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Physical activity in adults and older people

Levels of objectively measured physical activity in a population-based sample of Norwegian adults and older people (20–85 years)

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES • 2013

ISBN nr 978-82-502-0485-0

Summary

Introduction: Evidence from epidemiological research and clinical interventions clearly states that physical activity is essential to improve health as well as quality of life. The health gains of increasing physical activity are age-independent and those who benefit the most from increased physical activity are individuals with low levels of activity. Despite the well-documented health gains of performing regular physical activity, there is a paucity of data allowing us to assess the current situation regarding population level of physical activity in Norway. The available data on large-scale assessments of physical activity have relied on self-reported measures, a method that has validity and reliability problems.

Purpose: The overall purpose was to increase our knowledge regarding the patterns of physical activity in adults and older people and to investigate factors associated with physical activity, using objectively measured physical activity.

Participants and methods: The thesis is based on two separate studies. **Papers I-III** are based on a national cross-sectional multicentre study of Norwegian adults and older people (20-85 years), while **Paper IV** is based on a validation study of the ActiGraph GT1M activity monitor.

Main results: The results from **Paper I** showed that men and women had similar levels of overall physical activity, and activity levels were relatively stable until reaching approximately retirement age, after which activity levels declined. Adults and older people spent most of their time being sedentary and only 20% of the population met the current physical activity recommendations. **Paper II** showed that both indicators of overall physical activity and intensity-specific physical activity differed between BMI-categories and the odds of being overweight or obese increased with lower levels of physical activity. The differences in overall physical activity between the BMI-categories were most pronounced on weekends, where the obese participants display overall activity levels 25% lower than among the normal weight participants. Several correlates that might be important targets for intervention were identified in **Paper III**. These variables included self-efficacy, perceived behavioural control and physical activity identity. The observed interaction effects of the demographic and biological variables on the relationships between the correlates and physical activity did not seem to have a sufficient impact to justify interventions that are specific for sex, weight status, or level of education. Finally, the results from **Paper IV** showed that the activity monitor used to objectively assess physical activity in **Papers I-III**, the ActiGraph GT1M, provided valid measures of overall physical activity during walking in the light-to-moderate intensity rage. Furthermore, the activity monitor discriminated between level and graded walking, although graded walking decreased the accuracy of energy expenditure prediction. The GT1M did not capture energy expenditure adequately while cycling. However, the modest amount of cycling reported by the participants in **Papers I-III**, indicate that the population estimates of physical activity presented in this theses were not influenced by the accelerometers inability to capture energy expenditure while cycling.

Conclusions: In a large and nationwide sample of adults and older people, objective assessments of physical activity have revealed results that differ from those obtained by methods of self-report. The assessed high levels of sedentary behaviour and low adherence to current physical activity recommendations provides important knowledge and should help inform public health policy. This study should be a start of a recurring national surveillance system to monitor trends in objectively assessed physical activity levels.

Key words: Accelerometers, physical activity, sedentary behaviour, recommendations, adults, older people, overweight, obesity, BMI, correlates, ActiGraph, GT1M, cross-sectional, epidemiology.

Acknowledgements

This project was carried out at the Department of Sports Medicine at the Norwegian School of Sport Sciences. It is based on the the Physical Activity among Adults and Older People Study, a multicentre study funded by the Norwegian Directorate of Health and the Norwegian School of Sport Sciences, and a validation study funded by the Department of Sports Medicine at the Norwegian School of Sport Sciences.

This thesis is a result of the hard work of many individuals, and I would like to extend my most sincere gratitude to all of you who have made this possible.

First and foremost I offer my sincerest gratitude to my main supervisor Professor Sigmund Alfred Anderssen. You are the main reason that this thesis is now an actual product. Your skills as a researcher, supervisor, and leader, combined with your kind and caring personality are a fine match! Thank you for your never-ending support, dedication, and encouragement. I have been privileged to have you as my supervisor and I am privileged to have you as my friend.

My co-supervisor Elin Kolle: I have a lot to thank you for. You have provided me with invaluable help, guidance, enthusiasm, and encouragement throughout my PhD-period. Thank you for the many laughs and good times we have shared, both domestic and abroad. Thank you for your good friendship, it means a lot to me.

Professor Ingar Holme: Thank you for sharing your knowledge and enthusiasm for the field of physical activity and health. Your statistical advice and guidance have been crucial throughout my entire PhD-period. Sindre Dyrstad: Thank you the fruitful discussions and co-authorship for **Paper I**. Yngvar Ommundsen: Thank you for your help, advice, and co-authorship for **Paper III**.

I wish to extend my sincere gratitude to all those involved in ¨the Physical Activity among Adults and Older People study¨. As the project coordinator for this project, it has been a true pleasure to work with all of you. Your hard work and dedication made this project a success. A very big

thank you goes out to all the local project coordinators at each of the test centres: Sigurd Beldo at the University College of Finnmark; Thomas Dillern and Freddy Pedersen at the University of Nordland; Nils Petter Aspvik at the Norwegian University of Science and Technology; Ane Solbraa, Einar Ylvisåker and Geir Kåre Resaland at Sogn og Fjordane University College; Sindre Dyrstad at University of Stavanger; Hilde Lohne-Seiler and Ingirid Heald Stangeland at the University of Agder; Eva Støa at the University College of Telemark; Catherine Lorentzen at Vestfold University College, and Jon Egil Jakobsen at Hedmark University College. Throughout the data collection we were also a solid crew working out of the Department of Sports Medicine at the Norwegian School of Sport Sciences. Dear master students of the project: Johanne Støren Stokke, Ingeborg Barth-Vedøy, Karoline Steinbekken, Anita Stokkeland Øen and Silje Fimreite. You were dedicated and brilliant, and a delight to work with! Our ¨call-centre¨, Bjarte, Tove, Heidi, Emilie, Inger, Vibeke, and Lise, performed the tedious task of making reminder calls with enthusiasm and dedication.

Maria Hildebrand and Ingvild Børtnes: Thank you for your hard work during the data collection for the validation project and for co-authoring **Paper IV**.

To all the people working at the Department of Sport Sciences: Thank you for your continuous and invaluable support during my PhD-years. Thank you for pushing me to always wanting to perform at annual seminars and international meetings and conferences, a truly invaluable experience which makes all future endeavors a little less daunting. But more importantly: thank you for all the lunches, coffee-breaks, training sessions, summer-parties, Christmas-parties, and so much more. Immeasurable stuff like that is such an important part of why working at our department is such a pleasure. It makes the ups better and the downs easier to cope with.

Solveig Sunde: Thank you for being a kind and caring person, and for looking out for me during my PhD-period.

To all the past and present PhD-students at our department: You are an amazing group of people and I have greatly enjoyed working with you all. We will hopefully interact in one way or another for many years to come. Jostein Steene-Johannessen: Your continuous support and consideration during my years at the department has meant a lot to me. Tron Krosshaug: Thank you for being

the kind and including person that you are. Geir Kåre Resaland, Eivind Andersen, Torbjørn Solligaard, and John Bjørneboe: Your friendships are greatly appreciated. To all the daily inhabitants of SIM3: May Grydeland, Johanne Støren Stokke, Elisabeth Edvardsen, Tone Bere, Agnethe Nilstad, Hilde Moseby Berge, Marianne Martinsen, Kjersti Karoline Danielsen, Hilde Moseby Berge, Julie Stang, Maria Hildebrand, Eirik Kristianslund, Kam Ming Mok, and Oliver Faul. Working close to you over the last years (some longer than others) has been a true delight. Thank you for making the daily life at the office so enjoyable!

I am fortunate to have wonderful friends and family. To my mother-in-law Lise: Your help towards the end of this process was invaluable. Mom: Thank you for your continuous support, care, and for always believing in me. Dad: Although you are no longer with us, I know you would have been proud to see the culmination of this process.

Dear Synne, my loving wife and mother of our lovely girls, Anna and Mathea: I could not have done this without you. I am forever grateful for your support and care throughout this process. I love you and dedicate my thesis to you.

List of papers

This dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals:

I. Hansen BH, Kolle E, Dyrstad SM, Holme I, Anderssen SA. Accelerometer-determined physical activity levels in adults and older people. Med Sci Sports Exerc. 2012 Feb; 44(2): 266-72.

II. Hansen BH, Holme I, Anderssen SA, Kolle E. Patterns of objectively measured physical activity in normal weight, overweight, and obese individuals (20-85 Years): A cross-sectional study. PLoS ONE 2013 Jan; 8(1). e53044. doi: 10.1371/journal.pone.0053044.

III. Hansen BH, Ommundsen Y, Kolle E, Holme I, Anderssen SA. Correlates of objectively measured physical activity: A cross-sectional study of adults and older people (20-85 years) living in Norway (on request, revised and resubmitted to the International Journal of Public Health)

IV. Hansen BH, Børtnes I, Hildebrand M, Holme, I, Kolle E, Anderssen SA. Validity of the ActiGraph GT1M during walking and cycling (Under review)

Abbreviations

ACSM:	American College of Sports Medicine
BMI:	Body mass index
BMR:	Basal metabolic rate
CPM:	Counts per minute
CHD	Coronary heart disease
CVD:	Cardiovascular disease
CI:	Confidence intervals
DLW:	Doubly-labelled water
HR:	Heart rate
HUNT:	The Nord-Trøndelag health study
METs:	Metabolic equivalents
LPA	Light physical activity
MPA	Moderate physical activity
VPA	Vigorous physical activity
MVPA:	Moderate-to-vigorous physical activity
NHANES:	The National Health and Nutrition Examination Survey
OR:	Odds ratio
PA:	Physical activity
WHO:	World Health Organization

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Introduction

The knowledge about physical activity and its associations with health outcomes has increased considerably during the past decades. Evidence from epidemiological research and clinical interventions clearly states that physical activity is essential to improve health as well as quality of life. Regular physical activity is associated with decreased all-cause mortality (1-3) and is beneficial in the prevention and treatment of several non-communicable diseases (NCDs) such as cardiovascular disease (CVD) (4-8), diabetes type 2 (9-14), some types of cancers (15-18), asthma (19-21), and mental illnesses (22;23). The health gains of increasing physical activity are age-independent and those who benefit the most from increased physical activity are individuals with low levels of activity (24). The recommended amount of daily physical activity needed to yield significant health benefits for inactive individuals is 30 minutes of at least moderate intensity activity, which are achievable by most individuals (24;25).

Despite the well-documented health gains of performing regular physical activity, there is a paucity of data allowing us to assess population level of physical activity in Norway. The available data on large-scale assessments of physical activity have relied on self-reported measures, a method that has validity and reliability problems (26).

The paucity of data is problematic for several reasons. The importance of tracking trends in physical activity within populations is well recognized (27). Furthermore, self-reported measures of physical activity hampers the estimation of dose-response effects between physical activity and various health outcomes, (28), and limits the researchers' ability to identify factors that might be associated with the adoption and maintenance of behaviour. Lastly, as increasing the level of physical activity in the population is an important part of the public health agenda; the lack of large-scale assessments of population levels of physical activity hampers the ability to evaluate such interventions and initiatives.

Objective measurements of physical activity have the potential to produce better estimates of population levels of physical activity. They provide valid and reliable estimates of physical activity, and are feasible for use in large-scale assessments of physical activity (29). The focus of this thesis is to explore the patterns of physical activity in adults and older people and to investigate factors associated with physical activity, using objectively measured physical activity.

This introduction initially provides a short operationalization of the terms "physical activity" and related concepts, followed by a description of the most commonly used methods for assessing physical activity. Subsequently, the current Scandinavian recommendations for physical activity are described, followed by a description of what we already know regarding the levels of physical activity in Norway. Furthermore, the increased prevalence of overweight and obesity, the related adverse health effects and the association between physical activity and body mass index (BMI) are addressed. Finally, existing literature on known correlates on physical activity are presented.

Physical activity – definitions and basic principles

Physical activity and cardiorespiratory fitness

Physical activity is a complex multi-dimensional form of human behaviour that includes all bodily movement from fidgeting to participating in very vigorous exercise (30) and is commonly defined as any bodily movement produced by skeletal muscles that requires energy expenditure (31). It is an integral and complex part of human behaviour that occurs in a variety of modes and domains, with modes referring to the different specific activities in which individuals engage in (e.g. walking, running, carrying loads, or bicycling) and domains referring to the context or reason for the physical activity (e.g. transportation, household, or exercise) (30). Physical activity varies along four dimensions: frequency (number of bouts of activity), intensity (how strenuous the activity is), duration (time spent on a single bout of activity), and mode (the type of activity carried out). The total amount of physical activity that an individual engage in, is a function of frequency, intensity, and duration of the activity.

Cardiorespiratory fitness refers to the ability of the circulatory and respiratory systems to supply and utilize oxygen during sustained physical activity (32), and is a set of attributes rather that a behaviour (31). Cardiorespiratory fitness, defined as maximal oxygen uptake (VO_2max), is generally considered to be the best marker for functional capacity of the cardiorespiratory system. Because larger persons normally have larger absolute VO_2 by virtue of larger muscle mass, the term is often expressed relative to body weight (millilitres of oxygen consumed per kilogram of body weight per minute; $ml \cdot kg^{-1} \cdot min^{-1}$). The level of fitness is highly dependent of the modifiable factor of physical activity (33) and non-modifiable factors such as sex, age, and genetics (33-37). Although the genetic contribution to cardiorespiratory fitness is important, it most likely account for less of the variation in fitness than physical activity level does (37).

Leisure-time, occupational, and habitual physical activity

The two principal categories of physical activity are leisure-time physical activity and occupational physical activity. Leisure-time physical activity is a broad term that describes activities performed during free time, based on the individual`s interests and needs. Such activities include all forms of aerobic activities (informal activities such as walking, hiking, jogging, gardening, bicycling, and dancing etc.), as well as structured endurance and strength training programs, and sports. Occupational physical activity is physical activity that is associated with the amount of movement performed while at work (38). Habitual physical activity is a term often used to describe both leisure-time and occupational physical activity and is commonly defined as the level and pattern of energy expenditure during the usual activities of life, including both leisure and work.

Sedentary behaviour

In addition to physical activity, there is now considerable interest in the health effects of the behaviour one employs when not being physically active, commonly defined as sedentary behaviour (39). Sedentary behaviour is typically defined as a range of human endeavors that result in an energy expenditure of no more than 1.5 times resting energy expenditure and a sitting or reclining posture (40-42). Common sedentary behaviours include TV-viewing, video game playing, computer use (often referred to as “screen time”), passive transportation (driving automobiles, public transportation), and reading. In this context, an individual may be described as sedentary if he or she engages in large amounts of sedentary behavior. On the other hand, it is common for researchers to describe an individual as physically inactive when not meeting physical activity recommendations (39). As a result of these conflicting definitions, Tremblay et al (39) suggest that sedentary behaviour is defined as “any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining position", and that physical inactivity is used to describe those who not are not meeting physical activity recommendations.

Energy expenditure

Measurements of activity are often expressed in terms of energy expenditure (43), a concept that is the function of basal metabolic rate (BMR), thermic effect of food, and activity thermogenesis (the energy expenditure of physical activity). BMR is the energy expended when an individual is lying at complete rest, in the morning after rest in post-absorptive state, and is under most circumstances accountable for the largest proportion of total energy expenditure. Thermic effect of food is the increase in energy expenditure associated with digestion, absorption, and storage of food, and accounts for 10% of total energy expenditure. Activity thermogenesis displays the largest inter-individual differences and varies from five percent in a sedentary individual to 45–50% in an individual with a high level of physical activity (44).

METs (metabolic equivalents) are commonly used to express energy expenditure, and represents energy expenditure in relation to body weight (43). One MET is equivalent of resting energy expenditure, and is considered equal to an oxygen uptake of 3.5 $ml \cdot kg \cdot min^{-1}$ in adults (45). Other ways of expressing physical activity are: amount of work performed (watts), time period of activity (hours, minutes) or as units of movements (counts or steps) (43).

Assessment of physical activity

Accurate, valid and reliable assessments of habitual physical activity are important for several reasons: document the frequency and distribution of physical activity in population groups; monitor time trends in physical activity; gain insight into the interactions between habitual physical activity and health; identify correlates of physical activity that might be targets for interventions or health programs aimed at increasing physical activity; and to evaluate the efficacy and effectiveness of interventions or health programs aimed at increasing physical activity (27;46;47).

A wide range of methods for assessment of physical activity are available and the method of choice is a function of several parameters. Factors such as the extent of participant interference and participant effort of a particular method, whether the method provides information on activity context and activity structure, the objectivity of the data, as well as the time and cost involved for the researcher, should be evaluated. The methods are commonly divided into subjective and objective methods, based on whether the method is relying on an individual`s ability to recall physical activity (subjective) or if the method objectively records physical activity performed by the individual by the use of instruments or monitors (objective). Table 1 is adapted from Westerterp et al (46) and provides an overview of the most commonly used methods for assessing physical activity. The table provides a summary of the comparative description of the separate methods in a context of assessment of habitual physical activity (rank 1: highest score; rank 5: lowest score). Overall, objective methods are preferred over subjective methods, and motion sensors emerge as the preferred method, scoring high on most parameters, with the exception of contextual information. Although motion sensors are not perfect markers of physical activity, they certainly eliminate subjectivity of obtaining physical activity information.

Table 1. Ranking of methods for the assessment of physical activity on six different parameters, where 1 denotes the highest and 5 the lowest rank (46).

	Participant interference	**Participant effort**	**Contextual information**	**Activity structure**	**Objective data**	**Observer time/cost**
Self-reports, diaries, interviews	4	5	2	4	5	2
Behavioural observation	5	1	1	2	4	5
Doubly labelled water	1	2	5	5	1	4
Heart rate monitoring	3	4	4	3	3	3
Motion sensors	2	3	3	1	2	1

In the following, the most commonly used techniques for assessing physical activity will be briefly presented. There is an emphasis on motion sensors, particularly accelerometers, as it is the primary method of assessment used in this thesis. Lastly, new and promising techniques are briefly presented.

Self-reports, diaries and interviews

Questionnaires, including diaries, and interviews are the most common tool for the assessment of physical activity. The advantages and problems of self-report have been extensively reviewed (26;48-51). The method has low costs, is relatively easy to administer, poses a small burden on the participant and is feasible for use in large populations. Self-report relies entirely on the participants´ ability to provide the researcher with accurate information on his or her level of physical activity, thereby introducing several potential sources of errors. Individuals who knowingly do not participate in recommended amounts of regular physical activity are prone to over report their level of physical activity (social desirability bias). Further, to recall physical activity is a highly complex cognitive task, which may limit the validity of information provided by some individuals (recall bias). Lastly, one should be aware that leisure activities with high intensity (e.g. soccer, jogging, or aerobics) are associated with a well-known terminology, whereas the terminology associated with activities of light or moderate intensity vary more (domestic activities and office work), which consequently may lead to imprecise estimates of such activities (26;48-51).

Behavioural observation

Direct behavioural observation was one of the first methods used to assess physical activity, involving an observer that records observations while watching an individual. Although considered the gold standard for physical activity assessment, the method has not been validated due to lack of criterion methods. However, face validity appears to be good (43), and direct observation is often used as the criterion method in validation studies of other assessment methods (30). Strengths of the methods are that it provides quantitative and qualitative information on physical activity behaviour and contextually rich data that helps researchers to understand how physical activity is influenced by surrounding physical and social factors. The method is limited by its time-consuming nature, large participant intrusiveness, and risk of reactivity, as observing someone`s behaviour might be behaviour-altering (30).

Doubly-labelled water

The doubly-labelled water method (DLW) is considered the gold standard for assessing energy expenditure in free-living settings (52). Enriched H_2 and ^{18}O atoms are ingested by the participant and energy expenditure is calculated by estimating carbon dioxide production using isotope dilution. The DLW method measures energy expenditure over longer periods (1-3 weeks) and provides a good estimate of total energy expenditure, with an accuracy of 4-7% (53). However, the high cost of the stable isotopes and the sophisticated analysis technique limits the usefulness of the DLW method in epidemiological studies (52). The method does not provide the researcher with any information of the day-to-day variation of physical activity, nor the patterns of activity throughout the day, and it requires that the participant carefully registers energy intake.

Heart rate monitoring

Heart rate monitoring is based on the assumption of a linear relationship between heart rate and oxygen consumption in activities of moderate to vigorous intensity (54). Energy expenditure is estimated using individually calibrated heart-rate energy-expenditure equations, and the method shows reasonable agreement with energy expenditure measured by DLW (55). The method is socially acceptable and can be applied for periods long enough to provide representative estimates of energy expenditure. However, heart rate is affected by several factors other than physical activity (such as age, physical fitness, emotional state, and food intake), and the relationship between heart rate and energy expenditure is not robust while at rest or performing activities at lower intensities (55).

Motions sensors

When a person moves, the limbs and body are accelerated. Theoretically this happens in proportion to the muscular forces responsible for the accelerations and thus to energy expenditure (56). Since almost all forms of physical activity involve movement of the trunk or limbs, the direct measurement of movement is attractive. The most common motion sensors are pedometers and activity monitors that contain accelerometers. Such devices provide objective measures of motion that can be used in their raw form or transformed into estimates of physical activity intensity or energy expenditure.

Pedometers

Mechanical pedometers count the number of times a certain acceleration threshold is exceeded and sums this to produce an overall estimate of total steps taken. Piezoelectric pedometers count the number of zero crossings in the accelerometer waveform to determine steps taken. Numerous studies have established the validity and reliability of pedometers under controlled laboratory conditions and free-living settings (57-62), have established that the devices provide a low-cost estimate of the total volume of physical activity. Pedometers are however limited by their inability to quantify intensity, duration or frequency of activity bouts. Several studies have suggested that pedometers might underestimate physical activity at slower speeds, due to the actual vertical acceleration being below the devices sensitivity thresholds (58;63).

Accelerometers

The principle of accelerometry is that the devices measure the accelerations and decelerations of human movement. Acceleration is the change in velocity over time, expressed in multiples of gravitational force ($g=9.8\ m/s^2$) (64). In physical activity research, the raw accelerations are converted to a numeric count-value by the summation of the absolute values of the sampled change in acceleration over a given time frame (counts per minute) (65;66). The accelerations recorded while moving are proportional to muscular forces used while moving and these counts can be translated into energy expenditure (67), making the devices capable of quantifying the intensity of movement which can be used to estimate physical activity over time (66). The devices also time-stamp the recorded movement thereby making explorations of activity patterns possible. Limitations include an underestimation of the energy cost of several activities due to their limited ability to detect arm movement (e.g. upper body strength training), external work (carrying heavy loads), or activity with little or no of the hip (e.g. cycling) (46;57). Further, studies have also indicated that tilt-angle might have a negative effect on the devices, causing them to significantly underestimate physical activity in overweight and obese individuals. This have, however, only been found in spring-levered devices, while piezoelectric monitors does not seem to be affected by abdominal adiposity or tilt angle (58;59;68;69). In general, accelerometers have been shown to provide an accurate assessment of physical activity, but less accurate prediction of energy expenditure, especially in a free-living environment (70).

There are many commercially available brands of activity monitors that contain accelerometers, and commonly used monitors are the AM 7164 and the GT1M manufactured by ActiGraph (Pensacola, Florida, USA) and the Actical, manufactured by Philips Respironics (Bend, Oregon, USA). In the following, literature regarding the ActiGraph activity monitors will be presented. The ActiGraphs are the most widely validated and applied activity monitors in epidemiological research and is the brand used in the studies that this thesis is built upon.

