; contd.
Morrow, J. R. J. Measurement issues for the assessment of physical activity. Physical activity assessments for health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002: 37-72.
Nichols, J. F., Morgan, C. G., Chabot, L. E., Sallis, J. F. and Calfas, K. J. "Assessment of physical activity with the Computer Science and Applications, Inc., accelerometer: laboratory versus field validation." Res Q Exerc Sport. 2000;71:36-43.
Norman, A., Bellocco, R., Vaida, F. and Wolk, A. "Age and Temporal Trends of Total Physical Activity in Swedish Men." Med Sci Sports Exerc. 2003;35:617-622.
Norton, K. and Olds, T. Antropometrica. A textbook of body measurment for sports and health courses. Australia, UNSW press. 1996: 80-90.
Oja, P. and Borms, J. Health enhancing physical activity. Oxford, UK, Meyer & Meyer Sport. 2004.
Orsini, N., Bellocco, R., Bottai, M., Pagano, M. and Wolk, A. "Age and temporal trends of total physical activity among Swedish women." Med Sci Sports Exerc. 2006;38:240-5.

Paffenbarger, R. S., Jr., Hyde, R. T., Wing, A. L. and Hsieh, C. C. "Physical activity, all-cause mortality, and longevity of college alumni." N Engl J Med. 1986;314:605-13.
Pate, R. R., Pratt, M., Blair, S. N., et al. "Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine." Jama. 1995;273:402-7.
Pietrobelli, A., Wang, Z. and Heymsfield, S. B. "Techniques used in measuring human body composition." Curr Opin Clin Nutr Metab Care. 1998;1:439-48.
Sallis, J. F. Correlates of physical activity. Physical Activity & Behavioral Medicine. Sallis, J. F. and Owen, N., Sage Publications. 1999.
Sallis, J. F. and Saelens, B. E. "Assessment of physical activity by self-report: status, limitations, and future directions." Res Q Exerc Sport. 2000;71:S1-14.
Saris, W. H., Blair, S. N., van Baak, M. A., et al. "How much physical activity is enough to prevent unhealthy weight gain? Outcome of the IASO 1st Stock Conference and consensus statement." Obes Rev. 2003;4:101-14.
Shephard, R. J. "Issues in exercise, fitness, and subjective perceptions of fitness of physical education teachers." Percept Mot Skills. 2002;95:361-2; discussion 432.
Sjostrom, M., Oja, P., Hagströmer, M., Smith, B. and Bauman, A. "Health-enhancing physical activity across European Union countries: the Eurobarometer study." Journal of Public Health. 2006;14:291-300.
Socialstyrelsen. Kost och Motion (In Swedish). Stockholm, Allmänna förlaget. 1971.
Socialstyrelsen. Kost, Motion & Hälsa (In Swedish). Stockholm, Allmänna Förlaget. 1992.
Socialstyrelsen. Health in Sweden - Sweden´s Public Health Report 2005. Stockholm (in Swedish), The national board of health and welfare. 2005.
Starling, R. D. Use of doubly labeled water and indirect calorimetry to assess physical activity. Physical activity assessment in health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002: 197-210.
Suitor, C. W. and Kraak, V. I. Adequancy of evidence for physical activity guidelines development, workshop summary. Washingtotn, D.C., The national academies press. 2007.
Timperio, A., Salmon, J. and Crawford, D. "Validity and reliability of a physical activity recall instrument among overweight and non-overweight men and women." J Sci Med Sport. 2003;6:477-91.
Troiano, R. P. "Large-scale applications of accelerometers: new frontiers and new questions." Med Sci Sports Exerc. 2007;39:1501.
Trost, S. G. "Objective measurement of physical activity in youth: current issues, future directions." Exerc Sport Sci Rev. 2001;29:32-6.
Trost, S. G., McIver, K. L. and Pate, R. R. "Conducting accelerometer-based activity assessments in field-based research." Med Sci Sports Exerc. 2005;37:S531-43.
Trost, S. G., Owen, N., Bauman, A. E., Sallis, J. F. and Brown, W. "Correlates of adults' participation in physical activity: review and update." Med Sci Sports Exerc. 2002;34:1996-2001.
Tudor-Locke, C., Henderson, K. A., Wilcox, S., Cooper, R. S., Durstine, J. L. and Ainsworth, B. E. "In their own voices: definitions and interpretations of physical activity." Womens Health Issues. 2003;13:194-9.
Verhagen, E., van Sluijs, E. and van Mechelen, W. Risks of physical activity. Physical activity and health. Bouchard, C. Leeds, UK, Human Kinetics. 2007: 287-300.
Ward, D. S., Evenson, K. R., Vaughn, A., Rodgers, A. B. and Troiano, R. P. "Accelerometer use in physical activity: best practices and research recommendations." Med Sci Sports Exerc. 2005;37:S582-8.
Warnecke, R. B., Sudman, S., Johnson, T. P., O'Rourke, D., Davis, A. M. and Jobe, J. B. "Cognitive aspects of recalling and reporting health-related events: Papanicolaou smears, clinical breast examinations, and mammograms." Am J Epidemiol. 1997;146:982-92.
Welk, G. Physical assessment in health-realted research. Leeds, UK, Human Kinetics. 2002a.

Welk, G. J. Use of accelerometery-based activity monitors to assess physical activity. Physical activity assessment in health-related research. Welk, G. J. Leeds, UK, Human Kinetics. 2002b: 125-142.

Welk, G. J. "Principles of design and analyses for the calibration of accelerometry-based activity monitors." Med Sci Sports Exerc. 2005;37:S501-11.

WHA. World Health Assembly 57.17. Global Strategy on diet, physical activity and health. 2004.

Yngve, A., Nilsson, A., Sjostrom, M. and Ekelund, U. "Effect of monitor placement and of activity setting on the MTI accelerometer output." Med Sci Sports Exerc. 2003;35:320-6.