ActiGraph activity monitor

The Actigraph activity monitors are the most commonly used brand of activity monitors and have been used in population-based studies to assess physical activity (29;71-73). The first version of the ActiGraph accelerometer-based activity monitor, formerly marketed as Computer Science and Application (CSA) and Manufacture Technology Incorporated (MTI), was designed in 1993. During past decades, the Actigraph monitors have been developed. The AM 7164 was replaced by the GT1M in the mid 2000s, and this replacement represents a significant change in technology, going from the piezoelectric accelerometers in the AM 7164 to the capacitive micro electro-mechanical system (MEMS) based accelerometers embedded in the GT1M. Although ActiGraph states that the AM 7164 and the GT1M provide comparable output, observations indicate that inter-generation differences exist, both for overall physical activity (counts per minute; CPM) (74-76), and at certain intensities (74;76;77). More recently, ActiGraph have released further updated versions of the ActiGraph, namely the GT3X and the GT3X+, but these updates represents minor changes and does not appear to yield significantly different output compared to the GT1M (78;79).

The ActiGraphs are extensively tested for reliability and validity, and only a selection of the relevant literature will be presented in the following. Generally, the ActiGraphs displays a high degree of intra- and intermonitor reliability, both in mechanical and free-living settings (80;81), and they provide valid estimates of habitual physical activity, compared to estimates of energy expenditure obtained using the DLW-method.(52;82;83). The first validation studies appeared shortly after the monitors became commercially available. Janz et al (84) reported relatively good correlations between the ActiGraph counts and heart rate in children during activity (r=0.50-0.74). Melanson and Freedson (85) examined the validity of the ActiGraph in adults while walking and running on a treadmill. The results showed that the device was able to detect changes in speed, and they reported a significant correlation (r=0.81) between ActiGraph counts and measured energy expenditure. Although following validation studies generally showed that the accelerometers were highly correlated with energy expenditure during ambulatory activity (0.77-0.86), studies also showed that when lifestyle activities were included, correlations decreased (r=0.55-0.59) and energy expenditure were consequently underestimated (57;86;87). There is a general consensus that such underestimation of energy expenditure is due to the devices` inability to measure upper body movement, ambulatory movements including little or no accelerations of the hip, changes in terrain and/or loading activities properly (57;86;87).

The most common method for validations and calibration studies has been to compare activity counts and measured oxygen consumption during specific activities selected to mimic key elements of daily living, typically walking and running (88;89). Freedson et al (88) developed one of the first regression equations to estimate energy expenditure from activity counts from the ActiGraph model 7164. The authors derived specified activity count cut-points corresponding to different intensity levels (i.e. light, moderate, hard, and very hard). More recently, studies have included both dynamic and static activities that are more generalizable to the full range of activities encountered in daily life (57;86;90;91). The use of such a wide range of activities and intensities has produced variation in the published equations and cut-points. In effect, data obtained using a relatively robust technology have been splintered by the calibration process into a wide range of summary measures that are much less comparable than they could be, and this inconsistency hampers our ability to interpret data obtained from accelerometers across the lifespan, across populations and across brands and generations of accelerometers (92). Both Crouter et al (93) and Rothney et al (94) have compared published regression equations and they both conclude that one equation is unable to estimate energy expenditure for all activities accurately and equations developed to measure energy expenditure during walking are not accurate for most other activities.

Most of the validation and calibration studies of the ActiGraph activity monitors have been performed using the AM 7164 (52;81;85;88;95-97). The observed inter-generation differences in accelerometer output might therefore be problematic. Although the AM 7164 appears to be valid for estimating energy expenditure during a range of walking and running speeds (52;81;85;88;95;96), this is not equally established for the GT1M. Furthermore, the AM 7164 was not able to discriminate between level and graded walking (uphill and downhill) (85;97;98). As graded walking yields different energy expenditure compared with level walking, this represents a potential source of over- or underestimation of energy expenditure. To our knowledge, the validity of the ActiGraph GT1M regarding the ability to discriminate between level and graded walking has not yet been established thoroughly.

Additionally, as the GT1M measures vertical acceleration and is most often attached to the hip or lower back in epidemiological studies (29;71;99;100), activities with little or no vertical acceleration are poorly registered by the monitor. Bicycling is one of those activities where a hip-mounted uniaxial accelerometer is expected to record little movement. This might be a concern when used in populations where bicycling is common. Prevalence of daily commuting by bike is for example about 20% in Denmark (101), and it is estimated that a bike is used for ≈5% of daily trips (commuting to work/school, errands, and trips for leisure) made by Norwegians (102). Although most studies that use uniaxial accelerometry acknowledge the monitors inability or reduced ability to capture cycling adequately, few have attempted to estimate the actual size of the underestimation of energy expenditure that occurs during cycling (30).

Increased use of bicycles for active commuting and recreational purposes can theoretically meet a population's need for health-enhancing physical activity, thus providing a potential solution to physical inactivity (103). However, the shortcomings of uniaxial accelerometry might prevent such an increase to be recognized. As the use objective assessments of physical activity at population levels are increasing, an estimate of how much error cycling introduce to the assessment of overall physical activity would be of interest to the research community as well as health policy makers.

Emerging techniques

Recently, several devices that combine heart rate, global positioning systems (GPS) and/or accelerometers have been developed. An example of such a device is the ActiHeart, where the best features of heart rate monitoring and accelerometers are combined by using heart rate in the high intensity ranges and the counts from the accelerometer in the low intensity ranges. The ActiHeart is technically reliable, valid, and the device yields promising for estimating energy expenditure during walking and running (104). However; the device lacks validation in free-living settings, requires independent calibration of heart rate by each user, and is relatively expensive, limiting the feasibility of this device for use in large scale studies. Evidence regarding the potentially better predictive properties of other characteristics of raw acceleration is also emerging. The accuracy of currently available equations for estimating energy expenditure varies greatly between participants with different characteristics (e.g. age, height, and body mass). This is at least partly due to the fact that identical accelerations may not result in the same metabolic costs for different individuals, although the activity count values may be the same (105). By increasing the number of acceleration samples per minute, more analytically sophisticated approaches relying on automated pattern recognition and machine learning, have been applied to several aspects of physical activity monitoring. Examples of such work is the identification of different types of physical activity by Poder et al (106), and the use of neural network to estimate energy expenditure by Rothney et al (105). Promising results of this emerging field yields high probabilities of correct identifications of types of activity (106), and reduced estimation errors from minute-by-minute energy expenditure (105). However, computational complexity and the need for a large number of labelled examples of a diverse set of activities limits the current feasibility of the method.

Recommendations for physical activity

Recommendations for physical activity are intended to identify the minimum level of physical activity required for maintaining good health. Such recommendations were first issued in the US by the American College of Sports Medicine in 1978 (107). These recommendations were based on the evidence that vigorous activity sufficient to improve cardiorespiratory fitness had a major impact on numerous health outcomes (32), hence they promoted vigorous activity. However, of the studies showing health gains as a result of physical activity, very few have demonstrated that such intensity was indeed required (108). Although high intensity might be necessary to achieve maximum health benefits, the evidence indicated that high intensity was not necessary to significantly lessen the risk of several non-communicable diseases, including coronary heart disease (CHD) and diabetes type 2. Epidemiological studies with at least three levels of exposure consistently point to a reduction in risk between the least active group and the next active (109), indicating that no minimum amount of daily physical activity appears to exist. Paffenbarger et al (2) showed that individuals who expended an extra 500-1,000 kcal per week had a 22% lower mortality compared with physically inactive individuals. Leon et al (7) showed that 30 minutes of daily leisure-time activity (corresponding to an energy expenditure of approximately 150 kcal) was associated with 63% as many fatal CHD events and sudden deaths, and 70% as many total deaths as those with less activity. In a review of six longitudinal studies on Finnish men, the attributable risk (the avoidable proportion of deaths caused by cardiovascular disease (CVD)) associated with low levels of leisure-time physical activity was 22-39%, compared with 10-33%, 9-21%, 6-15%, 3-6%, for smoking, high total cholesterol, hypertension, and overweight, respectively (110). As with CVD, a dose-response relationship between physical activity and risk of developing diabetes type 2 appears to be present. Furthermore, prospective studies have shown that regular physical activity is associated with an about linear decrease in the age-adjusted risk of developing diabetes type 2 (9;12), exemplified by a 6% decrease per 500 kcal expended by leisure-time PA shown by Helmrich et al (9).

The abovementioned studies are some examples of the evidence that forms the evidence base for physical activity recommendations. It appears that a target dose that will yield health gains for individuals with low levels of physical activity is moderate intensity activity of approximately 150 kcal per day or just above 1000 kcal per week. Furthermore, an equal health impact can be expected with higher intensities, and thus shorter duration. All energy expenditure beyond this target dose will yield further health gains.

Since the first recommendations issued in 1978, several revisions and specifications have been made. Most importantly is probably the distinctions made between physical activity and its relation to health versus fitness in the more recent versions of the recommendations (111). In 2004, the Scandinavian physical activity recommendations were presented by the National Counsil on Nutrition and Physical Activity (24). They stated that *"for all inactive adults, daily physical activity of moderate and/or vigorous intensity corresponding to an energy expenditure of about 150 kcal yields substantial health benefits. This energy expenditure is equivalent of brisk walking for about 30 minutes, and the activity can probably be divided into shorter intervals of physical activity during the course of the day, for instance intervals lasting 10 minutes"*. The Council further stated that an increase in activity beyond this duration and intensity will yield additional benefits, and more physical activity (about 60 minutes daily) with a moderate and/or vigorous intensity corresponding to an energy expenditure of 300 kcal might be needed for prevention of weight gain.

The current recommendations do not differ between adults and older people as the health gains of increasing physical activity for inactive individuals are independent of age (32). However, for older people, additional benefits of physical activity include improved strength and functional ability and reduced mortality (112-114). The recommendations should not be viewed as an absolute cut-off value for good or bad health, as the dose-response relationship between physical activity and health outcomes is continuous. With the possible exception of a few very active people, the available evidence indicates that everyone would benefit from just a little more activity, and those who perform very little physical activity may achieve the greatest health gain (24).

Although the recommendations are based on data from high quality studies including randomized controlled trials and large cohort studies (24), one should note that the physical activity information that the recommendations are based on, is self-reported. There is a lack of studies that link objectively assessed activity to various health outcomes (115). Therefore, care should be taken when assessing adherence to the recommendations based on objectively assessed physical activity. The dose-response relationship between objectively assessed physical activity and health outcome may differ from the relationship between self-reported activity and health.

Lately, there has been a growing interest in the adverse health effects potentially connected to sedentary behaviour and it is discussed whether the recommendations should include reducing time spent being sedentary (40;116;117). Emerging evidence suggests that sedentary behaviour, as distinct from a lack of moderate and/or vigorous physical activity, has independent and qualitatively different effects on human metabolism, physical function, and health outcomes and thus should be treated as a separate and unique concept (40;118-122). To exemplify, an individual can meet or exceed recommendations, yet still spend a considerable amount of time pursuing sedentary behaviour. Conversely, those who do not meet recommendations can accumulate large amounts of light intensity activities (such as household and childcare activities) and thereby have low volumes of sedentary behaviour. Thus, spending less time in moderate-to-vigorous physical activity would not lead to more time classified as sedentary, or the other way around. Consequently, sedentary behaviour and moderate-to-vigorous physical activity can be independent of each other and coexist (123). This is supported by studies showing weak correlations between the two behaviours (40;124;125). However, future conclusions about the independent effects of sedentary behaviour should be supported by data from studies in which all levels of physical activity are differentiated clearly and assessed independently (126).

Population levels of physical activity

Although the health benefits of regular physical activity have been known since the mid 1950s, comparisons of patterns of participation in physical activity between countries and regions were unachievable until a decade ago (127). This was largely due to the absence of standardized instruments suitable for international use, and early efforts to characterize patterns of activity relied primarily on measures of occupational classification or only estimates of leisure-time physical activity (2;8;128). During the 1990s, the standard instrument The International Physical

Activity Questionnaire (IPAQ) was developed to assess physical activity worldwide. After showing acceptable reliability (correlation generally around 0.8) and criterion validity (correlations generally around 0.3) in a large multi-national validation study (129), the IPAQ has been used in numerous national and regional prevalence studies.

An example of the use of the IPAQ is the comparative international study of physical activity from 20 countries presented by Bauman et al (130). The authors classified the level of physical activity as low, moderate, or high. The prevalence of high varied from 21-63%. In eight countries, over half of the adult population was categorized with high physical activity. In 17 of 20 countries, men reported high physical activity more frequently than women. The prevalence of low physical activity varied from 9-43%. The ways in which activity was accumulated differed across populations, some reported mostly vigorous activity and others mostly walking. The results from the Norwegian part of this study are presented in detail by Anderssen et al (131). The main findings were that 56% of men and 38% of women accumulated more than or equal to 3.5 hours per week of physical activity of at least moderate intensity (defined as meeting physical activity recommendations). Men spent significantly more time pursuing vigorous activity (4.42 vs. 1.69 hours per week) and moderate activity (5.30 vs. 3.74 hours per week), compared with women, who on the other hand appeared to spend more time walking (8.59 vs. 6.71 hours per week). No differences were observed in time spent sitting (45-48 hours per week) and increasing age was associated with a decrease in physical activity, but only for men.

In addition to Anderssen et al (131), several studies have assessed physical activity among Norwegian adults and older people. Søgaard et al (132) reviewed available information on physical activity during leisure-time, and cautiously summarized that 30-60% of all adults were active for at least 2 hours per week. Furthermore, the prevalence of individuals that were moderately active during leisure-time had increased somewhat from 1985 to 2000. National time-use surveys conducted by Statistics Norway have regularly assessed leisure-time physical activity and data are available for the period 1997-2007. These data also indicate that leisure-time physical activity is increasing in the general population. According to the most recent data for the age group 16-79 years, 42% reports to be exercising at least 3-4 times per week and 24% reports to exercise less that 1-2 times per month (133).

As the short and incomplete review of available information on population levels of physical activity given above shows, trying to synthesise the information is a complicated task. However, although the empirical basis is weak, it is the general impression that habitual physical activity have gradually decreased over time. Rapid urbanization, the mechanization of our environment and the increased use of automobiles, as well as other inventions have altered the lives of millions of people (134). The shift away from occupations that require physical activity to occupations comprising of mostly sitting and sedentary behaviour is evident (135), and have resulted in a steady decline in occupational physical activity (136-138). Although it also seems to exist some agreement that leisure-time physical activity have increased somewhat over the last three decades, this increase have probably not been enough to offset the large decline in occupational physical activity (137;139;140).

The lack of accurate and reliable assessment of physical activity remains an important challenge for public health. The available data does not provide sufficient information on important issues such as population level of physical activity, changes in activity behaviour over the life course, the domains in which activity change, the sociodemographic characteristics of those whose levels of physical activity is most likely to decline, and what other factors are associated with low levels of activity (141).

This scarcity of knowledge is at least partly due to the fact that obtaining accurate population-level assessments of physical activity is a complicated task (28). The available data on levels on physical activity is almost exclusively based on self-reports that by nature are susceptible to many forms of bias (26;141). Although they are useful for many aspects of physical activity epidemiology, such as registering the different modes and domains of physical activity, they have substantial limitations for accurately quantifying overall and intensity-specific physical activity. They risk over- or underestimating true physical activity levels and amount of sedentary behaviour as they are based on the individuals` ability to perform the complex cognitive task of recalling a complex and multi-dimensional behaviour, and oftentimes shows contradictory evidence compared with objectively assessed physical activity (141-143). Furthermore, the perception of the meaning of physical activity might vary between countries, sexes, and age groups, as well as over time. This hampers comparisons between studies and precludes meta-analysis being made (144).

The uses of objective methods to assess physical activity eliminate many of the limitations of self-report and are increasing in popularity (143). Although the method is widely used in small-scale research, the availability of large-scale population-based studies that have assessed physical activity objectively, are relatively scarce. There are few studies that have assessed population levels of physical activity in adults using objective methods, with the potential to compare physical activity levels across sex, age groups and body mass index categories. The existing ones are presented in Table 2.

Hagstrømer et al (71) presents large-scale data on objectively assessed physical activity in Swedish adults and older people. A total of 1,114 randomly recruited participants were included and activity was assessed using the ActiGraph AM 7164. There were no apparent differences in overall physical activity between the sexes, although men engaged in more moderate-to-vigorous physical activity compared with women. Adherence to physical activity recommendations was low, although highly dependent in how the recommendations are operationalized (discussed on page 58-59). Contrary to the Swedish study, Troiano et al (29) showed that among US adults and older people, men had higher levels of overall physical activity and moderate-to-vigorous physical activity compared with women. Overall physical activity declined relatively linear with increasing age, and adherence to recommendations of physical activity was less than 5%. A Chinese study showed similar results as the NHANES regarding the age-related decline in overall physical activity, but no apparent differences between the sexes was observed (145). More recently, two large-scale assessments of physical activity in adults have been conducted, which are not referenced in **Paper I**. Baptista et al (146) showed that the Portuguese showed relatively stable levels of overall physical activity through adulthood, with a slight decline in activity after reaching 50 years, and a marked decline after reaching 65 years. Men had a somewhat higher overall physical activity compared with women, and adherence to physical activity recommendations was 3-9%. Colley et al (139) presented Canadians data and showed that 15% of the sample met the physical activity recommendations, and that men had higher levels of overall physical activity and steps per day compared with women. Of the registered wear time, 69% was classified as sedentary behaviour. Care must be taken when comparing the Canadian study with the rest of the studies. Although activity was assessed objectively, the activity monitor used in the study, the Actical (Philips Respironics, Oregon, USA), differ markedly from the ActiGraphs used in the other studies. The Actical is omnidirectional and waterproof, thereby capturing accelerations in several axes, and brand-specific cut-points for labelling of intensity-specific activity were used.

Table 2. Overview of large scale studies using objective measures of physical activity in adults and older people. PA variables are presented for men (M) and women (W).

Study	Participant characteristics	Response (%)	Device, Epoch length	Inclusion criteria[e]	Counts per minute[f]	Sedentary behaviour (minutes) [g]	MVPA, *MVPA_bout*[h]
ABC study 2001-02 (Sweden)[ab]	N: 1,172 18-75 yrs 54% women 45% BMI ≥25	68%[c]	ActiGraph AM 6174 60 sec	Days: ≥4 Min/day: ≥600 Non-wear: ≥60	M: 409/368/321 W: 389/366/304	M: 497/505/505 W: 486/485/485	M: 41/35/29 W: 36/32/23 *M: 13/13/16* *W: 6/14/13*
NHANES study 2003-04[b] (USA)	N: 2,925 18-75 yrs 51% women 65.3 BMI ≥25	NR	ActiGraph AM 6174 60 sec	Days: ≥4 Min/day: ≥600 Non-wear: ≥60	M: 436/365/242 W: 329/294/231	M: 444/484/539 W: 462/483/501	M: 42/31/15 W: 23/18/10 *M: 10/8/6* *W: 7/6/5*
Shanghai Physical Activity Study 2005-08 (China)	N: 619 53.5 (9.4) yrs 51% women 48% BMI ≥25	56% [d]	ActiGraph AM 6174 60 sec	Days: ≥2 Min/day: ≥600 Non-wear: ≥60	M: 285 W: 291	M: 517 W: 499	M: 78 W: 81
Portugal Physical Activity Study (Portugal) 2006-08	N: 1,982 18-65+ 63% women	NR	ActiGraph GT1M 15 sec	Days: ≥3 Min/day: ≥600 Non-wear: ≥60	NR	M: 594/574/570/572/612 W: 579/546/529/536/596	M: 48/47/49/47/31 W: 41/42/46/44/23
Canadian Health Measures Study (Canada) 2007-09	N: 2,832 20-79 yrs 53% women	42%	Actical 60 sec	Days: ≥4 Min/day: ≥600 Non-wear: ≥60	NR	M: 571/570/594 W: 572/588/602	M: 33/26/17 W: 24/21/12 [I]

[a]Results from ABC and NHANES stems from a comparison article by Hagstrømer et al (142), and differ somewhat from what is reported in the original papers (71;142). This is due to differences in data reduction procedures
[b]2005–2006 accelerometer data were recently release and are similar to those from 2003–2004 (147;148)
[c]Of a representative sample of 3,300 individuals, an eligible sample of 2,262 where reached by telephone, and 1556 agreed to participate (68% of *eligible* sample) (71)
[d]The Shanghai PA Study includes a randomly selected subsample already included in the Shanghai Cohort Studies (145)
[e]Days: days of accelerometer-wear needed; Min/day: number of minutes of wear time needed per day; Non-wear: Threshold (minutes of consecutive zeros) for identification of non-wear time
[f]Physical activity variables are presented in age cohorts: ABC and NHANES: 18-39/40-59/60-75 years, Shanghai study: 40-49/50/59/≥60, Canadian study: 20-39/40-59/60-79, Portuguese study: 18-29/30-39/40-49/50-64/65+
[g]Sedentary activity: minutes of activity below threshold (<100)
[h]MVPA: moderate-to-vigorous physical activity; MVPA-bout: minutes in bouts of ≥10 consecutive minutes, above MVPA threshold
[I]Not stated if these values are accumulated in bouts or not
NR: Not reported

Physical activity and BMI

Epidemiologic studies commonly use BMI as an indicator of overweight and obesity. It is a measure of weight adjusted for height and does not measure body composition directly, but the underlying assumption is that at a given height, higher weight is associated with increased fatness (149). At least half of the adult populations in many developed countries are currently overweight or obese (BMI≥25). The WHO reported that, since 1980, the rates of obesity have increased threefold in Northern America, the United Kingdom, Central and Eastern Europe, Pacific Island, Australia, and China (47). American data indicate that as much as 70% of the population aged 20 years or older are either overweight or obese (150). The most common criteria's for defining weight status based on BMI are those recommended by the WHO (Table 3) (151).

Table 3. The WHOs definition and classification of weight status based on BMI

BMI	Weight category
< 18.4	Underweight
18.5 – 24.9	Normal weight
25.0 – 29.9	Overweight
30 - 34.9	Obesity Class I
35.0-39.9	Obesity Class II
≥ 40	Obesity Class III

Norwegian data draws a similar picture as have been seen in the rest of the world. Although there are no nationally representative surveys that have longitudinally tracked the weight of the Norwegian population, the Nord-Trøndelag health study (HUNT) provide novel and rich data on various health outcomes in a sub-national sample (152). The study has shown that the proportion of overweight and obese adults and older people have increase by 25% for men and 18% for women over the course of 22 years, with the most recent data showing that 75% of men and 61% of women have BMIs above 25 (153).

The prevalence of overweight and obesity is alarmingly high. It is well established that obese individuals, defined as having a BMI of 30.0 or more, have increased death rates from heart disease, stroke, and several different forms of cancers (154). Results regarding the potential risk of being overweight (having a BMI of 25.5-29.9) are somewhat ambiguous, with studies showing little or no effect on all-cause mortality (155;156), or small increases in risk of disease and premature death (155;157;158). However, a large meta-analysis by Berrington de Gonzales et al

(159) included 1.46 million white adults and showed that both overweight and obesity are associated with increases in all-cause mortality. The lowest all-cause mortality was seen in those with a BMI of 20.0-24.9 (159).

The worldwide increase in prevalence of overweight and obesity has occurred over the last three decades (151). Although much is known about the development of overweight and obesity at the individual level, the aetiology behind the increased prevalence of the condition at national and international levels are not fully understood. It is not likely that the human genotype has changed substantially during the coincident time period. Fat gain occurs when energy intake exceeds energy expenditure and dietary overconsumption is often suggested as the main driving force behind the obesity epidemic. However, several nutrition surveys indicate otherwise. In the U.S, parallel with the increase in overweight and obesity, both average fat intake adjusted for total calories and average total daily caloric intake decreased and the consummation of low-calorie products increased (139). Norwegian national surveys portraits a similar scenario. Over the past two decades the prevalence of overweight and obesity have increased by 18-22%, while concurrent trends in energy intake indicates a decline in total energy intake as well as fat intake (160). Although nutritional surveys have inherent weaknesses and they are prone to underreporting of energy-dense foods like fat and sugar (137), such diverging trends suggest a dramatic decrease in physical activity energy expenditure. This might provide a potential explanation for the current obesity epidemic (137;139;140). It is estimated that daily occupational-related energy expenditure has decreased by more than 100 calories over the last 50 years, which is sufficient to account for a significant proportion of the concurrent weight gain (135).

This estimate is supported by numerous studies, using both subjective and objective assessments of physical activity, showing weight-related differences in level of physical activity (137;161-163). However, although evidence shows that reduced energy expenditure is a probable cause for the reported increase in prevalence of overweight and obesity, the true magnitude of the association between physical activity and weight status might be attenuated by lack of precision in the assessment of activity and body composition (26;28;29;144;164). Questionnaires, which traditionally have been the means of assessing physical activity, are not able to adequately capture all types of activity. Especially, the method lacks the ability to capture the more dispersed incidental activity, which has been shown to have a potential impact on overweight and obesity (161). Objective assessment of physical activity has the potential to overcome many of the challenges related to self-reported physical activity because they are unobtrusive and capable of accurately assessing the overall levels and intensities of physical activity (46;165). Furthermore, objective assessments of physical activity have the potential to disclose weight-related differences in patterns of physical activity that might have been overlooked in earlier studies due to a lack of measurement precision. Such information has the potential to help inform interventions aimed at increasing levels of physical activity in certain population subgroups.

Correlates of physical activity

As the global burden of NCDs and overweight and obesity are increasing and habitual physical activity appears to be decreasing, understanding the causes of physical activity are essential in order to develop and improve public health interventions (166). Physical activity is a multi-dimensional and multi-determined behaviour that is not yet fully understood, as few efforts to increase physical activity at a population level show lasting effects (167).

Comprehensive reviews have shown that variables from different levels of influence are consistently associated (i.e. correlated) with physical activity (162;168;169). Some of the most consistent correlates of physical activity include genetics, demographic and socioeconomic factors, which by nature are more or less stable and non-modifiable. Family and twin studies have reported heritability coefficients of 0.3-0.6 for self-reported physical activity, which indicates that there is a moderate contribution of genetic factors to the explanation of physical activity (168). Furthermore, age is commonly reported to be inversely related to physical activity, and men usually engage in more physical activity compared with women (130;162;168;170). Research also show that increasing weight is associated with lower levels of physical activity (171) and physical activity is positively associated with increased socio-economic position, such as level of education or income (172-175).

Other correlates of physical activity are subject to modification (162;169). These include psychological, socio-environmental, physical-environmental and political factors and are often embedded in theories and models of health-behaviour change (176). The majority of theories have focused on the cognitive, affective, and social influences surrounding the individual and his/her choice to be active. Theories that have received some empirical support include the theory of reasoned action and planned behaviour (177;178), expectancy-value or decisional theories (179), relapse prevention models (180;181), the trans-theoretical model (182;183) and the self-determination theory (184;185).

Previous studies aimed to increase physical activity have largely focused on individual level factors and have been met with limited success, particularly with respect to maintaining changes in physical activity. Given the diversity and complexity of factors influencing physical activity, research aimed at identifying its correlates should be conceptualized within a social ecological framework, allowing integration of multiple levels (individual, social, environmental, and political) in order to provide the best possible understanding of physical activity behaviour (186;187).

The literature on physical activity is replete with findings of cross-sectional associations between a range of biological, psychological and social-environmental correlates and levels of physical activity (176). However, several factors limit the ability of subsequent research to build on previous findings (176). Such factors are diversities in research design, in which theories that was applied, which variables and populations that were included, and how physical activity was defined and measured (162;176). The latter has been proven especially problematic, as self-reported physical activity is prone to many limitations (26). It has been demonstrated that the complexity of measuring physical activity or even the failure to do so adequately, have been one of the conundrums that has inhibited our understanding of what motivates individuals to adopt and maintain an active lifestyle. This might also be a contributing factor to the limited success of interventions that aim to increase and maintain physical activity (188).

The literature on the correlates of objectively measured physical activity is scarce. Although studies that have used activity monitors have confirmed the earlier findings from self-report that non-modifiable factors such as age, gender, and level of education (142) and the physical environment are associated with physical activity, studies on the psychological and socio-environmental correlates of physical activity are absent. Such information is vital, as knowledge of factors that determine physical activity might be population-specific and the effect of such factors might change over time. These factors might be the ones to target in intervention efforts to increase physical activity. Of particular interest is whether the correlates of physical activity are different for different strata's of the population being studied. Studies agree to some extent that physical activity is associated with sex, weight status, and level of education and weight status. Therefore it is of particular interest to assess whether these variables moderate the effects of the correlates of objectively assessed overall physical activity. Such information is currently not available and might aid researchers and decision-makers to decide whether interventions aimed at increasing physical activity should be tailored accordingly or not.

Need of new information

There is paucity of data on population levels of physical activity. The available information is hampered by methodological limitations, precluding the tracking of trends in physical activity, the estimation of dose-response effects between physical activity and various health outcomes, and the identification of factors that might be associated with adopting and maintaining an active lifestyle. Thus, there is a need of a large-scale population-based study including a nationally representative sample of adults and older people in order to objectively assess their physical activity level. Furthermore, for valid and reliable estimates of physical activity to be obtained, it is crucial that the tools for assessments are as accurate and appropriate for the population to which it is applied, as possible.

The specific aims of the separate papers were as follows:

- To describe current levels of physical activity and sedentary behavior among Norwegian adults and older people, using an objective assessment method (**Paper I**)
- To explore the association between physical activity and body mass index, to assess potential differences in patterns of activity across BMI-categories and to determine the independent contribution of physical activity on the risk of being overweight or obese (**Paper II**)
- To assess the associations between biological, psychological, socio-environmental and physical-environmental correlates and physical activity, and to investigate whether the effects of the included correlates differ across sex, BMI-categories or level of education (**Paper III**)
- To examine the validity of the ActiGraph GT1M to assess physical activity while walking and cycling, and to assess the potential underestimation of physical activity during cycling (**Paper IV**)

Materials and methods (Papers I-III)

The thesis is based on two separate studies. **Papers I-III** are based on a national cross-sectional multicentre study of Norwegian adults and older people (20-85 years), while **Paper IV** is based on a validation study of the ActiGraph GT1M activity monitor. The two studies differ substantially in study design and methodological approach, and will be described separately.

Study design and sampling

The Physical Activity among Adults and Older People Study was a multicentre study involving 10 regional testcentres throughout Norway (Figure 1). The testcentres were chosen to reflect geography and population density, and included universities or college universities that had a sport science curriculum. The Norwegian School of Sport Science was the testcentre in the Oslo-region and was the coordinating unit for the study.

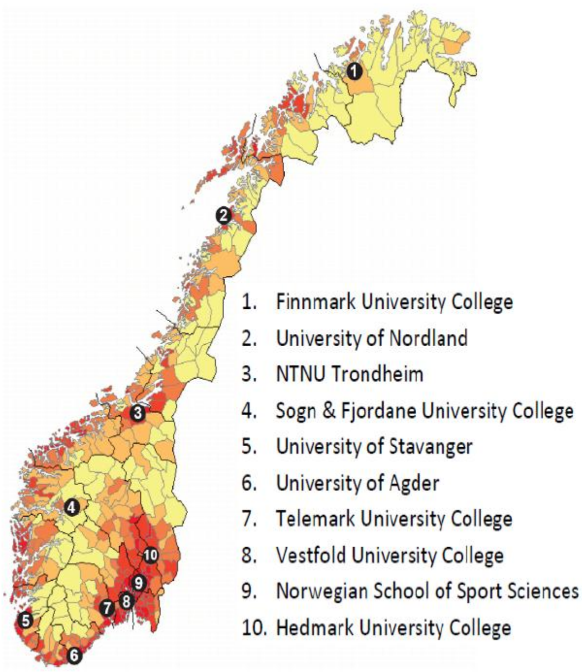

Figure 1. Map of Norway indicating the 10 testcentres involved in the study

A representative sample of 11,515 adults and older people (20– 85 years) from the areas surrounding each test centre was drawn from the Norwegian population registry (Figure 2). The only inclusion criterion was that the participants had to be aged between 20 and 85 years. The recruitment strategy included several mechanisms such as local media coverage, personalized invitational letters and offers of individual survey reports. The study information and informed consent was distributed via mail to the representative sample; 267 invitations were returned because of an unknown address. This resulted in an eligible sample of 11,248 individuals invited to participate. Written informed consent was obtained from 3,867 individuals (34%). Three hundred and eighty-two did not return any data. These were defined as withdrawals from the study. While 332 individuals gave no reason for withdrawal, 31 withdrew for medical reasons, 9 because the study burden was too large and 10 individuals reported that they never received any study material. This gave a final sample of 3,485 participants (31%). The study was approved by the Regional Ethics Committee for Medical Research and the Norwegian Social Science Data Services AS (Appendix I).

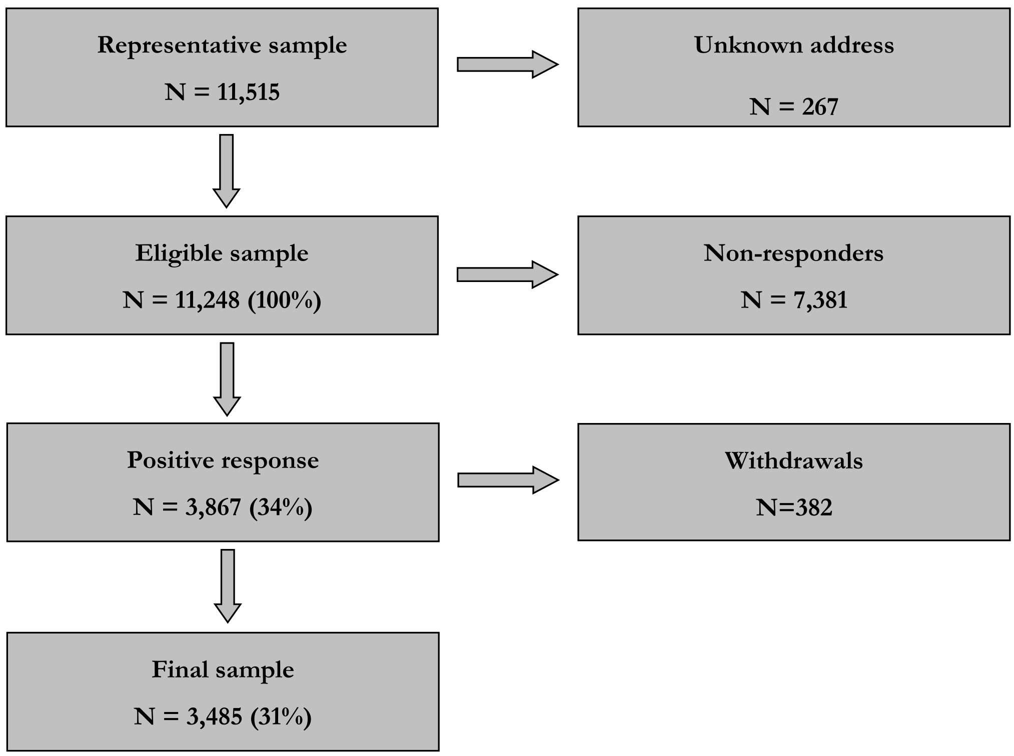

Figure 2. Flow chart of invitees (**Papers I-III**)

Sample size calculations

The critical variable in the statistical power calculations is the primary outcome variable. In **Papers I-III** the outcome variable is overall physical activity level expressed as mean counts per minute (CPM). We knew the population variation from earlier studies including children (99). Further, calculations were made using a two-tailed test assuming Type I error rate=0.05 and statistical power=0.8. The sample size calculations for differences between groups were based on number required per cell to detect a minimum of 7% difference in CPM. This yielded a minimum group size of 445 participants. Based on the aims of the study to compare physical activity levels between different strata's of the population (i.e. age groups, sexes, BMI-categories, level of education), we aimed to gather physical activity data from approximately 4000 individuals.

Study protocol

Data was collected between April 2008 and April 2009 (Figure 3). Test personnel at each testcentre mailed study invitations to invitees. The invitation package contained study information, consent form and a prepaid return envelope (Appendix II). After receiving signed consent forms from invitees, test personnel distributed the study material containing a pre-programmed accelerometer, instructions for use (Appendix III), main questionnaire (Appendix IV), additional questionnaire (Appendix IV), and a prepaid return envelope. Standardized instructions included how to wear the monitor and to remove it for water activities and while sleeping at night. Participants were also instructed to answer the main questionnaire when receiving the study material and the additional questionnaire after completing of the seven days of registration. After the registration period, the participants returned the accelerometers by prepaid express mail to their respective test centre.

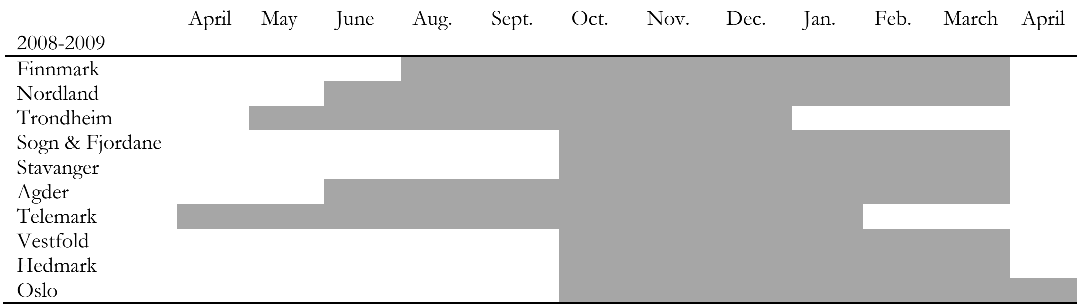

Figure 3. Overview of the data collection period for the ten testcenters.

Measures

Socio-demographic variables

Data on sex, age, country of origin, number of children and civil status were available from the population registry of Norway. In most analyses in **Papers I-III**, age was dichotomized to those aged less that 65 and those aged 65 years or more.

Physical activity assessment

The ActiGraph GT1M (ActiGraph, LLC, Pensacola, FL, USA) activity monitor was used to assess the participants level of physical activity. The activity monitor is lightweight (27 g) and small (3.8 cm × 3.7 cm × 1.8 cm) and comprises a solid-state monolithic accelerometer that uses microprocessor digital filtering. During installation of the accelerometer in the circuit, its response to 1g acceleration of the earth is fixed and does not drift, thereby removing the need for unit calibration (77). The accelerometer registers vertical acceleration in units called counts and samples data at a rate of 30 times per second in user-defined sampling intervals (epochs).

Data reduction

The accelerometers were initialized and downloaded using the ActiLife software provided by the manufacturer (ActiGraph, Pensacola, FL, USA). The data were collected in 10-second epochs. To analyse the data, the 10 second epochs were collapsed into 60-second epochs for comparisons with other studies. The data were reduced using an SAS-based software program (SAS Institute Inc., Cary, NC, USA) called CSA Analyzer (csa.svenssonsport.dk). Data were included if the participant had accumulated a minimum of 10 hours of valid activity recordings per day for at least four days, which is in accordance with similar studies (142) and in line with the suggestions by Trost et al (189). Wear time was defined by subtracting non-wear time from 18 hours (all data between 00:00 and 06:00 were excluded). Non-wear time was defined as intervals of at least 60 consecutive minutes with zero counts, with allowance for 1 minute with counts greater than zero. After the accelerometer data reduction, the database was scanned for unrealistic and/or duplicate data indicating defective monitor.

For **Papers I-III**, the following types of outcome variables were derived from the accelerometers: 1) a measure of overall physical activity (CPM); 2) accumulated amount (minutes or hours) of intensity-specific physical activity (number of time units with a CPM below or above a given threshold); 3) an estimate of adherence to physical activity recommendations; and 4) number of steps taken per day.

CPM evaluates the raw data provided by the accelerometer without imposition of any external criteria other than determination of wear and non-wear time. CPM was calculated by dividing the sum of the activity counts for a valid day by the numbers of minutes of wear time in that day across all valid days. Intensity-specific physical activity is derived from the minute-by-minute data using standardized cut points for intensity threshold based on linear regression associations between accelerometer counts and measured energy expenditure (e.g. METs). Sedentary behaviour is a behaviour or activity that demands not much more that a resting metabolic rate (for example lying, reclining or sitting down while awake), and minutes with CPM values of less than 100 were defined as sedentary behaviour (41). Please note that sedentary behavior is referred to as *sedentary activity* in **Paper I**. Light physical activity were defined as activities that demand more than a resting metabolic rate but not more than 3 METs (slow walking, grocery shopping, fidgeting, gardening, playing with children, and household activities). Minutes with a count value of 100-2,019 were defined as minutes of light physical activity. Moderate physical activity was defined as activities that demand 3-6 METs of energy expenditure. Minutes in the count range of 2,020-5,999 were defined as minutes of moderate intensity physical activity. Although cut points vary, most published cut points for moderate activity are approximately equal to 2,000 CPM, which is equivalent of walking at about 3-4 kilometers per hour ($km \cdot h^{-1}$). Vigorous physical activity is normally defined as activity with an energy expenditure exceeding 6 METs and most published cut points lies around 6000 CPM. In some of the analyses in **Papers I-III**, moderate and vigorous activity are added up and treated as one variable, moderate-to-vigorous physical activity (MVPA). Additionally, in **Paper I**, the terms “low physical activity” and “lifestyle physical activity” are used. These variables represent a splitting of the light intensity range (1.5-3 METs) into two subcategories, originally proposed by Matthews et al (92). The cut points for intensity-specific physical activity used in this study (Table 4) are identical to those applied to the NHANES-data set regarding adults and older people (29;163).

Table 4. The cut points for intensity-specific PA used in **Papers I-III**.

Count values	Intensity category
0-99	Sedentary activity
100-759	Low intensity PA
760-2,019	Lifestyle activity
100-2,019	Light intensity PA
2,020-5,999	Moderate intensity PA
≥2,020	Moderate-to-vigorous intensity PA
≥ 6,000	Vigorous intensity PA

Steps taken per day

Steps taken per day was determined using the "threshold crossing mode" embedded in the accelerometer. This mode counts the number of times the acceleration-generated signal crosses through the baseline reference each epoch and is, according to the manufacturer, representative of the number of steps taken. Cycle counts approximate the number of steps taken per epoch and is totalled to represent accumulated steps taken over the monitoring time frame (62). Total cycle counts averaged over number of days of valid monitor indicated steps taken per day. The current Scandinavian recommendations regarding physical activity does not include a minimal number of steps that should be accumulated over the course of a day. However, a threshold of 10,000 steps per day is often associated with a level of physical activity that is beneficial for health (190-192), therefore the prevalence of the sample that accumulated at least 10,000 steps per day are reported in additional to adherence to physical activity recommendations.

Adherence to physical activity recommendations

Estimated adherence to the current Norwegian physical activity recommendations were estimated by scanning the raw data file for bouts of MVPA (continuous CPM values equal to or above 2,020) lasting at least 10 minutes, with allowance for 2 drops below threshold. Number of minutes in bouts of MVPA were summed and divided by number of valid days of accelerometer data. If daily minutes of MVPA exceeded (or was equal to) 30 minutes, the individual was classified as adherent to the recommendations. This operationalization of the physical activity recommendations is in concordance with the stated need for the activity to be performed in continuous bouts of MVPA in order to yield significant health benefits.

Demography

Data on anthropometry (height in centimetres and weight in kilograms), level of education, prevalence of various diseases, self-reported health, and tobacco use were collected from the main questionnaire. BMI was computed as weight (kg) divided by meters squared (m^2). Overweight and obesity were defined as a BMI of 25- 29 and $\geq$30, respectively (32). Educational attainment was categorized into four groups: less than high school, high school, less than 4 years of university and university of 4 years or more. To subjectively assess health status, participants were asked to rate their perceived health status as very poor, poor, either, good, or very good. Because of the low prevalence of poor health (n=104, 3.0%) and very poor health (n=3, 0.1%), the answers were grouped into two categories for the analyses: very poor/poor/either and good/very good (not good vs. good).

Correlates of physical activity

The included psychological correlates considered likely to mediate physical activity were: self-efficacy for physical activity (193), perceived behavioral control over physical activity (194;195), and physical activity identity (196). The included socio-environmental correlate likely to mediate physical activity were social support, from either family or friends (197), whereas the perceived community attributes comprised the physical-environmental correlate. The inclusion of the physical-environmental correlate was guided by the empirical literature on the environmental factors that have been associated with physical activity in various settings and populations groups (198). All psychological, behavioral, and environmental correlates were derived from previously developed and validated scales and are presented in Table 5.

Table 5. Included correlates of physical activity with Cronbach´s alpha, and examples of scale items

Variable	**Scale range**	**Cronbach´s Alpha (α)**	**Reference for item**
Psychological correlates			
Self-efficacy	1-7	0.91	(193)
"I am sure that I can perform the planned physical activity even though I am tired"			
"I am sure that I can perform the planned physical activity even though I feel depressed"			
Perceived behavioural control	1-7	0.67	(195)
"I control whether I perform regular physical activity or not"			
"If I wanted to, it would be no problem for me to perform regular physical activity"			
Physical activity identity	1-5	0.91	(196)
"I control whether I perform regular physical activity or not"			
"I regard myself as a person who is interested in physical activity"			
Socio-environmental correlates			
Social support from family	1-5	0.86	(197)
"How often do members of your family encourage you to be physically active"			
"How often do members of your family talk about the health benefits of physical activity"			
Social support from friends	1-5	0.89	(197)
"How often do your friends encourage you to be physically active"			
"How often do your friends talk about the health benefits of physical activity"			
Physical-environmental correlates			
Perceived community attributes	1-4	0.79	
"To what extent does your community have: safe places where you can walk?"			
"To what extent does your community have: grocery stores within a walking distance of 10-15 minutes?"			

Self-reported variables of physical activity

Participants reported the type of physical activity they most commonly participated in (main questionnaire). In addition, participants also answered a short, one-page questionnaire targeting the actual week of accelerometer registration (additional questionnaire). The participants reported the weather and state of surface for each of the seven days of registration. Weather was classified as good, fair, or poor, and surface as dry, icy, or wet. The additional questionnaire further assessed the amount of cycling, swimming and strength training that the participants performed during the registration period.

Drop out analysis

Due to the relatively low response rate, a drop-out analysis of non-responders was initiated. The drop-out analysis was carried out by Statistics Norway using registry linkage. The non-responding individuals received written information on the purpose of the drop-out analysis and could actively reserve themselves from inclusion in the drop-out analysis. This resulted in a reservation rate of 7%.

The representative sample (n=11,515) contained information on the geographical location, age, sex, number of children, and civil status of the sample. Statistics Norway linked this information with registry information regarding income and level of education and compared the responders with the non-responders. The analysis revealed significant differences in response rates between the different test centres. Response rates were highest for the subsamples in Sogn & Fjordane and Oslo, and lowest in Vestfold and Telemark. The odds ratio (OR) for a positive response was 2.2 (95% Wald Confidence Intervals: 1.8-2.5) in the Sogn & Fjordane subsample, when contrasted to the other testcentres. Independent of testcentre, level of education was the strongest predictor of a positive response. The likelihood of a positive response among those with education at university level was approximately 3 times as high as for those with a high school education (OR: 3.3, 95% Wald Confidence Intervals: 2.9-3.8). Income also affected the participation, and a tipping point of approximately 100,000 NOKs (≈14,000 USD) appeared, meaning that positive response rates were significantly lower for those with a registered income below 100,000 NOK, compared with those with a higher income. However, as income increased above 100,000 NOKs, the independent effect of income disappeared, indicating that other factors, namely level of education, explained much of the effects of income alone. Further, response rates increased with increasing number of children, up until 4 children, after which it declined, and response rates were slightly higher among women, compared with men. Age was also a significant predictor of a positive response, with the lowest rates in the younger and older age spectrum. However; the importance of age lessened when controlling for level of education. Lastly, respondents were more likely to be of ethnic Norwegian origin.

Statistical analyses

In **Papers I-III** demographic variables were given as proportions, mean values, mean and standard deviation (SD) or standard error of the mean (SEM), and 95% confidence intervals (CI). Differences between groups in physical activity level were tested by general linear models (GLMs) of covariance with Bonferroni adjustments for multiple comparisons were appropriate. Differences in proportions meeting physical activity were assessed using chi-square analyses. As physical activity varied somewhat with test centre and age, these variables were consequently controlled for in the association analyses.

In **Paper I**, linear regression analysis was used to estimate the changes in activity with increasing age. In **Paper II**, Student's *t*-test for independent groups was used to identify differences in anthropometric data between sexes and chi-square tests were used to test for differences in self-reported health and level of education between BMI-categories. GLMs were performed to identify differences in physical activity between BMI-categories. A one-way repeated measurement analysis was conducted to explore whether the impact of type of day (weekday or weekend) differed across BMI-category. Logistic regression was performed to assess the impact of quintiles of physical activity on the likelihood that participants were either overweight or obese.

In **Paper III**, hierarchical regression was applied to analyse the relationships between physical activity and the hypothesized correlates of physical activity. Demographic and biological variables were entered as block 1. Block 2 contained the psychological correlates (self-efficacy, perceived behavioural control, and physical activity identity), whereas socio-environmental correlates (social support from family and friends) were included in block 3. The physical-environmental correlate (perceived community attributes) was entered in block 4. Unstandardized coefficients (b) and the individual contribution of each predictor variable to the explained variance (semi-partial correlation squared) were reported. Furthermore, interaction terms for potential moderators of the relationship between the correlates and physical activity (sex, BMI and level of education) were computed (e.g. sex multiplied by self-efficacy). The significant interactions were then graphically displayed in order to explore the directions and strengths of the interactions.

All statistical analyses were performed using PASW Statistics 18 for Windows (IBM Corporation, Route, Somers, NY, USA) and a two-tailed alpha level of 0.05 was used for statistical significance.

Materials and methods (Paper IV)

In order to validate the ActiGraph GT1M during level and graded walking and cycling, we conducted a methodological trial in a laboratory-setting, using energy expenditure measured by indirect calorimetry as the criterion method.

Study design and sampling

A sample of 20 healthy participants (23-39 years) from Oslo and surrounding areas, with no ambulatory restrictions, were recruited to participate in the study. Participants were given detailed information about study procedures and signed written informed consent documents. The study protocol was reviewed by the Regional Committee for Medical Research Ethics.

Study protocol

Participants met at the exercise physiology laboratory at the Norwegian School of Sport Sciences at three separate days. On day 1, information of the study was given, the participants were accustomed to the testing equipment, and anthropometrical measures were made. Weight were measured to the nearest 100 g with a digital scale (Seca Model 708, Seca Ltd, Birmingham, UK) and height to the nearest 0.1 cm. Participants were measured in light clothing and without shoes.

On day 2, participants performed two sessions of treadmill walking. Session one consisted of 5-minute intervals of walking on a motorized treadmill (Woodway, Elg 2, Germany) at 0% inclination at speeds of 3, 4, 5, 6, and 7 $km \cdot h^{-1}$. These speeds were selected to reflect the intensity of effort ranging from light to moderate intensity physical activity. During session two, participants completed 5-minute intervals speeds of 3, 5, and 6 $km \cdot h^{-1}$ at 5% inclination and at 3, 4, and 5 $km \cdot h^{-1}$ at 8% inclination. On day 3, participants performed one session of treadmill walking at -5% inclination at speeds of 4, 5, and 6 $km \cdot h^{-1}$, and one session of 5-minute intervals at a cycle ergometer (Lode Excalibur Sport, Lode BV, Groningen, the Netherlands) at cadences of 60 and 80 RPM with 40, 60, and 80 watts of resistance.

During each session, participants wore an ActiGraph GT1M activity monitor (Pensacola, FL, USA) secured with an elastic belt over the auxiliary line on the right hip. Oxygen uptake was measured by a metabolic cart (Jaeger Oxycon Pro; Wursburg, Germany) using a Hans Rudolph two-way mouth piece (2700 series; Hans Rudolph Inc., Kansas City, USA). Heart rate (HR) was assessed by a Polar Electro FT1 heart rate monitor (Polar, Kempele, Finland) worn around the chest at the level of the sternum. CPM, steady state VO_2 and mean HR was calculated using the last 3 minutes of exercise for each interval. METs were calculated by dividing the steady state VO_2 by 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. An external timepiece was used to synchronize the accelerometer internal clock with the VO_2 output.

Statistical analyses

In **Paper IV,** *t*-tests for independent samples were used to examine differences in descriptive characteristics between the sexes, oxygen uptake and accelerometer output. Linear regression was used to establish the relationship between METs and CPM and GLMs with Bonferroni adjustments were used to explore differences in CPM and METs during treadmill and ergometer cycle sessions. All statistical analyses were performed using PASW Statistics 18 for Windows (IBM Corporation, Route, Somers, NY, USA) and a two-tailed alpha level of 0.05 was used for statistical significance.

Summary of results

Characteristics of the participants (Papers I-III)

The characteristics of the study population in **Papers I-III** are presented in Table 6. The final sample comprised 1,859 women and 1,626 men, whose mean ages (SD) were 48.3 (14.9) years and 50.0 (14.9) years, respectively. Forty one per cent of the women and 60% of the men were classified as either overweight or obese (BMI≥25). Seventeen percent of the sample were current smokers, with prevalence being higher for women compared with men (18% vs. 15%, $p<0.05$). The most commonly reported diseases and conditions were rheumatism (10%), asthma (9%), poor mental health (9%), cardiovascular disease (5%), cancer (5%), diabetes type 2 (3%) and osteoporosis (2%). A total of 82% percent of the normal-weight individuals reported having at least good health, and the corresponding percentages were 75% for overweight and 58% for obese individuals.

Table 6. Participant characteristics (n=3,485) by age and sex

	20−64 years				64−85 years			
Variable	**Women**	**SD**	**Men**	**SD**	**Women**	**SD**	**Men**	**SD**
N	1564		1330		295		296	
Age (yrs)	43.8	11.6	45.2	11.8*	71.9	5.7	71.8	5.3
Height (cm)	167.5	6.0	180.7	6.3*	163.8	5.4	177.2	6.7*
Weight (kg)	69.8	12.5	85.9	12.8*	66.3	10.2	81.1	11.7*
BMI (kg/m²)	24.9	4.4	26.3	3.6*	24.7	3.5	25.8	3.2*
BMI category (%)								
Overweight	29.2		45.9*		32.2		44.1*	
Obesity	11.4		14.0*		7.8		10.1*	
Overweight and obesity	40.6		59.9		39.9		54.2	
Educational level (%)								
Less than high school	8.4		9.7		37.3		31.6	
High school	35.9		41.4		36.2		35.8	
University <4 yrs.	27.0		22.3		14.6		18.6	
University ≥4 yrs.	28.7		26.5		11.8		14.0	
Self-reported health (%)								
Good (good/very good)	77.3		76.3		74.5		68.7	
Not good (very poor/poor/either)	22.3		23.7		25.5		31.3	
Daily smokers (%)	19.6		15.6		12.9		10.1	

*$P<0.05$ for sex within age group

Of the final sample, 86 participants did not wear the accelerometer at all, data from 14 participants were lost due to defect monitors, and 188 participants had less than 4 days of valid accelerometer recordings. The remaining 3267 (1859 women) participants wore the accelerometer for an average of 6.8 days and the average mean daily wear time was 14.6 h (SD 1.1). A comparison between those who did and did not provide sufficient accelerometer data revealed small differences in age, BMI and level of education.

Paper I

The objectively assessed data on overall physical activity (CPM), steps taken per day, sedentary behaviour and intensity-specific physical activity are presented in detail in Table 7. There were no differences between the sexes regarding CPM or steps/day. Adjusted for age, women had a CPM of 335 (95% CI: 328 to 341) and accumulated a total of 8113 steps per day (95% CI: 7973 to 8252). In comparison, men had a CPM of 342 (95% CI: 335 to 349) and took on average 7951 steps per day (95% CI: 7802 to 8101).

Table 7. Overall physical activity, steps per day, sedentary behaviour (minutes), and intensity-specific physical activity (minutes), by age group and sex.

	Women			**Men**			**All**		
Age	**n**	**Mean**	**95% CI**	**n**	**Mean**	**95% CI**	**n**	**Mean**	**95% CI**
Counts per minute									
20-64	1465	345	337 to 352	1242	349	341 to 357	2707	347	341 to 352
65-85	282	287	268 to 305	278	305	286 to 324	560	296	281 to 311
All	1747	335	328 to 341	1520	342	335 to 349	3267	338	333 to 343
Steps per day									
20-64	1457	8440	8282 to 8598	1235	8188*	8021 to 8355	2692	8314	8195 to 8433
65-85	282	6565	6165 to 6965	277	6750	6348 to 7152	559	6658	6338 to 6977
All	1739	8113	7973 to 8252	1512	7951	7802 to 8101	3251	8038	7936 to 8139
Sedentary behaviour									
20-64	1465	530	527 to 534	1242	555*	551 to 560	2707	543	540 to 546
65-85	282	545	536 to 553	278	567*	558 to 575	560	556	550 to 562
All	1747	533	529 to 537	1520	557*	553 to 561	3267	545	542 to 548
Light intensity PA									
20-64	1465	316	313 to 320	1242	289*	285 to 293	2707	303	300 to 306
65-85	282	273	266 to 281	278	247*	239 to 255	560	260	255 to 266
All	1747	309	306 to 312	1520	282*	278 to 286	3267	296	293 to 298
Low intensity PA									
20-64	1465	238	236 to 241	1242	207*	204 to 210	2707	223	221 to 225
65-85	282	213	208 to 219	278	186*	181 to 192	560	200	196 to 204
All	1747	234	232 to 236	1520	203*	201 to 206	3267	219	217 to 220
Lifestyle PA									
20-64	1457	78	76 to 80	1242	82*	80 to 84	2707	80	79 to 82
65-85	282	60	56 to 64	278	61	57 to 65	560	60	58 to 63
All	1747	75	73 to 77	1520	79*	77 to 80	3267	77	76 to 78
MVPA									
20-64	1457	34.3	33.1 to 35.4	1242	36.5*	35.2 to 37.8	2707	35.4	34.5 to 36.2
65-85	282	25.6	22.8 to 28.4	278	30.2*	27.3 to 33.0	560	27.9	25.9 to 29.9
All	1747	32.8	31.7 to 33.9	1520	35.4*	35.4 to 36.6	3267	34.1	33 to 35
Bouts of MVPA									
20-64	1457	18.2	17.9 to 19.8	1242	16.1*	15.1 to 17.1	2707	17.5	16.8 to 18.2
65-85	282	15.6	13.2 to 18.1	278	18.4	15.9 to 20.9	560	17.0	15.3 to 18.8
All	1747	18.3	17.4 to 19.2	1520	16.5*	15.6 to 17.5	3267	17.4	16.8 to 18.1

$P < 0.05$ for sex within age group
[a]All values were adjusted for age and test center, and intensity-specific physical activity are additionally adjusted for daily wear time (minutes)
[b]Sixteen participants had no step data

The participants wore the activity monitor for an average of 15 hours per day, out of which 62% of the time were classified as sedentary (≈9 hours per day). Men accumulated more sedentary behaviour compared with females, the mean difference was 24 minutes per day (95% CI: 19 to

29). Thirty-four per cent of the time (≈5 hours per day) was classifies as activities of light intensity (e.g. slow walking or fidgeting), and women performed significantly more light intensity physical activity, compared with men, the mean difference was 27 minutes (95% CI: 22 to 33 minutes). The remaining 4% of the wear time consisted of activities of at least moderate intensity (MVPA). Men accumulated more daily MVPA compared to women, with a mean difference of 2.6 minutes per day (95% CI: 1.1 to 4.3). Figure 4 displays the intensity-specific physical activity data as proportions of the daily wear time, by 15 year age groups and sex.

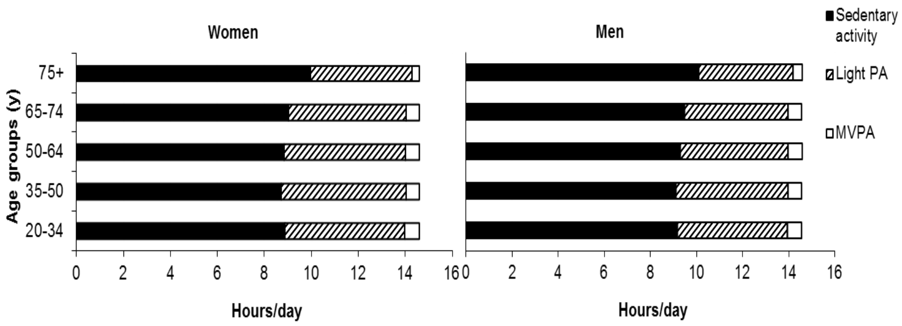

Figure 4. Distribution of intensity-specific PA by age groups (15 year cohorts) and sex

Both CPM and steps/day remained steady with age, until 65 years, after which activity levels declined. The individuals in the oldest age group had lower CPM than those aged 20-64 years (the mean difference was 70 CPM, 95% CI: 58 to 83). In the oldest age group (65+) the estimated decrease was 9 CPM per year (95% CI: 7 to 12) (Figure 5). Similar tendencies were observed for steps per day, with an estimated yearly decrease of 215 steps (95% CI: 168 to 263) among the oldest participants. Figure 5 displays the CPM levels by 15 year age cohorts and sex.

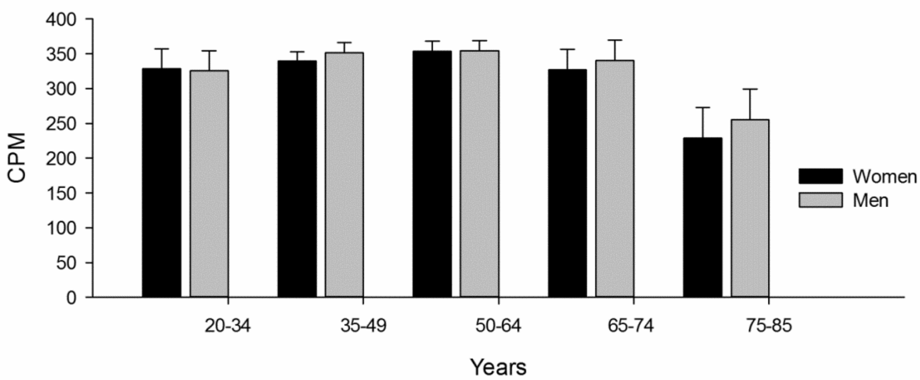

Figure 5. Overall physical activity (CPM) in 15-year cohorts, by sex (95% CI)

One in every five participants met the current physical activity recommendations (20%), and the adherence did not differ between women and men. However, in the 20-64 years age group, four percent more women than men met the recommendations (95% CI: 0.5 to 6.5). The proportion of participants that accumulated at least 10,000 steps per day (23%) was slightly higher compared with the proportion that met the current physical activity recommendations.

Table 8. Prevalence (95% CI) of the population meeting current physical activity recommendations

	Women	95% CI	Men	95% CI	All	95% CI
≥30 minutes of daily MVPA in bouts of 10 minutes						
20-64	21.8	19.7 to 23.9	18.4*	16.2 to 20.6	20.2	18.7 to 21.7
65-85	18.8	14.2 to 23.4	23.0	18.1 to 27.9	20.9	17.5 to 24.3
All	21.4	19.5 to 23.3	19.2	17.2 to 21.2	20.4	19.0 to 21.8
≥ 10,000 steps per day						
20-64	26.7	24.4 to 29.0	21.7*	19.4 to 24.0	24.4	22.8 to 26.0
65-85	13.8	9.8 to 17.8	14.8	10.6 to 19.0	14.3	11.4 to 17.2
All	24.4	22.6 to 26.6	20.4*	18.4 to 22.4	22.7	21.3 to 24.1

*$P<0.05$ for sex within age group

Adherence to the recommendations depends on how the recommendations are defined and operationalized. The operationalization in Table 8 is in line with the current Scandinavian recommendations of at least 30 minutes of continuous MVPA (24), which are based studies that have used self-reports of physical activity as their exposure variable. The lack of studies that use objectively assessed physical activity as the exposure variable indicate that what the current define as the minimal amount of physical activity needed, might not be a correct. Compared with objective assessments, self-reported physical activity generally yields higher levels of physical activity. Hence, the minimum amount of daily activity needed might be lower than the current estimate. Figure 6 illustrates the adherence to physical activity recommendations with threshold of 20, 25, or the current 30 minutes of continuous MVPA.

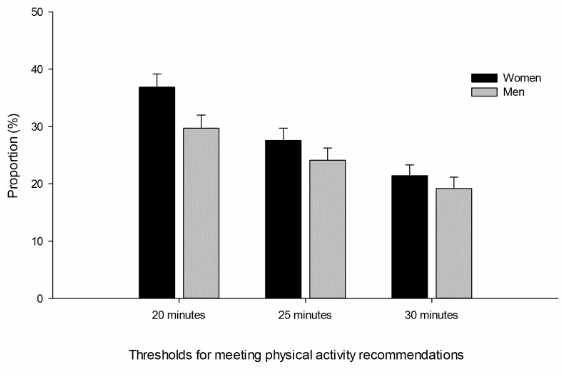

Figure 6. Adherence to physical activity recommendations defined as ≥30, ≥25, and ≥20 minutes of MVPA in blocks

Paper II

The prevalence of overweight and obesity was 30% and 11% for women, and 47% and 13% for men, respectively. Health status differed across BMI- categories, with 82% of normal weight participants reported having at least good health, while similar percentages were 75% and 58% for overweight and obese, respectively.

Overweight and obese participants performed less overall physical activity, physical activity of at least moderate intensity, and took fewer steps, compared with normal weight participants. Normal weight women had a higher CPM and steps per day compared with both overweight and obese women, respectively. Similar patterns were seen for men, although only reaching statistical significance for CPM. Compared with normal weight participants, obese women and men were sedentary for 17 minutes (95% CI: 3 to 32) and 22 minutes (95% CI: 7 to 37) more per day, respectively. The amount of light PA did not differ between weight categories, but moderate-to-vigorous physical activity decreased significantly with increasing BMI-category.

The impact of type of day on CPM differed between the BMI-categories. Compared with normal weight participants, obese participants had a 19% lower CPM on weekdays (355 CPM vs. 287 CPM), and a 25% lower on weekends (370 CPM vs. 279 CPM). Plots of hourly distribution of CPM indicated that the differences were particularly visible at around midday and early afternoon (Figure 7).

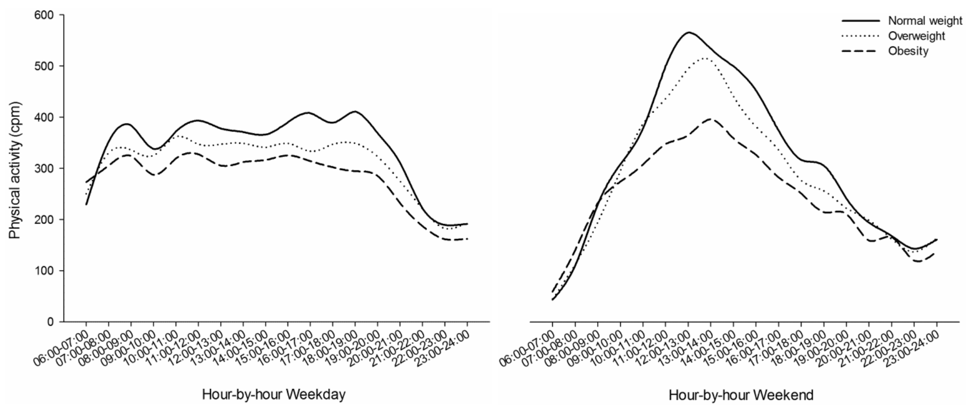

Figure 7. Hourly distribution of overall physical activity (cpm) for normal weight, overweight and obese individuals on weekdays and weekends

Overall, CPM explained between 8% (Cox and Snell R-squared) and 11% (Nagelkerke R-squared) of the variance in weight status. Participants in the most active quintile of overall PA had a 53% lower odds (OR: 0.47, 95% CI: 0.37 to 0.60) for having a BMI above or below 25, and a 71% lower odds (OR: 0.29, 95% CI: 0.20 to 0.44) for having a BMI above or below 30. Similar findings were observed for quintiles of MVPA. The relative odds reductions associated with a higher level of physical activity are presented in Figure 8. The four models displayed are adjusted for age, sex, self-reported health status, level of education and smoking.

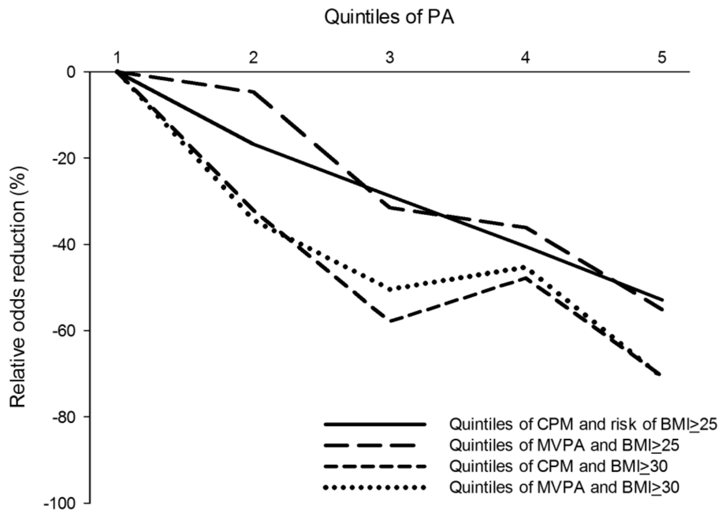

Figure 8. Relative odds reduction (%) for being overweight and/or obese associated with increased CPM or MVPA

Paper III

The mean scores for the psychological and physical-environmental correlates were relatively high, whereas the mean scores for the socio-environmental correlates were moderate. The demographic and biological factors included in the model accounted for 12% of the variance in CPM. Age group, health status, and weight status displayed the largest amount of explanatory power, explaining 5.0%, 2% and 2% of the variance, respectively ($p \leq 0.001$). The psychological correlates of self-efficacy, perceived behavioural control and physical activity identity increased the total explained variance to 19% ($p \leq 0.001$). Each of the psychological correlates individually contributed to increasing the explanatory power of the model, with physical activity identity being the most important factor, contributing with 3% of the explained variance ($p \leq 0.001$). Entering socio-environmental correlates and the physical-environmental correlate yielded no further significant increases in amount of variance explained by the total set of correlates.

Altogether, seven of the 22 interaction terms contributed significantly to increasing the explanatory power of the predictor variables, indicating that these moderated the relationships of the sets of correlates to physical activity. However, the size of the interaction effects should be considered as relatively modest.

Paper IV

Significant differences in all measured variables between consecutive velocities in the 3-7 $km \cdot h^{-1}$ range during level walking were observed. The relationship between CPM and METs during level walking was linear (R^2=0.82, p≤0.001).

The relationship between CPM and METs during graded walking differed somewhat from level walking. At 5% grade, the explained variance in metabolic cost due to increases in CPM was similar to level walking (R^2=0.815), compared with a somewhat lower explained variance at 8% gradient (R^2=0.677, *p*≤0.001). Although the GT1M appears to discriminate between level and graded walking, the size of the difference in CPM is not large enough to reflect the increased EE observed during graded walking, thus underestimating EE during uphill walking. Furthermore, we observed a reduced EE during walking at -5% grade, while CPM was high, indicating an overestimation of EE during downhill walking

Iincreased workload were not associated with an increase in CPM during ergometer cycling, either at 60 RPM (R^2=0.00) or 80 RPM (R^2=0.002), as shown in figure 9. The average CPM for all data points during cycling was 1,157 (SD=974) and mean EE during cycling was 5 METs. An EE of 5 METs during level walking yielded approximately 4300 CPM, indicating that the GT1M underestimates PA during cycling with 73%.

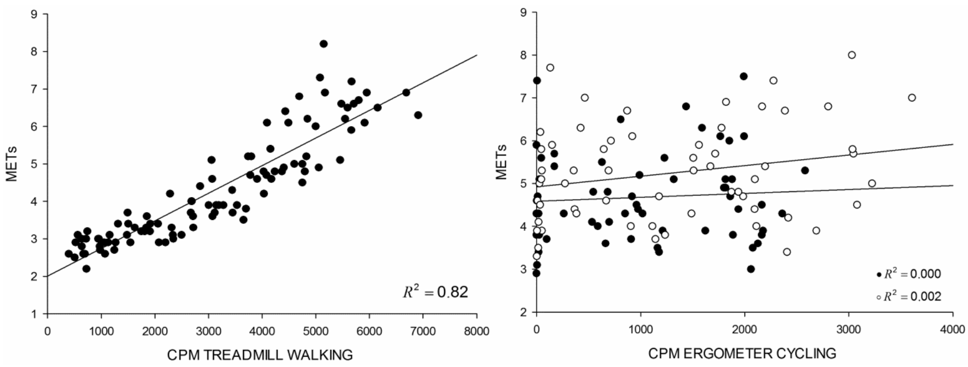

Figure 9. Energy expenditure (METs) as a function of CPM during walking and ergometer cycling.

Discussion

The following general discussion will focus on the main results, study population and the strengths and limitations of the studies.

Levels of physical activity

The results from **Paper I** provide novel information on the level of overall PA and intensity-specific physical activity, and the adherence to current physical activity recommendations in Norwegian adults and older people. The absence of a sex-related difference in overall physical activity contradicts previous literature, where higher levels of physical activity among men compared with women have been a constant finding (162;170). Using accelerometers, the difference in overall physical activity has also been confirmed in US, Canadian, and Portuguese samples of adults and older people (29;146;199). However, a lack of difference between the sexes is observed among Swedish and Chinese adults and older people, when physical activity is assessed objectively (142;145). The contradictory evidence from studies using subjective methods and the results presented in **Paper I** might reflect the inabilities of self-report to measure activities not classified as traditional exercise, such as walking and household activities. Such activities are normally classified as activities of light intensity (200). When light intensity activity was isolated, we observed that women accumulated more minutes of activities in this intensity range. Additionally, women accumulated more steps per day, compared with men. We therefore believe, as a result of improved assessments of physical activity, the common notion that men are more active that women is population-specific and does not apply to Scandinavia.

Another commonly reported finding is that physical activity decline with increasing age (162). When the results of the current study are compared with the results from the Physical Activity among Norwegian Children Study (PANCS) (99), the observed decrease in overall physical activity of 31% from 9-year old children to 15-year old adolescents, continued into adulthood. The observed decrease in overall physical activity is 30% for women and 35% for men, when the 20-64 year age group were compared with the 15-years-old adolescents in the PANCS-study. After entering adulthood, activity levels remained relatively constant until reaching approximately retirement age. From ages 50-64 to 65-75 years, activity levels declined by 12% for women and

8% for men. Further, moving from 65-74 to 75-85 year age group were associated with an additional decline of 36% in women and 30% in men. The finding that overall PA appears to be relatively stable across adulthood was somewhat surprising given that increasing age is commonly reported to be associated with declining rates of physical activity (162). Studies of objectively assessed physical activity in populations of adults and older people are somewhat ambiguous regarding the effects of age on physical activity. In the US, the decline in activity seemed to be relatively linear with increasing age (29), while the Swedish data were more similar to those of the present study. Although not presented by categories of increasing age, only a minor effect of age on overall physical activity was observed in the Swedish sample (71). A similar pattern were also apparent in the Portuguese study, where activity levels were stable in adults, with no decreases observed before reaching the age of 65 years (146). These studies indicate that activity levels do not decrease across adulthood in apparently healthy adults. However, given the limitations of a cross-sectional design, a cohort-effect of age cannot be ruled out. If the general impression that population levels of physical activity were higher in the past is true, it is likely that the older participants in the study had higher levels of physical activity when they were younger, compared with the younger participants in the study. If that is the case, an age-related decline in physical activity would be masked by the low levels of physical activity among the younger participants in the study.

Eighty percent of the participants did not meet the current physical activity recommendations. In comparison, 80% of 9-year-olds and 50% of 15-year-olds in Norway met the recommendations (99). This decline in adherence mirrors the decline in overall activity observed when entering adulthood. The percentage that met the recommendations were somewhat higher than what was reported in the US and Portugal (29;146), but relatively similar to the estimates obtained in the Swedish study and among Canadian adults and older people (142;199). One must keep in mind, however, that differences in how recommendations are defined and operationalized, as well as the use of different brands and generations of activity monitors, hampers comparisons between studies.

The accelerometer cut-points used in this study to translate the count value into an estimate of intensity-specific physical activity were similar to those used in the NHANES (29;142). The strengths of these cut-points are that they are based on a weighted average of four commonly used sets of cut-points (88;95;201;202). However, these four sets of cut-points used treadmill or track walking as the criteria. Cut points are sensitive to the types of activities being performed and therefore it is possible that activities that require relatively high energy expenditure and concurrently produce little vertical movement were underestimated in the results presented in **Papers I-III**.

The results of **Paper I** represent the first description of levels of physical activity and sedentary behaviour among Norwegian adults and older people, using an objective method to assess physical activity. The majority of time awake was spent being sedentary and the adherence to physical activity recommendations was low. This new evidence on population levels of physical activity clearly shows that strategies are needed to reduce sedentary behaviours and increase activity levels. Such strategies need to be implemented at several levels, including the structural level (transportation and urban planning). It is evident that the numerous advances in information technologies and the increased use of labour saving devices have engineered sedentary behaviours into our daily lives, and many of the settings where physical activity occurred naturally in the past have been removed.

The association of physical activity and BMI

The results presented in **Paper II** are consistent with those of studies that used accelerometers to measure physical activity in large populations of adults and older people. Overall physical activity decreased consistently with increasing BMI. Tudor-Locke et al. (163) presented similar findings for US adults and older people. However, while only negligible differences between the sexes within each BMI-category were observed in our study, higher levels of activity among men compared with women was observed within each BMI-category in the US sample.

The relative differences in physical activity between BMI-categories were larger for intensity-specific physical activity compared with overall physical activity and steps taken per day. Normal weight women performed twice as much MVPA in bouts as obese women. Similar results have also been reported by others (142;163;203). The larger relative difference in intensity-specific physical activity between BMI-categories compared with overall physical activity may be explained partly by thermodynamics. Because of the greater body mass, resting energy expenditure is higher in obese individuals compared with normal weight individuals, and the metabolic cost of exercise is greater. An obese individual might perform an activity where the energy expenditure exceeds 3 METs, while the concurrent acceleration signal detected by the accelerometer does not exceed the standardized cut point for moderate activity. Hence, heavier individuals might perform physical activity with an actual energy expenditure exceeding moderate intensity, but the accelerometer might label the intensity as light. This illustrates the challenges of applying one set of cut points to a population that is heterogeneous with regards to age and BMI. However, although the metabolic cost of exercise increases with body mass, we are confident that the differences in physical activity between BMI-categories are real and important to public health, but care must be taken when interpreting the results regarding intensity-specific physical activity.

The observed weight-related differences in hourly activity patterns of overall physical activity across weekdays and weekends, has been identified by others. Cooper et al. (205) showed that although the obese participants were consistently less active than non-obese participants, no significant differences were observed while participants were at work (205). Although time at work could not be identified in our study, the patterns of overall physical activity suggest that differences were least pronounced between the hours of 09:00 and 16:00 on weekdays and largest around midday and early afternoon on weekends. Further, compared with normal weight participants, obese participants displayed 19% lower overall PA on weekdays and a 25% lower overall PA on weekends. The majority of the analysed sample reports working either full time (59%) or part time (11%). Thus, the observed larger relative difference in overall physical activity between obese and normal weight participants on weekends compared with weekdays implies that obese participants are more likely to pursuit sedentary behaviours when not constrained by work.

The results of **Paper II** represent the first exploration of the association between objectively measured physical activity and BMI in Norwegian adults and older people. Although the study design prohibits causal relationships to be established, the independent contribution of physical activity on the risk of being overweight or obese indicates the importance of an active lifestyle in the prevention of overweight and obesity. This is an important finding, as the obesity epidemic shows no signs of abating. The condition represents a serious health risk for the individual as well as costs for the health care system. We acknowledge that multiple factors other than PA, such as the energy intake, consummation of specific foods and beverages, alcohol use, and television watching, play vital roles in the development of overweight or obesity. However, we believe that the findings of the present study provide additional information on the relationship between physical activity and BMI and suggest that there might be a particular scope for targeting the weekend as a source of increased physical activity among overweight and obese individuals.

Correlates of physical activity

The total independent variable set of correlates accounted for 19% of the explained variance in overall physical activity. Age group (below or above 65 years) was the most important predictor of overall activity level, uniquely explaining 5.0% of the variance in the dependent variable, a finding that is consistent with findings from studies using self-reported physical activity (162). Concerning the remaining demographic and biological variables, the results are in conjunction with other studies. Civil status appears to have minimal impact on physical activity (172;173) while smoking was inversely related to physical activity (172;209).

Self-efficacy was a significant independent contributor to overall physical activity, as shown by others (210;211). A number of studies have found that perceived behavioural control predicts physical activity behaviour (212;213), which was also observed in the present study. Physical activity identity was the strongest predictor of all the correlates, and yielded a significant independent addition of variance accounted for in physical activity as age group did. The explanatory power of physical activity identity is supported by others. In a community-based study of 2,336 Norwegian adults, physical activity identity was found to be the strongest predictor of forward transition in the stages of change in physical activity (196;213). The importance of physical activity identity to amount of physical activity performed is confirmed in earlier studies of self-reported physical activity (214), and these earlier findings combined with the results of the current study provide strong evidence for the inclusion of attempts to foster the development of physical activity identity, in interventions aimed at enhancing physical activity behaviour.

In our model, social support did not contribute to the explanatory power of the model. Although social support appears to be a consistent correlate for physical activity (162), the findings are not consistent (215). Further, perceived community attributes did not relate significantly to physical activity. A similar finding was reported in a review by Wendel Woe et al (2007), reported that availability, accessibility and convenience of recreational facilities were less consistent correlates of physical activity. The authors proposed that this might have been due to the use of non-validated measures of environments and/or behaviour (216). Although the item assessing perceived community attributes in the present study displayed reasonable internal consistency, the mean score was relatively high. This might have impeded the ability of the item to discriminate sufficiently between high and low levels of community attributes, and objective measurement of neighbourhood walkability, street connectivity, population density and sidewalk conditions would maybe have yielded different results.

Furthermore, a significant interaction appeared of the demographic and biological variables in the relationship between the correlates and physical activity. However, the size of the interaction effects was modest and did not cause any changes in the direction of the effects of the correlates. Therefore, tailoring of strategies to increase overall physical activity in the population according to sex, weight or level of education does not seem necessary.

Despite certain limitations, we believe that the present study contributes to the understanding of physical activity and it correlates. To our knowledge, this is the first study that has examined the independent and interactive influences of demographic, biological, psychological, socio-environmental and physical-environmental correlates of objectively assessed physical activity. The results of the study can serve as an empirical evaluation of a social-ecological model of physical activity and the order of entry of blocks of variables into the hierarchical regression model is of relevance to intervention design. Although the explanatory power of each correlates independently was relatively modest, they yield important information as there is consistent evidence showing that small increases in physical activity can benefit peoples` health significantly (217;218). Small changes in overall physical activity are achievable by most individuals and there appears to be no lower threshold for what is needed in order to yield a significant health benefit (108).

The validity of the ActiGraph GT1M activity monitor

The data output from the GT1M during level walking rose linearly with speed over the walking range (3-7 $km \cdot h^{-1}$) and explained 82% of the variance in energy cost expressed in METs. This is similar to what have been observed in studies of the GT1Ms predecessor, the ActiGraph AM 7164. Because the speeds of walking used in our study ranged from casual to brisk walking, the highly linear relationship between speeds and CPM indicates that the GT1M can be useful to distinguish different speeds while walking on level ground. This finding is in conjunction with previous studies of the AM 7164, and supports the validity of the GT1M for assessing levels of physical activity among adults and older people, as a large proportion of daily physical activity is spent in locomotion (219). One could however argue that these findings are most applicable to treadmill walking as there is a difference in gait and thus detection of bodily movement between treadmill and outside walking (89). However, studies have indicated good agreements between accelerometer output obtained while walking on treadmill and while walking in free-living settings (220).

Unlike the AM 7164, the GT1M appears to discriminate between treadmill gradient. This might be a result of inter-generation differences in the accelerometers and their sampling frequency. The MEMS-based accelerometer in the GT1M samples data at 30 Hertz compared with piezoelectric-based AM 7164 who samples data at 10 Hertz (56). If step length is decreased and step frequency is increased during uphill walking, as shown for uphill running (37(221), the amount of vertical acceleration will increase accordingly (95). This might be picked up by the GT1M and not the AM 7164. However, the observed increase in CPM does not seem to reflect the concurrent increase in energy expenditure, leading to an underestimation of energy expenditure during uphill walking. Correspondingly, the results from downhill walking indicate that energy expenditure is overestimated during this activity. Thereby it appears as the overestimation of energy expenditure during downhill walking is evened out by the underestimation of energy expenditure during uphill walking. This indicates that the limitation of over- and underestimation of energy expenditure during graded walking is no threat to the validity of the monitor for assessing ambulatory activities in a free-living setting where walking consists of level as well as graded walking.

Uniaxial accelerometer attached to the hip yielded significantly fewer counts in cycling than in walking, thus underestimating intensity in cycling. There were no linear relationship between increased workload and energy expenditure while cycling. Therefore, we calculated the average CPM and MET-value for all data points while cycling. Mean CPM during cycling was 1,157, with a corresponding MET-value of 5.0. A MET-value of 5.0 equalled a CPM value of ≈4,300 while walking. Hence, we calculate the underestimation of CPM during cycling to be 73% ((1,157/4,300)*100). However, due to the large variations in CPM obtained while cycling, this estimate is uncertain. Nevertheless, as cycling is a common activity both for leisure activities as well as for transport, this estimate is useful for researchers aiming to assess physical activity in populations were cycling is a common activity.

Several limitations of the validation study presented in **Paper IV** should be acknowledged. The study sample was relatively small (n=20), which might introduce the risk of making type II errors. However, the sample was relatively homogenous with regards to age, height and weight, thereby reducing the risk of the results being affected by extreme values in the sample. Furthermore, we were able the discriminate between treadmill speeds and gradients, which suggest that the sample size was adequate for the hypothesis of the study. Furthermore, the use of $3.5\ ml \cdot kg^{-1} \cdot min$ as the standard resting metabolic rate is debated and ideally it should have been individually measured. However, it is unlikely that this would have affected the relationship between CPM and METs.

Methodological considerations

In epidemiological studies, the goal is to achieve the highest degree of accuracy and generalizability in making estimates of outcomes and/or exposures. In order to achieve such accuracy, the outcomes or exposures must be estimated with little as little error as possible. There are many potential sources of errors when obtaining information from participants in a study, and they are traditionally classified as either random or systematic. Random errors are most often attributable to measurement precision, sample size, and/or study design, and can be viewed upon as the opposite to precision. Systematic errors include selection bias, information bias and confounding, and the opposite of bias is validity. Awareness of random and systematic errors and how they can impact study results is of vital importance in order to draw appropriate conclusions (222). Before such errors are discussed, some comments about the study design are given.

Study design

Research can crudely be divided into observational and experimental studies. Observational studies include cross-sectional, case-control, and cohort studies. Experimental studies are those in which the researcher affects what happens to all or some of the participants (223). In the following, emphasis will be on observational study designs, particularly cross-sectional, as this is the study design used in the study that **Papers I-III** are based on. Research designs differ in strength regarding the causality they allow to be established (176). Experimental designs using a control group and randomly assigning participants to undergo intervention or not, are considered the best design to evaluate causality (222). However, such designs are rarely used for epidemiological purposes.

The cross-sectional design of the study in **Papers I-III** prohibits the ability to distinguish between cause and effect. This is because the exposures and outcomes are measured at the same time-point and thus it is not possible to determine whether the exposures are really exposures for the outcomes or if they are consequences of the perceived outcomes. However, cross-sectional studies are suitable for obtaining prevalence data and generating hypothesis. The establishment of physical activity prevalence in the Norwegian population is one the main aims of this thesis, and thus is the cross-sectional design appropriate.

Random errors

Sample size

Random errors represent the variability in the data that we cannot really explain, such as sampling variation and random measurement variation (222). Sampling variation occurs as no sample will be identical to the target population. Consequently, the estimates obtained will vary from sample to sample, although the confidence intervals will inform how close the estimate is likely to be to the underlying true population value. Sampling variation can be reduced by increasing the sample size (222). In **Papers I-III**, the final sample consisted of 3,485 individuals, which gave high precision both in the overall estimates and estimates in subgroups based on age and gender. The study was initially powered to detect differences at a minimum of 7%, when comparing subgroups of age and sex. Although post-hoc size calculations are not recommended, we observed smaller variations in the primary outcome variable (overall physical activity) compared with the variation we based the power calculations on. This indicates that the sample size we calculated to be sufficient in order to detect a 7% difference between groups, were in fact a conservative estimate. Thus, sampling variation is probably to the reliability of the results of the study**.** However, although overall sample size was large, a very limited percentage of the final sample originated from countries other than Norway (2%). This prohibited derivation of estimates of physical activity related to ethnicity, because precision would be jeopardized and the risk of making type II errors would be large.

Measurement variation

Random measurement variation may lead to a reduction of the reliability of the measurements, and the risk of such error can be minimized by securing precision in measurement (222). The primary outcome variables in most of the analyses in **Papers I-IV** are derived from the accelerometers. This measure has many advantages over self-reports of physical activity, primarily not being dependent on participant interaction (46), and is considered to provide valid and reliable measures of physical activity. Although the measured variation in physical activity is generally large, this is because of inter-individual variation in behaviour, and not in measurement variation. The ActiGraphs displays a high degree of reliability, both in mechanical and structured free-living settings (79;81;95), and is a valid measure of free-living physical activity (46) and we believe that random variation in the measurements of physical activity is not a concern for the results of the study. However, several of the other included variables (e.g. body weight, height, health status, level of education, and correlates of physical activity) are self-reported which might reduce the precision of the measure. As a result of this decreased precision, some of the associations studied might be impaired due to random measurement variation.

Systematic errors

Selection bias

Bias is another term for systematic error. A study can be biased because of the way participants have been selected (selection bias), the way the variables have been measured (information bias), or some confounding factors not completely controlled for (confounding) (222).

Selection bias occurs when the sample that is under study is not representative of the target population on which conclusions are to be drawn. A limitation of **Papers I-III** is the relatively low response rate, which might introduce selection bias and thereby jeopardize the generalizability of the study. Given the present risk of selection bias, it is important to describe the non-responders in the study since we aim to generalize the findings to the general Norwegian population. Analysis of the non-responders in our study by the use of registry linkage showed that they were more likely to be either at the younger or older end of the age spectrum, unmarried and not of Norwegian origin and had lower educational and income levels, compared with the responders. This has also been observed in most population-based surveys (224;225), and therefore we cannot rule out the possibility that the results of **Papers I-III** are somewhat overestimated because of selection bias. However, we recognize that the overall response rate in the study is comparable with similar studies (102;123;226), and significantly higher than in commercial surveys. Response rates can be calculated and presented in several ways and we believe that the response rate we report is an honest and reliable calculation of the actual participation in the study. It is however the author`s impression that in the general epidemiological literature, unless response rates are good, they are either not reported or masked by e.g. reporting percent of the included sample that completed the study, with no information regarding the invited sample.

Furthermore, it is not evident that a higher response rate would have eliminated the possibility of selection bias. Several studies have demonstrated only moderate changes in prevalence estimates and socio-demographic distribution when comparing results from different studies with response rates ranging from 30% to 70% (224;227). The inclusion of participants from throughout Norway, and similar prevalence of overweight or obesity and diabetes type 2 as in other national estimates strengthens generalizability of the study. This indicates that the results presented in **Papers I-III** have a general validity corresponding to similar studies and that the study sample was fairly representative of the general population in Norway. In addition, it is reasonable to assume that a larger proportion of people than reported never received the invitation to participate, or were unable to process the information. Although we did not investigate the reasons why some chose not to participate in the present study, invitees or their relatives occasionally reported that the invitee was dead, institutionalized or cognitively not able to participate. The overall response rate

Information bias

Information bias in epidemiologic studies is present when information collected about or from study participants is erroneous, and can occur regardless of whether the variables are obtained using objective (accelerometers) or subjective (questionnaires) methods. Imperfect measures obtained from questionnaires may be biased due to a tendency to exaggerate or underestimate certain behaviour (social desirability bias) and because certain recalling certain behaviours (i.e. physical activity) is a complex cognitive task (recall bias) (26). Social desirability bias and recall bias might have led to an over-report of physical activity, if physical activity had been self-reported. It is commonly known that this method over report PA, and comparisons of self-reported with objectively measured PA from the present study show that the estimates obtained vary greatly (unpublished data). The use of an objective measure of physical activity eliminates social desirability and recall bias related to the main outcome variable, but might introduce other types of information bias.

Reactivity

Another potential limitation is the possibility that the participants altered their behaviour while under study, which is a common phenomenon (i.e. the Hawthorne effect). The potential reactivity to wearing an activity monitor has not been studied extensively. During four one-week periods, Clemes and Parker (228) had an adult sample wear pedometers. Blinded to the aim of the study, participants were informed that the pedometer was a ¨body posture monitor¨ prior to the first one-week period (covert monitoring). Following the covert monitoring period, the participants wore the pedometer under three more conditions (sealed, unsealed, or unsealed while recording daily step in an activity log). Although the week of wearing an unsealed pedometer and registering steps yielded higher step count compared with the covert period, no statistical differences was reported between the covert and sealed period. Based on this study, reactivity is probably not a source of concern in our study, but cannot completely be ruled out. The ActiGraphs have no display and therefore provide no information of activity level while they are worn.

Shortcomings of uniaxial accelerometry

The ActiGraph GT1M used in the study is waist-mounted and uniaxial, and is therefore likely to miss upper body movement such as weight training and carrying heavy loads (24). Other activities likely to be underestimated are swimming and cycling. Of the activities poorly registered by the monitor, cycling was by far the most common. Participants reported the total minutes spent cycling (i.e. bicycling for leisure or transport or exercising on a stationary bike) during the 7 days of wearing the accelerometer, and the average amount was 22 minutes (data not shown).

To investigate to potential underestimation of overall physical activity due to cycling in the results presented **Papers I-III**, we used the results presented in **Paper IV**. Mean CPM during cycling was 1,157, with a corresponding MET-value of 5.0. A MET-value of 5.0 equalled a CPM of ≈4300 while walking. This indicates that ≈3143 counts are lost every minute during cycling, compared with walking (4,300-1,157). The average CPM for the entire sample in **Papers I-III** was 338. CPM is a function of total counts registered divided by total amount of valid wear time. The average total wear time was 5,957 minutes and total number of accumulated counts was 2013466. Thus, a total of 69,146 counts (3134 counts*22 minutes) are missing from the CPM-equation due to cycling. If we add the missing counts to the CPM-equation, the new CPM is 350. Compared with the unadjusted CPM, the inclusion of the counts that is not registered during cycling represents a difference of 3%. This indicates that cycling is not a threat to the validity of the results of **Papers I-III** because of the modest amount of cycling reported. However, great care should be taken when physical activity is assessed using uniaxial accelerometers in populations with high prevalence of cycling, as the size of the underestimation of overall physical activity increases with increasing amounts of cycling. However, accelerometers are sensitive to ambulatory activities such as walking. The participants reported walking as the most frequently performed during the study period, and this diminishes the possibility that physical activity level was underestimated in **Papers I-III** due to the shortcomings of uniaxial accelerometry.

Confounding factors

Confounding can be thought of as a mixing of effects (222). Several potential confounding factors were included in the analyses in the papers. Examples of potential confounders are those included in the regression analysis in **Paper II,** where the association between overall PA and BMI-defined weight category was assessed. Age, sex, level of education, smoking, and self-reported health were included because of their known association with body weight. Inclusion of potential confounders in multivariate analysis enables the researcher to isolate the associations between the variables of interests. Nevertheless, confounding by variables not measured can never be ruled out, and examples of such variables for the mentioned example are genetics and diet.

A potential confounder of the results in **Papers I-III** is seasonality of physical activity. Season of the year has been identified as a potential factor that affects physical activity in both children (229) and adults (230;231). Norway is climatically diverse and due to its high latitude (latitude range: 57°N to 72° N, longitude: 10° E) there are large variations in daylight. Therefore, it is plausible that physical activity is influenced by season. The data collection went on for one full year (Figure 3). When exploring the effects of season, we observed that overall activity level varied somewhat with season (data not shown), even after adjusting for test-centre. Activity levels were somewhat lower levels during the winter, compared with the rest of the year. However, these effects were small and the adjusted and unadjusted (for season) overall physical activity levels differed by less than 1%, thus is the seasonality not likely a source of concern.

Accelerometer data reduction and interpretation

The use of objective measures of physical activity facilitates comparisons between studies and populations. However, differences in study protocols and in algorithms used to reduce the raw data from the accelerometer can affect the accelerometer-derived outcome variables of physical activity. Hence, care must be taken when comparing results across studies.

Hagstrømer et al (71) presented accelerometer-determined adherence rates to physical activity recommendations to be less than 1%, when counting minutes in bouts of MVPA lasting at least 10 minutes. When compared with the estimates presented in **Paper I** (18-22%), the Swedish estimate appears to be extremely low. However, there are differences in how adherence is operationalized in the two studies. In the Swedish study, participants had to exceed the minimum threshold of at least 30 minutes of continuous moderate-to-vigorous activity on every valid day of accelerometer wear in order to meet the recommendations. In our study, participants had to accumulate a mean daily amount of 30 minutes of continuous moderate-to-vigorous activity to meet the recommendations. Using this operationalization, we allow for days with less activity if they are accompanied by days of more activity. We believe that this operationalization of the recommendations is more in line with the evidence that the recommendations are based upon, which are an estimate of a weekly dose of physical activity needed to maintain health.

The severity of not acknowledging these methodological differences can be illustrated by the following: By simply comparing the estimates of adherence, one could easily conclude that 20 times as many Norwegians compared with Swedes meet the recommendations, when in fact activity levels are very similar. Following the initial publication of the Swedish study (71), the data was reanalyzed in order to be compared with data from the NHANES-study (142). Although the reanalyzed data does not state adherence to physical activity recommendations, the number of minutes of moderate-to-vigorous physical activity accumulated in bouts are almost identical to those presented in **Paper I**. It is therefore not likely that the Swedish adherence to the recommendations would differ substantially from the Norwegian estimate if they were operationalized in a similar way.

Conclusions

Based on the results presented in **Papers I-IV** the following conclusions can be drawn:

1. Contradictory to historical data on levels of physical activity, no differences between the sexes were observed for overall physical activity or steps taken per day. Activity levels were relatively stable until reaching approximately retirement age, after which activity levels decline. The high level of sedentary behaviour and low adherence to physical activity recommendations indicate that population levels of physical activity are low. Adults and older people spend most of their time pursuing sedentary behaviours and four out of five do not meet current PA guidelines.

2. Both indicators of overall physical activity and intensity-specific physical activity differed between BMI-categories. The differences in overall physical activity between the BMI-categories were most pronounced on weekends, where the obese participants had a level of overall physical activity 25% lower compared with the normal weight participants. The risk of being overweight or obese decreased linearly across increasing quintiles of physical activity.

3. Several correlates that might be important targets for intervention were identified. These variables included self-efficacy, perceived behavioural control and physical activity identity. The observed interaction effects of the demographic and biological variables on the relationships between the correlates and physical activity did not seem to have a sufficient impact to justify interventions that are specific for sex, weight status, or level of education.

4. The activity monitor used to assess the physical activity in **Papers I-III**, the ActiGraph GT1M, provided valid measures of overall physical activity during walking in the light-to-moderate intensity range. The GT1M discriminated between level and graded walking, but underestimated energy expenditure during uphill walking and overestimated energy expenditure during downhill walking. There was no association between energy

expenditure and accelerometer data output during cycling. We crudely estimated that the GT1M underestimates overall physical activity by ≈73% during cycling, compared with walking. The modest amount of cycling reported by the participants in the study (**Papers I-III)**, indicate that the population estimates of physical activity presented in this theses are not influenced by the GT1M inability to capture energy expenditure while cycling adequately.

Recommendations for future research

This thesis presents novel data regarding the population levels of physical activity in Norwegian adults and older people. However, to assess trends in physical activity and to evaluate health initiatives to increase physical activity in the population, a recurring surveillance system must be established using identical methods and data reduction procedures as presented in this thesis. That would allow for for the linkage of longitudinal data on objectively measured physical activity and sedentary behavior with various health outcomes, thereby potentially disclose the dose-response relationship between physical activity and health.

In order to ensure representability and generalizability of such a surveillance system, we need to develop strategies that will counteract the observed decline in response rates in epidemiological studies. The aetiology behind the declining rates is complex, but probably comprises a certain survey fatigue in the general population. To counteract this is no simple task and might include offering of worthwhile incentives, avoidance of traditionally busy periods such as holidays, and increased use of reminders.

Furthermore, we should strive to accomplish some sort of international consensus on how to process and present accelerometer data. Although great progress has been made in this field, comparability between studies is still jeopardized by the use of different protocols and procedures. With that being said, the great heterogeneity among humans with regards to biological variables, social factors, and the large variations in physical activity might prevent such a consensus to be made. A useful compromise might be to develop guidelines that states minimal requirements for how and what to reported when using accelerometers.

As the methodological advances drives physical activity epidemiology further, with the use of combined methods, triaxial accelerometers and more advanced use of the raw acceleration signal, it is vital that researchers ensure the retrospective comparability of their studies.

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Paper I

Accelerometer-Determined Physical Activity in Adults and Older People

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ABSTRACT

HANSEN, B. H., E. KOLLE, S. M. DYRSTAD, I. HOLME, and S. A. ANDERSSEN. Accelerometer-Determined Physical Activity in Adults and Older People. *Med. Sci. Sports Exerc.*, Vol. 44, No. 2, pp. 266–272, 2012. **Purpose**: There is a lack of large-scale comparable data on the population levels of physical activity (PA) and sedentary activity. We conducted a cross-sectional population-based multicenter study to describe the levels of PA and sedentary activity and to determine adherence to current national PA recommendations in Norwegian adults and older people. **Methods**: In 2008 and 2009, PA was assessed objectively for seven consecutive days using the ActiGraph GT1M accelerometer in 3867 participants age 20–85 yr. A total of 3267 participants provided valid PA assessments that met all inclusion criteria. **Results**: Women and men did not differ in the overall activity levels (335 and 342 counts per minute, respectively) or in steps per day (8113 and 7951 steps per day, respectively). However, for intensity-specific PA, men accumulated significantly more minutes of sedentary activity and moderate-to-vigorous PA (MVPA) compared with women (557 vs 533 min of sedentary activity, $P \leq 0.001$ and 35 vs 33 min of MVPA, $P = 0.01$). Both overall activity levels and steps per day remained steady with age, until 65 yr, after which activity levels declined. **Conclusions**: Overall, the study sample spent 62% of their time being sedentary, 25% in low-intensity PA, 9% in lifestyle activity, and 4% in MVPA. One in five people met current national PA recommendations. These results suggest that adults and older people spend the majority of their time being sedentary and that adherence to PA recommendations is low. **Key Words:** ACTIGRAPHY, EPIDEMIOLOGY, CROSS-SECTIONAL STUDIES, MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY, SEDENTARY ACTIVITY

Regular physical activity (PA) is beneficial for preventing noncommunicable diseases and obesity (34). Although the numerous health benefits of PA are well documented, population levels are suspected to be low (11). Therefore, increasing PA and decreasing sedentary activity are important targets of public health promotion. Although both global (2,33) and national (20) health initiatives include focus on national monitoring of PA levels, there is a lack of large-scale comparable data on PA at the population level.

PA epidemiology has traditionally been based on self-report methods, which by nature are susceptible to many forms of bias (25). The method has substantial limitations for accurately quantifying PA levels and often produces contradictory evidence compared with measurements based on objective methods (22). This contradictory evidence hampers comparisons between studies and makes it difficult to assess the population level of PA adequately.

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Submitted for publication March 2011.
Accepted for publication July 2011.

0195-9131/12/4402-0266/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e31822cb354

Because of the limitations of self-report, interest in objective measurements of PA has increased (27). The use of accelerometers allows for accurate measurement of intermittent and spontaneous intensity-specific PA and is currently viewed as the minimum standard for PA assessment in epidemiological research (3).

In children, data on objectively measured PA are accumulating rapidly, and large-scale studies from several countries have compared across groups on the basis of sex, age, social class, region, and country (12,23,24). We are aware of only two studies that used objective measurement of PA in nationally representative samples of adults and older people in Western populations and one study in an Asian population (4,21,28). Hence, there is a need for more studies in the adult population.

The purpose of this study was to assess objectively the levels of PA and sedentary activity in adults and older people living in Norway. We wanted to explore the overall activity levels by age and sex and to determine the percentage of the population meeting the current national PA recommendations to accumulate at least 30 min of daily moderate-intensity PA.

METHODS

Design. This was a multicenter study involving 10 regional test centers throughout Norway. A representative sample of 11,515 adults (20–85 yr) from the areas surrounding each test center was drawn from the Norwegian population registry. The only inclusion criterion was that the participants had to be between ages 20 and 85 yr. The recruitment strategy included several mechanisms, such as local media coverage, personalized invitational letters, and offers of individual survey reports. The study information and informed consent were distributed via mail to the representative sample; 267 invitations were returned because of an unknown address. This resulted in an eligible sample of 11,248 individuals invited to participate. Written informed consent was obtained from 3867 subjects (34%). Three hundred eight-two subjects did not return any data, giving a final sample of 3485 participants. Of the final sample, 86 did not wear the accelerometer, 14 had defective monitors, and 118 participants were excluded for providing less than 4 d of valid accelerometer data, giving an analyzed sample of 3267 participants (94% of the final sample) with at least 4 d of valid accelerometer recordings. The study was approved by the Regional Ethics Committee for Medical Research, the Norwegian Social Science Data Services, and the Norwegian Tax Department.

Assessment of PA. The ActiGraph GT1M (ActiGraph, LLC, Pensacola, FL) was used to assess the participants' PA level. The accelerometer is lightweight (27 g) and small (3.8 × 3.7 × 1.8 cm) and comprises a solid-state monolithic accelerometer that uses microprocessor digital filtering. The accelerometer's response to 1*g* acceleration of the earth is fixed upon installing it into the circuit, which removes the need for unit calibration (13). The accelerometer registers vertical acceleration in units called counts and samples data at a rate of 30 times per second in user-defined sampling intervals (epochs). The number of steps per day was registered as number of cycles of the signal, which is claimed to be representative of the number of steps taken (14).

The participants received a preprogrammed accelerometer by mail. Standardized instructions included how to wear the accelerometer over the right hip in an elastic band while awake and to remove it for water activities such as swimming. The participants wore the accelerometer for seven consecutive days. After the registration period, the participants returned the accelerometers by prepaid express mail.

The accelerometers were initialized and downloaded using the ActiLife software provided by the manufacturer (ActiGraph LLC). The data were collected in 10-s epochs. To analyze the data, the 10-s epochs were collapsed into 60-s epochs for comparisons with other studies. The data were reduced using an SAS-based software program (SAS Institute, Inc., Cary, NC) called the CSA Analyzer (csa.svenssonsport.dk). Data were included if the subject had accumulated a minimum of 10 h of valid activity recordings per day for at least 4 d, which is in accordance with similar studies (5) and in line with the suggestions by Trost et al. (29). Wear time was defined by subtracting nonwear time from 18 h (all data between midnight and 6:00 a.m. were excluded). Nonwear time was defined as intervals of at least 60 consecutive minutes with zero counts, with allowance for 1 min with counts greater than zero.

The PA levels assessed by the accelerometer are presented as 1) mean counts per minute (cpm), 2) number of minutes spent in intensity-specific categories, 3) number of steps registered per day, 4) percentage of the study population meeting the national PA recommendations, and 5) percentage of the study population accumulating ≥10,000 steps per day.

Counts per minute (cpm) is a measure of overall PA and was expressed as the total number of registered counts for all valid days divided by wearing time. To identify PA of different intensities, count thresholds corresponding to the energy cost of the given intensity were applied to the data set. Sedentary activity was defined as all activity below 100 cpm, a threshold that corresponds with sitting, reclining, or lying down (8,19). Low-intensity PA was defined as counts between 100 and 759, and time in lifestyle activity (e.g., slow walking, grocery shopping, vacuuming, and child care) was defined as counts between 760 and 2019 (5,18). Moderate-to-vigorous PA (MVPA) is equivalent to an energy expenditure of ≥3 METs and was defined as all activity ≥2020 cpm (28). This level of activity corresponds to walking at speeds of ≥78 $m \cdot min^{-1}$ as well as more vigorous activities (18). The numbers of minutes per day at different intensities were determined by summing all minutes where the count met the criterion for that intensity, divided by the number of valid days.

Adherence to the current Norwegian PA recommendations was examined by determining the percentage of participants accumulating a minimum of 30 min of daily moderate PA in bouts of 10 min or more (1). All MVPA that occurred in bouts of ≥10 min (with allowance for interruptions of 1–2 min) during the registration period was divided by the number of valid days to examine whether PA recommendations were met. This definition allowed participants to have longer bouts of activity on certain days and to be less active on other days and still meet the recommendations.

Other measures. Data on demography, anthropometry, education, prevalence of disease, and tobacco use were collected from a questionnaire. Body mass index (BMI) was computed as weight (kg) divided by height squared (m^2). Overweight and obesity were defined as a BMI of 25–29 and ≥30, respectively (32). Educational attainment was categorized into four groups: less than high school, high school, less than 4 yr of university, and university for 4 yr or more. Participants also reported the type of PA they most commonly participated in.

Dropout analysis. Statistics Norway completed a dropout analysis that compared factors between those who responded positively and those who were invited but did not respond. The factors analyzed were age, sex, country of birth, number of children, civil status, level of education, and level of income. Level of education was the strongest predictor of a positive response. The probability of a positive response increased with increasing age to 50–59 yr and with increasing number of children up to three children but leveled off above these values. Women had a higher

TABLE 1. Physical characteristics of the study sample (n = 3485) by age and sex.

Variable	20–64 Women	20–64 Men	65–85 Women	65–85 Men	All Women	All Men
n	1564	1330	295	296	1859	1626
Age (yr)	43.8 ± 11.6	45.2 ± 11.8*	71.9 ± 5.7	71.8 ± 5.3	48.3 ± 15.0	50.0 ± 15.0
Height (cm)	167.5 ± 6.0	180.7 ± 6.3*	163.8 ± 5.4	177.2 ± 6.7*	166.9 ± 6.1	180.1 ± 6.5
Weight (kg)	69.8 ± 12.5	85.9 ± 12.8*	66.3 ± 10.2	81.1 ± 11.7*	69.3 ± 12.3	85.0 ± 12.8
BMI (kg·m^{-2})	24.9 ± 4.4	26.3 ± 3.6*	24.7 ± 3.5	25.8 ± 3.2*	24.9 ± 4.3	26.2 ± 3.5
Overweight (%)	29.2	45.9*	32.2	44.1*	29.7	45.6
Obesity (%)	11.4	14.0*	7.8	10.1*	10.9	13.3
Educational level (%)						
Less than high school	8.4	9.7	37.3	31.6	12.9	13.7
High school	35.9	41.4	36.2	35.8	36.0	40.4
University <4 yr	27.0	22.3	14.6	18.6	25.0	21.6
University ≥4 yr	28.7	26.5	11.8	14.0	26.1	24.3

Data are presented as mean ± SD, unless stated otherwise.
* P < 0.05 for sex within age group.

probability of a positive response compared with men, as did married individuals compared with unmarried or divorced individuals. People born outside of Western Europe had a lower probability of a positive response compared with those born in Western Europe.

Statistics. All statistical analyses were performed using PASW Statistics 18 for Windows (IBM Corporation, Somers, NY). Descriptive data are presented as proportion, mean and SD or SEM, and 95% confidence interval (CI) where appropriate. Because of the small differences in overall PA level across the age range of the study population, the data are presented for two main age groups: 20–64 and 65–85 yr. Overall activity level (cpm) varied between test centers and with age, and these variables were considered potential confounders in the association analyses between overall activity level and other factors. Registered monitor wearing time also varied by age and was considered a potential confounder where appropriate. Differences between groups were assessed using ANCOVA with Bonferroni adjustments for multiple comparisons. Differences between the proportions of individuals meeting PA recommendations were assessed using chi-square tests. Linear regression analyses were used to estimate the changes in activity with increasing age. All tests were based on two-sided probability.

EPIDEMIOLOGY

RESULTS

The physical characteristics of the study population are presented in Table 1. The final sample comprised 1859 women and 1626 men, whose mean ± SD ages were 48.3 ± 14.9 and 50.0 ± 14.9 yr, respectively. Overall, 37% and 12% of the participants were classified as overweight and obese, respectively. Twenty-two percent reported being either current smokers or current users of smokeless tobacco, and 33% reported having smoked previously. The most commonly reported diseases and conditions were rheumatism (10%), asthma (9%), poor mental health (9%), cardiovascular disease (5%), cancer (5%), type 2 diabetes (3%), and osteoporosis (2%).

Participants achieved a mean of 6.8 d of valid activity recordings and a mean daily accelerometer wear time of 14.6 ± 1.1 h. The total PA (cpm) and number of steps taken per day are presented in Table 2; cpm did not differ between men and women in either age group. The participants age 20–64 yr had a higher cpm than did those age 65–85 yr; the mean difference was 70 cpm (95% CI = 58–83). Within the age group of 20–64 yr, cpm did not change with increasing age. By contrast, in the age group of 65–85 yr, the estimated decrease in cpm was 9 per year (95% CI = 7–12). Women in the 20- to 64-yr age group achieved, on average, 256 more steps per day compared with men (95% CI = 30–474). As with cpm, steps taken per day were stable across age in the 20- to 64-yr age group but decreased by an estimated 215 steps per year in the older age group (95% CI = 168–263).

Table 3 presents the means for minutes per day of total accumulated time spent in PA at different intensities and for minutes per day spent in bouts of ≥10 min of MVPA.

TABLE 2. Mean ± SEM accelerometer counts per minute and mean ± SEM steps per day, by age and sex.[a]

Age	Women n	Women Mean ± SEM	Men n	Men Mean ± SEM	All n	All Mean ± SEM	Mean Difference (Men − Women)	95% CI
Counts per minute								
20–64	1465	345 ± 3.8	1242	349 ± 4.0	2707	347 ± 2.8	4	−6 to 14
65–85	282	287 ± 9.5	278	305 ± 9.6	560	296 ± 7.6	18	−5 to 41
All	1747	335 ± 3.3	1520	342 ± 3.5	3267	338 ± 2.4	7	−2 to 16
Steps per day[b]								
20–64	1457	8440 ± 81	1235	8188 ± 85	2692	8314 ± 61	−252*	−474 to −30
65–85	282	6565 ± 204	277	6750 ± 205	559	6658 ± 163	−185	−300 to 670
All	1739	8113 ± 71	1512	7951 ± 76	3251	8038 ± 52	−162	−366 to 42

P < 0.05 for sex within age group.
[a] All values are adjusted for age and test center.
[b] Sixteen participants have no step data.

TABLE 3. Mean ± SEM minutes per day[a] of sedentary activity, low PA, lifestyle PA, MVPA, and time spent in bouts of MVPA.

	Women		Men		All			
Age	*n*	Mean ± SEM	*n*	Mean ± SEM	*n*	Mean ± SEM	Mean Difference (Men − Women)	95% CI
Sedentary activity								
20–64	1465	530 ± 2.0	1242	555 ± 2.2	2707	543 ± 1.5	25*	19 to 31
65–85	282	545 ± 4.4	278	567 ± 4.4	560	556 ± 3.1	22*	10 to 34
All	1747	533 ± 1.8	1520	557 ± 2.0	3267	545 ± 1.3	24*	19 to 29
Low-intensity PA								
20–64	1465	238 ± 1.3	1242	207 ± 1.5	2707	223 ± 1.0	−31*	−35 to −28
65–85	282	213 ± 2.8	278	186 ± 2.8	560	200 ± 2.0	−27*	−35 to −19
All	1747	234 ± 1.2	1520	203 ± 1.3	3267	219 ± 0.9	−31*	−34 to −27
Lifestyle PA								
20–64	1457	78 ± 0.9	1242	82 ± 1.0	2707	80 ± 0.7	4.3*	1.6 to 6.9
65–85	282	60 ± 2.0	278	61 ± 2.0	560	60 ± 1.5	0.5	−5.3 to 6.2
All	1747	75 ± 0.8	1520	79 ± 0.9	3267	77 ± 0.6	3.7*	1.3 to 6.1
MVPA								
20–64	1457	34.3 ± 0.6	1242	36.5 ± 0.7	2707	35.4 ± 0.4	2.3*	0.5 to 4.0
65–85	282	25.6 ± 1.4	278	30.2 ± 1.5	560	27.9 ± 1.0	4.6*	0.6 to 8.6
All	1747	32.8 ± 0.6	1520	35.4 ± 0.6	3267	34.1 ± 0.4	2.6*	1.1 to 4.3
Bouts of MVPA								
20–64	1457	18.2 ± 0.5	1242	16.1 ± 0.5	2707	17.5 ± 0.4	−2.1*	−3.5 to −0.7
65–85	282	15.6 ± 1.3	278	18.4 ± 1.3	560	17.0 ± 0.9	2.8	−2.7 to 6.2
All	1747	18.3 ± 0.5	1520	16.5 ± 0.5	3267	17.4 ± 0.3	−1.8*	−3.1 to −0.5

$P < 0.05$ for sex within age group.
[a] All values are adjusted for wear time, age, and test center.

Men in both age groups spent more time being sedentary and achieved more minutes of MVPA compared with women. Women in both age groups completed more minutes of low-intensity PA compared with men. In the 20- to 64-yr age group, the number of accumulated minutes in the different intensity categories did not increase with age, except for small changes in low-intensity PA and bouts of MVPA for men and small changes in lifestyle activities for women. Men showed an estimated decrease of 0.3 min of low-intensity PA (95% CI = 0.1–0.5) and increase of 0.1 min of MVPA per year (95% CI = 0.04–0.2). Women showed an estimated increase in lifestyle activity of 0.2 $\text{min}\cdot\text{yr}^{-1}$ (95% CI = 0.08–0.4). Changes with age were more apparent in the 65- to 85-yr age group. Women and men showed a yearly estimated increase in the amount of sedentary activity of 4.4 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 2.8–6.1) and 3.2 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 1.5–4.9), respectively. The yearly estimated low-intensity PA and lifestyle activity decreased by 1.6 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.6–2.7) and 1.5 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.8–2.3) for women and 0.7 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.3–1.7) and 1.4 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.6–2.2) for men. The yearly estimated MVPA decreased by 1.3 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.8–1.7) in women and by 1.1 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.5–1.7) in men. Similar but somewhat smaller changes were found for bouts of MVPA; the yearly estimated MVPA decreased by 0.9 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.5–1.3) in women and by 0.7 $\text{min}\cdot\text{d}^{-1}$ (95% CI = 0.2–1.3) in men.

The prevalence of adherence to the PA recommendations is shown for sex and age groups in Table 4. Overall, 20.4% of the study population met the PA recommendations, and this percentage did not differ between women and men. A slightly higher percentage of the participants accumulated ≥10,000 steps per day, compared with the PA recommendations (22.7% vs 20.4%, respectively). Sixty-six percent of participants meeting the PA recommendations also accumulated ≥10,000 steps per day.

DISCUSSION

The adults and older people who participated in this study spent 62% of their time awake being sedentary. Twenty percent of the study population met the current PA recommendations, and 22.7% accumulated ≥10,000 steps per day. Overall PA did not differ between sexes, although women in the younger age group (20–64 yr) accumulated, on average, 3% more steps per day compared with men in that age group. Both overall activity levels and steps per day were steady with age until reaching 65 yr, after which these values

TABLE 4. Prevalence (95% CI) of the population meeting current PA recommendations.

	Women	95% CI	Men	95% CI	All	95% CI	Mean Difference (Men − Women)	95% CI
≥30 min of daily MVPA, in bouts of 8–10 min								
Age								
20–64	21.8	19.7 to 23.9	18.4	16.2 to 20.6	20.2	18.7 to 21.7	−3.4*	−6.4 to −0.4
65–85	18.8	14.2 to 23.4	23.0	18.1 to 27.9	20.9	17.5 to 24.3	4.2	−2.5 to 10.9
All	21.4	19.5 to 23.3	19.2	17.2 to 21.2	20.4	19.0 to 21.8	−2.2	−5.0 to 0.6
≥10,000 steps per day								
Age								
20–64	26.7	24.4 to 29.0	21.7	19.4 to 24.0	24.4	22.8 to 26.0	−5*	−8.2 to −1.8
65–85	13.8	9.8 to 17.8	14.8	10.6 to 19.0	14.3	11.4 to 17.2	1	−4.8 to 6.8
All	24.6	22.6 to 26.6	20.4	18.4 to 22.4	22.7	21.3 to 24.1	−4.2*	−7.1 to −1.3

$P < 0.05$ for sex within age group.

decreased. Men accumulated more minutes of sedentary activity, lifestyle activity, and MVPA compared with women, whereas women accumulated more minutes of low-intensity PA and time accumulated in bouts of MVPA.

From studies using self-report, men traditionally report a higher level of PA compared with women (16,30). We observed no sex differences in overall PA in the present study. Similar findings have been reported in a Swedish study of accelerometer-determined PA (4). The authors noted that the assessment methods in older studies were designed primarily to capture leisure time exercise and not overall PA. The inconsistency between studies using self-report and those using objective measures might be attributable to the fact that females may spend more time doing activities that are normally not classified as real exercise, such as walking and household and child care activities. This assumption is supported by the observation that the women in the present study accumulate more minutes of low PA than men and that a higher percentage of women accumulated ≥10,000 steps per day. In light of this, the commonly accepted assumption that men are more physically active than women may no longer be valid, at least not in Scandinavia.

In 2005–2006, PA was assessed by accelerometry in 2299 randomly selected 9- and 15-yr-old Norwegian children (12). Overall PA level (cpm) decreased from 9 to 15 yr to a similar extent in boys and girls (30% and 32%, respectively). Combining these results with our present results suggests that this decline continues into and throughout adulthood. From ages 15 to 20–64 yr, the activity seems to decline by 30% in females and 35% in males. Despite the decline in PA from childhood to adolescence and further into adulthood, the activity level seems to be stable in adulthood until about retirement age. From ages 50–64 to 65–74 yr, activity levels declined by 12% in women and 8% in men (data not shown). Moving from the 65- to 74- to the 75- to 85-yr age group was associated with an additional decline of 36% in women and 30% in men (data not shown). These results show that the age-related decline in PA is most prominent in the transitions from youth to adulthood and from adulthood to retirement age. There is no known biological reason for the decline in PA from youth to adulthood, although the decline in activity observed when entering the 65- to 85-yr age group might be attributed to changes in health status associated with aging.

Recent evidence has shown that time spent pursuing sedentary activities, independent of time spent in MVPA, is related to numerous health outcomes (6). In the present study, most time awake was spent either being sedentary (62%) or in low-intensity PA (25%) and lifestyle activity (9%). Similar distributions were reported in a sample of adult Australians (9). Interestingly, in this Australian study, sedentary activity correlated positively with a clustered metabolic risk score, whereas light PA correlated negatively, indicating that metabolic benefits can be obtained by replacing sedentary activity with light PA (9), a finding that is also supported by others (15).

Eighty percent of Norwegian adults and older people are not meeting the current PA recommendations of 30 min of daily MVPA, sustained in bouts of 8–10 min. In comparison, 80% of children and 50% of adolescents in Norway meet the current PA recommendations for children and adolescents of at least 60 min of daily MVPA (12). When considering adherence to PA recommendations, one must acknowledge that the current recommendations are built upon data from several different studies including randomized controlled trials and large cohort studies (1). However, the PA information is mainly based on self-report, and there is a lack of objectively assessed PA for health outcome in adults (7). Because self-report and accelerometers indeed have different qualities in measuring the level of PA, one should be aware that the cut points for objectively assessed PA and health outcome are not yet known and may be different from the cut points that are now commonly used. Further, standards for accelerometer data reduction have not been established, and the use of different algorithms for determining intensity-specific PA will affect outcomes such as time spent in MVPA (17). However, the reported age-related decline in adherence to the PA recommendations corresponds with the reported age-related decline in overall PA. In our study, women spent an average of 18 min in bouts of MVPA each day, whereas men spent 17 $min{\cdot}d^{-1}$. Although the difference is small, this sex difference in bouts of MVPA might indicate that women engage in more sustained PA such as walks or training sessions. This is consistent with similar findings for steps per day, and the results are also consistent with the Swedish study, in which women and men accumulated 17 and 16 min in bouts of MVPA per day, respectively. However, these values are higher than those reported in the 2003–2004 NHANES study (9 and 11 min for women and men, respectively) (5).

The major strength of this study is the use of accelerometers to assess PA and the large sample size. Participants showed good compliance with the protocol, and few data were lost because of insufficient wearing time or defective monitors. We acknowledge some limitations of our study. The main limitation is the low participation rate. The dropout analysis showed that the responses varied according to sociodemographic variables, which is consistent with other population-based studies in Western countries (26). Although the activity levels reported in the present study might be somewhat overestimated because of positive selection, it is not evident that a higher response rate would have eliminated the possibility of selection bias. Several studies have demonstrated only moderate changes in prevalence estimates and sociodemographic distribution when comparing results from different studies with response rates ranging from 30% to 70% (26,31). In addition, it is reasonable to assume that a larger proportion of people than reported never received the invitation to participate or were unable to process the information. Although we did not investigate the reasons why some chose not to participate in the present study, invitees or their relatives occasionally reported that the invitee was dead, institutionalized, or cognitively not able to participate.

Another limitation lies within the nature of a waist-mounted uniaxial accelerometer. Like any waist-mounted activity monitor, an accelerometer located on the trunk is likely to underestimate upper body movement such as weight training and carrying heavy loads (10). Other activities likely to be missed or underestimated are swimming and cycling. However, accelerometers are most sensitive to ambulatory activities such as walking. The participants reported walking as the most frequently performed during the study period, and this diminishes the possibility that PA level was underestimated because the participants performed other activities such as cycling.

The numerous advances in information technologies and the development of labor saving devices have engineered sedentary activity into the modern lifestyle, and many of the settings where PA had occurred naturally in the past have been removed. The accumulating body of evidence on PA at the population level as well as the numerous health risks associated with being sedentary clearly shows that strategies to reduce sedentary activity and increase PA need to be implemented at several levels. Policy makers must initiate strategies to change PA behaviors at the structural level, including transportation and urban planning.

CONCLUSIONS

The high level of sedentary activity and low adherence to PA recommendations reported in the present study and several other studies indicate that population levels of PA are low. Adults and older people spend most of their time pursuing sedentary activities, and only 20% of the population meets the current PA guidelines. To assess temporal trends in PA and to evaluate health initiatives taken to increase PA at the population level, it is vital that a recurring surveillance system be established using the same standardized methods and data reduction procedures.

The study was funded by the Norwegian Directorate of Health and the Norwegian School of Sport Sciences.

The authors thank all the test personnel at the 10 institutions involved in the study for their work during the data collection: Finnmark University College, Hedmark University College, Norwegian University of Science and Technology Social Research, Sogn og Fjordane University College, University of Agder, University of Nordland, University of Stavanger, Telemark University College, Vestfold University College, and the Norwegian School of Sport Sciences.

The authors declare that they have no competing interests.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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Paper II

OPEN ACCESS Freely available online PLOS ONE

Patterns of Objectively Measured Physical Activity in Normal Weight, Overweight, and Obese Individuals (20–85 Years): A Cross-Sectional Study

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Abstract

Background: The magnitude of the association between physical activity (PA) and obesity has been difficult to establish using questionnaires. The aim of the study was to evaluate patterns of PA across BMI-defined weight categories and to examine the independent contribution of PA on weight status, using accelerometers.

Methods: The study was a cross-sectional population-based study of 3,867 adults and older people aged 20–85 years, living in Norway. PA was assessed for seven consecutive days using the ActiGraph GT1M accelerometer. Anthropometrical data was self-reported and overweight and obesity was defined as having a body mass index (BMI) of 25–$<$30 and $\geq$30 kg/m^2, respectively.

Results: Overweight and obese participants performed less overall PA and PA of at least moderate intensity and took fewer steps, compared to normal weight participants. Although overall PA did not differ between weekdays and weekends, an interaction between BMI category and type of day was present, indicating a larger difference in overall PA between BMI categories on weekends compared to weekdays. Obese participants displayed 19% and 25% lower overall physical activity compared to normal weight participants, on weekdays and weekends, respectively. Participants in the most active quintile of overall PA had a 53% lower risk (OR 0.47, 95% CI: 0.37 to 0.60) for having a BMI above or below 25 kg/m^2, and a 71% lower risk (OR: 0.29, 95% CI: 0.20 to 0.44) for having a BMI above or below 30 kg/m^2.

Conclusions: Overweight and obese participants engaged in less overall PA and moderate and vigorous PA compared with normal weight individuals. The weight related differences in overall PA were most pronounced on the weekend and the risk of being overweight or obese decreases across quintiles of PA.

Citation: Hansen BH, Holme I, Anderssen SA, Kolle E (2013) Patterns of Objectively Measured Physical Activity in Normal Weight, Overweight, and Obese Individuals (20–85 Years): A Cross-Sectional Study. PLoS ONE 8(1): e53044. doi:10.1371/journal.pone.0053044

Editor: Noel Christopher Barengo, Fundación para la Prevención y el Control de las Enfermedades Crónicas No Transmisibles en América Latina (FunPRECAL), Argentina

Received July 3, 2012; **Accepted** November 23, 2012; **Published** January 7, 2013

Funding: The study was funded by the Norwegian Directorate of Health and the Norwegian School of Sport Sciences. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

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Introduction

The adverse effects of overweight and obesity on health are well documented [1]. The prevalence of overweight and obesity has reached epidemic proportions worldwide [2], and Norwegian data indicate that 44% of women and 65% of men (aged 40–42 years) are either overweight or obese [3]. Although obesity is a complex disorder, a secular decrease in energy expenditure is believed to be an important contributor to both the development and maintenance of obesity [4,5].

Nutrition surveys conducted in Norway in the past decades show that energy intake has not increased substantially [6], whereas average weight and prevalence of overweight and obesity have increased, during the same time period [3]. Although the composition of available foods may have changed, the increase in weight can be explained at least partly by a gradual decrease in habitual physical activity (PA), most notably by the apparent transition in occupational PA demands [7] and by increased car use and time spent at screen-based entertainment [8,9].

Although the extent to which PA affects body composition has been evaluated comprehensively and there is generally an inverse relationship between PA and body weight [8,10–16], the true magnitude of the association might be attenuated by a lack of precision in the measurement of PA and body composition [17–20]. Objective assessment of PA using activity monitors such as accelerometers can overcome many of the challenges related to self-reported measures of PA because they are unobtrusive and capable of accurately documenting the degree, nature, and pattern of PA [21,22].

Accelerometers have been applied in large population-based studies of adults and older people and showed that overall PA, intensity-specific PA and time spent being sedentary differed according to body mass index (BMI) [23–26]. However, no studies of objectively assessed PA in a nationally representative Norwegian sample of adults and older people exist. The study will extent current knowledge by including analyses regarding differences in activity patterns between BMI-categories and the individual contribution of PA on the risk of being overweight or obese. Detailed information on the differences across BMI-categories in the amount of overall PA, intensity-specific PA, sedentary behaviour, as well as the patterns of PA is vital for developing our understanding of the aetiology of obesity, and will be useful for planning interventions to prevent weight gain and to increase PA in the general population.

The aim of the present study was to examine the relationship between PA and BMI by; 1) describing overall PA and intensity-specific PA across BMI categories; 2) evaluating the hourly patterns of overall PA stratified by BMI category across weekdays and weekend days 3) determining the independent contribution of overall PA and MVPA on weight status.

Methods

Ethics Statement

All participants provided written informed consent and the study was approved by the Regional Committee for Medical Ethics and the Norwegian Social Science Data Services AS.

Study Design and Sample

The study was a cross-sectional multicentre study involving 10 test centres throughout Norway. Representative samples of 11,515 invitees (20–85 years) from the areas surrounding each test centre were randomly sampled from the Norwegian population registry. The study information and informed consent form were distributed via mail to the representative sample; 267 invitations were returned because of an unknown address, resulting in an eligible sample of 11,248 individuals. Written informed consent was obtained from a total of 3,867 individuals (34%). A total of 382 did not return any data. Because this study focused on BMI-defined weight categories, we excluded six women who self-reported pregnancy, giving a final sample of 3,479 (53% women) individuals. Of the final sample, 86 individuals did not wear the accelerometer, 14 had a defective monitor, 118 were excluded for providing fewer than 4 days of valid accelerometer data, and 171 reported no height and/or weight. A total of 3,090 (89% of the final sample) individuals were included in the association analysis.

Assessment of PA

We used the ActiGraph GT1M accelerometer (ActiGraph, LLC, Pensacola, FL, USA) to assess each participant's PA level. This micro-electro-mechanical system accelerometer is lightweight (27 g) and small (3.8 cm×3.7 cm×1.8 cm) and comprises a solid state monolithic accelerometer that uses microprocessor digital filtering. The accelerometer registers vertical acceleration as the number of counts per user-defined sampling interval (epoch), providing the researcher with a measure of overall PA (mean counts per minute; CPM) and intensity specific PA (number of time units with a mean count per time unit below or above a given threshold). Steps taken per day (steps/day) are also reported as a function of the "threshold crossing mode" embedded in the accelerometer, which counts the number of times the acceleration-generated signal crosses through the baseline reference each epoch and, according to the manufacturer, is representative of the number of steps taken.

Each participant received pre-programmed accelerometer and questionnaire by mail. Standardized instructions included information about wearing the accelerometer in an adjustable cotton fabric belt over the right hip for seven consecutive days, and removing it for water activities such as showering and swimming. After registration, the participants returned the accelerometer and questionnaire by mail to their respective test centre.

Accelerometer Data Handling

Accelerometers were initialized and downloaded using software provided by the manufacturer (ActiLife, ActiGraph). Data were collected in 10-s epochs. The 10-s epochs were collapsed into 60-s epochs for comparison with other studies. The data were reduced to derivative variables with customized SAS-based macros (SAS Institute Inc., Cary, NC, USA), and included if the participant had accumulated at least 10 h of valid activity recordings per day for at least 4 days. Time periods of at least 60 consecutive minutes with zero counts, with allowance for 1 minute with counts above zero, was defined as non-wear time and thus, wear time was defined by subtracting non-wear time from 18 hours (all data between 00:00 and 06:00 were excluded to avoid the potential bias of participants wearing the monitor while sleeping). In addition to overall PA and steps/day, all time awake was categorised by intensity according to the specific activity CPM values. In particular, light intensity PA was defined by counts between 100 and 2,019 CPM, moderate intensity PA as counts between 2,020 and 5,999 CPM and 6,000 CPM represents the lower threshold for vigorous intensity activities [27]. Time spent at <100 CPM (not counting non-wear time) was classified as sedentary behaviour. Bouts of moderate-to-vigorous PA (MVPA) was calculated by summing all activity ≥2020 counts per minute that occurred in sustained bouts of at least 10 min (with allowance for one or two interruptions). To establish patterns of overall PA, minute-by-minute activity counts were summed for each hour of measurement for weekdays and weekend days, respectively.

Other Measures

Height and weight were self-reported by questionnaire and BMI was computed as weight (kg) divided by meters squared (m^2). BMI was categorized according to the guidelines set forward by the World Health Organization, with overweight and obesity defined as a BMI of 25–<30 and ≥30 kg/m^2, respectively [2]. Because of the small sample size, underweight participants (n = 35) were included in the normal weight category; this did not cause any significant change in overall PA for the normal weight participants. To assess health status, participants were asked to rate their perceived health status as very good, good, either, poor, or very poor. Because of the low prevalence of poor health (n = 104, 3.0%) and very poor health (n = 3, 0.1%), the answers were grouped into two categories for the analysis; very good/good and either/poor/very poor. Educational attainment was categorized into four groups: less than high school, high school, less than 4 years of university, and university for 4 years or more. Smoking habits were reported and dichotomized before the variable was entered into the analysis (smoking vs. not smoking). In order to register the amount of certain activities poorly registered by the accelerometers, participants also answered a 1-page questionnaire assessing the amount of cycling, swimming and muscular strength training performed during the 7-day registration period.

Statistical Analyses

The descriptive data are presented according to sex specific BMI categories as percentage, mean, and standard deviation (SD) or standard error of the mean (SE), and 95% confidence interval (CI) where appropriate. Student's *t*-test for independent groups was used to identify differences in anthropometric data between sexes. Chi-square tests were used to test for differences in self-reported health and level of education between weight categories. One-way analyses of covariance adjusting for age and test centre, with the Bonferroni post hoc tests, were performed to identify within-sex differences in PA between BMI categories.

A one-way repeated measurement analysis was conducted to explore whether the impact of type of day (weekday or weekend) differed across BMI category (normal weight, overweight and obese). Type of day was defined as the repeated factor in the analysis, with weight category as the between-subject factor, and age, sex and test centre as covariates. A Wilks̀ Lambda with a significance level of $p<0.05$ indicated a significant interaction effect between BMI category and type of day.

Logistic regression was performed to assess the impact of a number of factors on the likelihood that participants were either overweight or obese (classified as having a BMI $\geq$25 kg/m^2) or obese (BMI$\geq$30 kg/m^2). The independent variables included in the model were age, sex, level of education, self-reported health, smoking, and quintiles of either CPM or MVPA. These variables were included because of their known association to body weight. For the logistic regression, CPM and MVPA was categorized into quintiles and assigned ascending values where 1 was the least active group and 5 the most active group. A significant interaction was found between self-reported health and quintile of PA ($p = 0.016$). However, stratifying by health status did not change the direction of the relationship or the magnitude substantially and for sake of simplicity, the variable was included in the model and treated as a potential confounder. A total of 4 regression analyses were performed (quintiles of CPM and risk of BMI $\geq$25 kg/m^2, quintiles of CPM and risk of BMI $\geq$30 kg/m^2, quintiles of MVPA and risk of BMI $\geq$25 kg/m^2, and quintiles of MVPA and risk of BMI$\geq$30 kg/m^2). The resulting odds ratios are displayed graphically as reduction in relative odds (%). All statistical analyses were performed using PASW Statistics 18 for Windows (IBM Corporation, Route, Somers, NY, USA) and a two-tailed alpha level of 0.05 was used for statistical significance.

Results

The physical characteristics of the participants with complete anthropometric data are presented in Table 1. The prevalence of overweight and obesity was 30% and 11% for women, and 47% and 13% for men. Health status differed according to weight status. Although 82% of normal weight individuals reported having at least good health, the corresponding percentages were 75% for overweight and 58% for obese individuals.

The number of valid days of activity recordings (6.8 days, data not shown) and daily wearing time (880 min, data not shown) did not differ between the weight categories. The measures of PA stratified by BMI category are presented in Table 2. Normal weight women had a higher overall PA level and steps/day compared with both overweight and obese women. The mean difference between normal weight and obese women was 76 CPM (95% CI: 51, 101) and 1,971 steps/day (95% CI: 1,412, 2,529). Overall PA and steps per day displayed a similar pattern for men, although only reaching statistical significance for overall PA. The mean difference in overall PA between normal weight and obese men was 78 CPM (95% CI: 50, 106).

Normal weight women and men spent an average of 8.8 and 9.2 h per day, respectively, being sedentary. The amount of time spent being did not differ between normal weight and overweight participants, but obese women and men spent an average of 17 min (95% CI: 3, 32) and 22 min (95% CI: 7, 37) more, respectively, pursuing sedentary behaviours. The amount of light PA did not differ between BMI categories, but PA of at least moderate intensity decreased significantly with increasing BMI.

Overall PA decreased across BMI categories at both weekdays and weekends. However, a significant interaction (Wilks̀ Lambda 0.998, $p = 0.042$) was observed between type of day and weight category, indicating that the impact of type of day on overall PA differed between the BMI categories. Overall, differences in PA were larger between the BMI categories on weekends compared to weekdays. Compared to normal weight participants, obese participants displayed a 19.2% (355 CPM vs. 287 CPM) lower overall PA on weekdays, while similar difference on weekends 24.6% (370 CPM vs. 279 CPM). As displayed in Figure 1–2, these differences were particularly visible at around midday and early afternoon.

Logistic regression was performed to assess the impact of a number of factors on the likelihood that individuals would be either overweight or obese (Figure 3). The models containing all predictors were significant ($p<0.001$), indicating the ability to distinguish between normal weight, overweight and obese individuals. The model including quintiles of CPM explained between 8% (Cox and Snell R-squared) and 11% (Nagelkerke R-squared) of the variance in weight status. The models showed an increased odds ratio (OR) for being overweight or obese between quintiles of PA and the dose-response relationship was about linear (Figure 3). Participants in the most active quintile of overall PA had a 53% lower risk (OR: 0.47, 95% CI: 0.37 to 0.60) for having a BMI of 25 kg/m^2 or above, and a 71% lower risk (OR: 0.29, 95% CI: 0.20 to 0.44) for having a BMI of 30 kg/m^2 or above. Similar findings were observed for quintiles of MVPA.

Discussion

The present study shows a consistent decrease in PA level with increasing BMI. Overweight and obese participants had a lower overall PA level, took fewer steps each day, and performed less daily moderate and vigorous PA and MVPA performed in bouts of $\geq$10 minutes than did normal weight participants. Obese participants also accumulated more sedentary time, compared with normal weight participants.

The results of the present study are consistent with those of studies that used accelerometers to measure PA in large populations of adults and older people. Tudor-Locke et al. (2010) showed that, among Americans, overall PA decreased consistently with increasing BMI and that men had a higher overall PA than women, within each BMI category. The gradient between BMI categories was similar in the present study, indicating that the decrease in overall PA with increasing BMI is a consistent finding. However, only negligible sex differences within each BMI category were observed in our study. Norwegian women are consistently more active than American women, whereas Norwegian men are consistently less active than American males across all BMI categories, independent of age [25]. This finding also agrees with Swedish data showing a similar decrease in overall PA with increasing BMI but no apparent sex difference within each BMI category [26].

The relative differences in PA between BMI categories in the present study were larger for intensity-specific PA than for the indicators of overall PA. Normal weight women performed twice as much MVPA in bouts as obese women. Similar relative differences between intensity-specific PA stratified by BMI have been reported by others [24,25,28]. The larger relative difference in intensity-specific PA between BMI categories than in overall PA may be explained partly by thermodynamics. Because of the greater body mass, resting energy expenditure is higher in obese compared to normal weight individuals; the greater body mass is associated with a higher metabolic cost of PA for heavier

Table 1. Descriptive data for participants (SD) by weight category.

	Weight category											
	Normal weight				Overweight				Obesity			
	Women		Men		Women		Men		Women		Men	
n (%)	1046	(60)	638	(41)	519	(30)	707	(47)	190	(11)	206	(13)
Age (years)	47.5	(15.5)	49.6	(16.4)	50.5	(14.1)	51.0	(14.2)	48.5	(13.6)	49.0	(13.3)
Height (cm)	167.2	(5.8)	180.3	(6.6)	166.6	(5.8)	180.0	(6.1)	165.6	(7.5)	179.6	(7.4)
Weight (kg)	62.2	(6.5)	75.2	(7.6)	75.3	(6.4)	88.0	(7.4)	91.8	(12.4)	105.1	(11.4)
BMI (kg/m^2)	22.2	(1.8)	23.1	(1.5)	27.1	(1.4)	27.1	(1.4)	33.5	(4.4)	32.5	(2.4)
General health (%)												
Very good/Good	82.0		81.5		74.1		75.0		59.5		55.6	
Either/Poor/Very poor	18.0		18.5		25.9		25.0		40.5		44.4	
Education (%)												
Less than high school	11.3		12.8		15.9		13.7		13.2		17.2	
High school	32.1		35.4		42.2		41.3		42.6		51.5	
University <4 years	28.2		21.6		20.2		22.8		20.5		19.1	
University ≥4 years	28.3		30.2		21.7		22.3		23.7		12.3	

doi:10.1371/journal.pone.0053044.t001

individuals. An accelerometer calibration study showed that the true MVPA intensity threshold is substantially lower for obese compared with normal weight individuals [29]. Although the metabolic cost of exercise increases with body mass, we are confident that the differences in PA between BMI categories are real and are important to public health, although care must be taken when interpreting the results for intensity-specific PA. It should also be recognized that BMI category related differences in PA might be underestimated in the present study. A study of PA using pedometers showed that a larger percentage of obese individuals increased their PA compared to those who decreased their behaviour, when monitored over 1 year [30]. If a collective behaviour of increased PA among overweight and obese in order to affect weight is picked up in the present study, this might moderate the gradient in the relationship between PA and weight status.

According to the recommendation for PA and public health set forward by the Nordic Councils of Ministers, those who are physically inactive may achieve the greatest health gains of increasing their regular PA, independent of age [31]. Although cross-sectional, the linear reduction in relative odds for being overweight or obese observed with higher levels of physical activity indicates the importance of PA to weight management. The odds of being overweight or obese differed by 53–71% between the least and most active quintile of PA and the relationship between PA and risk reductions associated with higher quintiles of PA appears to be about linear.

To our knowledge, BMI related differences in hourly activity patterns of overall PA (counts per minute) across weekdays and

Table 2. Measures of PA and sedentary behaviour (95% Confidence Intervals) stratified by BMI category.

	Weight category											
	Normal weight				Overweight				Obesity			
	Women		Men		Women		Men		Women		Men	
Overall PA (CPM)	352	(344, 360)	368	(357, 379)	324	(313, 336)**	331	(320, 314)**	276	(257, 295)**	290	(270, 310)**
Steps per day	8554	(8374, 8734)	9196	(8177, 10.214)	7789	(7532, 8046)**	8621	(7654, 9587)	6583	(6163, 7003)**	6980	(5179, 8780)
Sedentary behaviour (min)	528	(524, 533)	552	(546, 558)	529	(523, 534)	558	(552, 564)	546	(535, 557)*	574	(5.64, 585)**
Light PA (min)	304	(300, 309)	284	(278, 289)	310	(304, 317)	284	(278, 289)	301	(291, 312)	273	(263, 283)
Moderate PA (min)	33.3	(32.0, 34.6)	35.6	(33.9, 37.3)	28.4	(26.6, 30.2)**	32.2	(30.5, 33.8)*	21.7	(18.8, 24.7)*	27.0	(23.9, 30.0)**
Vigorous PA (min)	2.6	(2.3, 2.9)	4.0	(3.5, 4.6)	1.4	(1.1, 1.9)**	1.6	(1.1, 2.1)*	0.7	(0.0, 1.4)**	1.1	(0.2, 2.1)**
Bouts of MVPA (min)	21.0	(19.9, 22.2)	19.3	(17.7, 20.8)	15.7	(14.1, 17.3)**	15.4	(14.0, 16.9)**	10.4	(7.8, 13.1)**	13.2	(10.4, 15.9)**

All values are adjusted for test centre and age, and indicators of intensity-specific PA were additionally adjusted for mean daily wear time.
*$p<0.05$, compared with normal weight, within sex.
**$P\leq0.001$, compared with normal weight, within sex.
doi:10.1371/journal.pone.0053044.t002

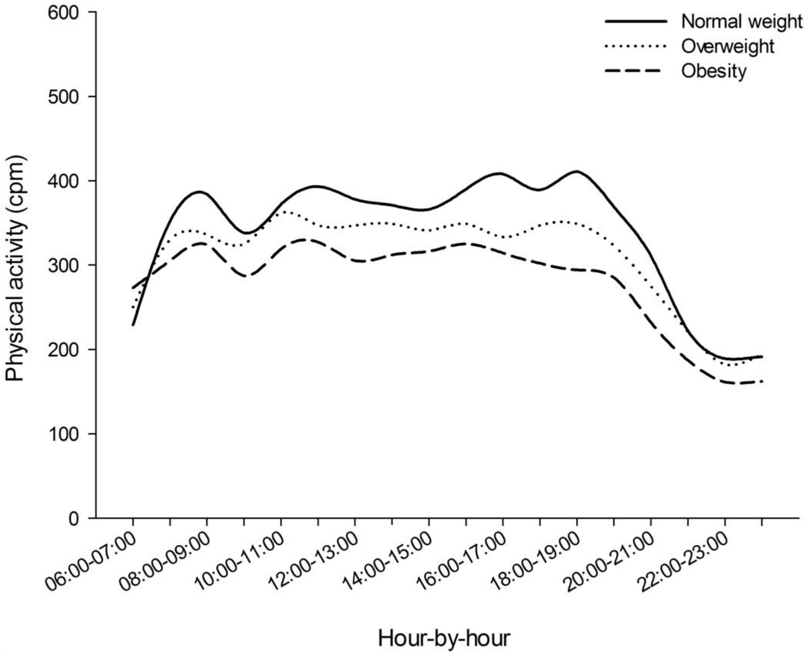

Figure 1. Hourly distribution of overall PA level (CPM) for normal weight, overweight and obese individuals on weekdays.
doi:10.1371/journal.pone.0053044.g001

weekends have not been examined in large and randomly selected samples of adults and older people. A study of 108 participants by Cooper et al. (2000) showed that although the obese participants were consistently less active than non-obese participants, no significant differences were observed while participants were at work [32]. Although time at work could not be identified in the present study, the patterns of overall PA suggest that differences were least pronounced between the hours of 09:00 and 16:00 on weekdays and largest around midday and early afternoon on weekends. Further, compared to normal weight participants, obese participants displayed 19% lower overall PA on weekdays and a 25% lower overall PA on weekends. As the majority of the analysed sample reports working either full time (59%) or part time (11%), the observed larger relative difference in overall PA between obese and normal weight participants on weekends compared to weekdays implies that overweight and obese participants are more likely to pursuit sedentary behaviours when not constrained by work.

The findings of this study must be interpreted in light of the following limitations. We acknowledge the limitations of a cross-sectional design in establishing a causal relationship between level of activity and weight status. However, it clearly shows quantitative differences in amount of PA performed as well as differences in patterns of activity. Further, although BMI is the most commonly used measure to identify and grade overweight and obesity in populations, the method's reliability had been questioned in individuals at the extremes of age, muscle mass, and height [33,34]. BMI accurately predicts obesity-related morbidity and mortality in epidemiological studies [35], and it provides a reliable and robust estimate of height-independent body fatness. Another limitation is that height and weight were self-reported, which might introduce bias because of the suspected underestimating that occurs when participants self-report body weight [36]. In order to control this source of error, trained test personnel measured the weight and height of a randomly selected sub sample of the initial participants (n = 904), in a laboratory. The largest discrepancy between the self-reported and objectively measured anthropometrical data was observed for overweight women who on average underestimated their weight by 1.4 kg, indicating that a bias as a result of self-reported weight is not a threat to the validity of the present study. Among men, a small, but significant, underestimation of weight was only observed in the normal weight category (0.44 kg).

We acknowledge that accelerometers are unable to register water activities such as swimming and to accurately assess movement associated with non-ambulatory activity such as cycling [37]. To try to account for this potential source of error, participants reported the frequency and duration of cycling and swimming performed during the week of assessment. No significant differences in the total time spent performing such activities were observed between the participants in the different weight categories (data not shown) indicating that the omission of these activities from the accelerometer counts did not affect the results.

Another limitation of the present study is the relatively low participation rate. Given the declining response rates in Norway, and in other countries [38,39], and the risk for selection bias, it is important to describe the non-responders in studies that attempt to examine samples that are representative of the general population [40,41]; however, such analysis is rarely available [38]. Analysis of

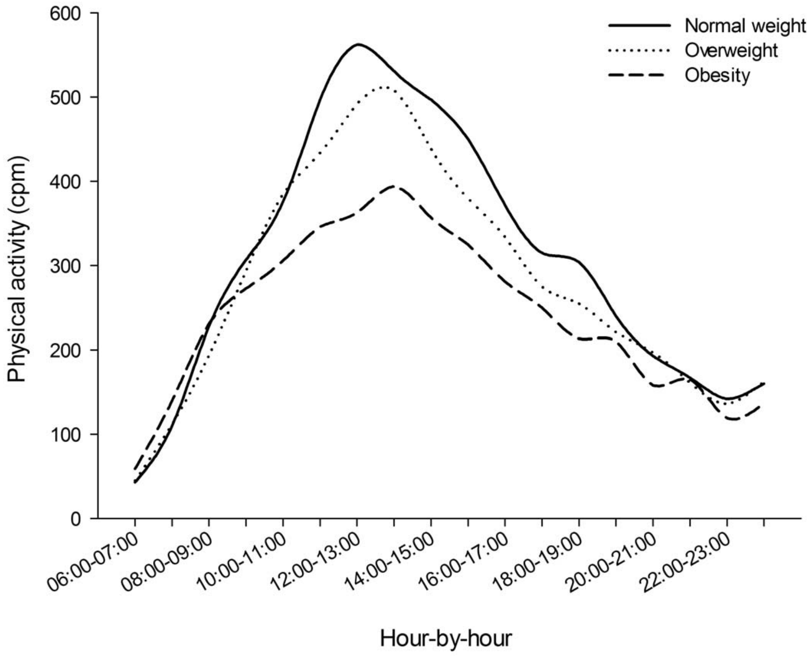

Figure 2. Hourly distribution of overall PA level (CPM) for normal weight, overweight and obese individuals on weekend days.
doi:10.1371/journal.pone.0053044.g002

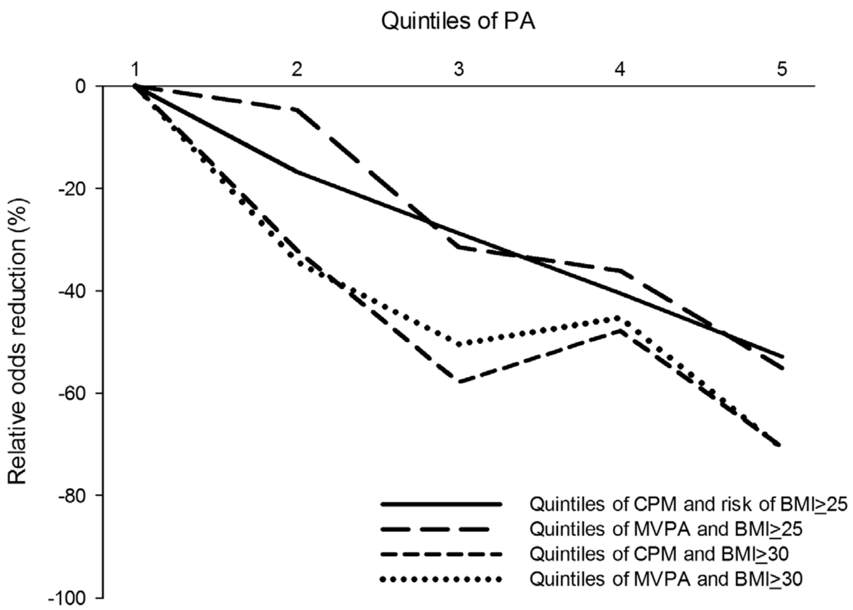

Figure 3. The reduction in relative odds for being overweight or obese associated with increased overall PA and MVPA (the models are adjusted for age, sex, level of education, smoking and self-reported health).
doi:10.1371/journal.pone.0053044.g003

the non-responders in our study by the use of registry linkage showed that they were more likely to be either at the younger or older end of the age spectrum, unmarried and not of Norwegian origin and had lower educational and income levels, compared to the responders [42]. This has also been observed in most population-based surveys [38,43]. Further, the sample included participants from throughout Norway, and the prevalence of overweight or obesity and other non-communicable diseases such as type 2 diabetes was similar to other national estimates. This indicates that the results from the present study have a general validity corresponding to similar studies and that the study sample was fairly representative of the general population in Norway. The study is the first epidemiological study to objectively show differences in activity patterns across weight categories and to demonstrate the contribution of PA to the prevalence of overweight and obesity in Norway.

The worldwide obesity epidemic shows no signs of abating, and, given the health risks and costs of the condition, it is crucial to understand as much as possible about the relationship between PA and weight status. Although we acknowledge that multiple factors other than PA, such as the energy intake, consummation of specific foods and beverages, alcohol use, and television watching. [44], play vital roles in the development of overweight or obesity, we believe that the findings of the present study provides additional information on the relationship between PA and BMI and suggests that there might be a particular scope for targeting the weekend as a source of increased PA among overweight and obese individuals.

Conclusions

Both indicators of overall PA and intensity-specific PA differ between BMI categories and the risk of being overweight or obese increased with decreasing PA level. The BMI category related difference in overall PA is largest on weekends, with obese participants displaying an overall PA level 25% lower than the normal-weight participants. These findings indicate the need for planned interventions to increase the overall level of PA in the population to counteract the environmental forces that are producing a gradual weight gain in the population. The continuing use of accelerometers to monitor longitudinally the level of activity in the general population is vital for identifying the dose response relationship between PA and the prevention and treatment of overweight and obesity.

Acknowledgments

We thank the following test personnel at the ten institutions involved in the study, for their invaluable work during the data collection: Sigurd Beldo (Finnmark University College), Jon Egil Jakobsen (Hedmark University College), Nils Petter Aspvik (NTNU Social Research AS), Ane Solbraa and Einar Ylvisåker (Sogn og Fjordane University College), Hilde Lohne-Seiler (University of Agder), Thomas Dillern and Freddy Pedersen (University of Nordland), Sindre Mikal Dyrstad (University of Stavanger), Eva Maria Støa (Telemark University College), Catherine Lorentzen, Signe Vallumrød og Anne Rabe (Vestfold University College), and Ingeborg Barth-Vedøy, Anita Stokkeland, Johanne Støren Stokke and Karoline Steinbekken (Norwegian School of Sport Sciences).

Author Contributions

Conceived and designed the experiments: BHH IH SAA EK. Performed the experiments: BHH IH SAA EK. Analyzed the data: BHH IH SAA EK. Wrote the paper: BHH IH SAA EK.

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Paper III

Dette er manuskript-versjonen av artikkelen.

This is the submitted version of the article.

Correlates of objectively measured physical activity in adults and older people: A cross-sectional study of population-based sample of adults and older people living in Norway

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Abstract

Objectives: The aims of this study were to identify correlates of objectively measured physical activity and to determine whether the explanatory power of these correlates differ with sex, weight status or level of education. Methods: Physical activity was assessed objectively in 3,867 participants, aged 20-85 years, for a consecutive 7 days using the ActiGraph GT1M activity monitor. Demographic and biological variables and levels of psychological, social environmental and physical environmental correlates were self-reported. Results: The complete set of correlates explained 18.6% (p<0.001) of the variance in overall physical activity. Age and physical activity identity were the most important factors, explaining 4.8% and 3.2% of the variance, respectively, whereas social environmental and physical environmental correlates did not significantly increase the amount of explained variance. Interaction effects between demographic and biological variables and the correlates were observed, but the effects were small. Conclusions: Self-efficacy, perceived behavioral control and physical activity identity might be important targets for intervention. The results further indicate that intervention efforts aimed at influencing these psychological correlates of physical activity may prove equally effective regardless of sex, weight status and level of education.

Introduction

Regular physical activity yields numerous health benefits (Haskell et al. 2007). However, the available data on population levels of physical activity indicate that this evidence has failed to stimulate a large proportion of adults and older people to become more physically active (Bouchard et al. 2012;Hagstromer et al. 2010). To counteract increases in sedentariness, effective interventions are required to increase physical activity at the population level. To develop such interventions, a comprehensive platform of knowledge on the factors that correlate with physical activity is needed (Bryan et al. 2007). Although the literature includes many findings of cross-sectional associations and longitudinal relationships between demographic, biological, psychological, social environmental, and physical environmental variables (commonly referred to as correlates) and physical activity (Trost et al. 2002;Bauman et al. 2002;Bauman et al. 2012), these are generally based on self-reported physical activity. The use of self-reports of physical activity has limitations, and may provide imprecise estimates of physical activity (Sallis and Saelens 2000). The complexity of measuring physical activity or even the failure to do so adequately, is one of the problems that has impeded our understanding of what motivates individuals to adopt and maintain an active lifestyle (Seefeldt et al. 2002).

Given the broad range and complexity of the factors that influence physical activity, research aimed at identifying its correlates should be conceptualized within a socio-ecological framework, allowing the integration of multiple levels and contexts in order to provide us with the best possible understanding of physical activity behavior. Previous interventions to increase physical activity aimed solely at cognitive and psychosocial variables have generally produced small effect sizes and usually the behavior changes were not sustainable, proliferating ecological models of health behavior that posit the need for multi-level interventions (Sallis et al. 2008;Stokols et al. 1996).

Further, as gradients in physical activity behaviour have been observed across ages and sexes, weight groups, and socio-economic positions in adults (Trost et al. 2002), it is important to assess whether such gradients interact with the predictive power of the correlates. If so, the directions and strengths of such interactions will indicate whether certain strata of the population require tailored interventions to increase their physical activity.

There is a paucity of studies using objectively assessed physical activity to investigate the association between physical activity and a broad range of biological, psychosocial and social environmental variables in a large population of adults and older people living in Scandinavia. Furthermore, the potential moderation effects of static factors on level of physical activity, such as sex, weight status, and level of education, have not been explored in this population. Therefore, the aims of this study were: (1) to ascertain the predictive power of a broad range of demographic, biological, psychological, social environmental, and physical environmental correlates of physical activity on objectively measured physical activity in a population of adults and older people; and (2) to identify and assess the potential moderating effects of demographic and biological variables on the relationship between the correlates and objectively measured physical activity.

Methods

Study design and sample

This was a nationally representative cross-sectional multi-centre study of objectively measured physical activity conducted in 2008-2009. In total, 10 test-centres collected data from selected adjacent municipalities across Norway. Written informed consent was obtained from 3867 individuals (34% of the invited sample). Detailed information on the flow of invitees and the results of a drop-out analysis performed via registry linkage are presented elsewhere (Hansen et al. 2012). In brief, compared with the responders, the non-responders were somewhat less educated and had a slightly lower income, and more likely to originate from countries other than Norway. The study was approved by the Regional Ethics Committee for Medical Research and the Norwegian Social Science Data Services AS.

Measures

Physical activity

Physical activity was measures using the ActiGraph GT1M activity monitor (ActiGraph, LLC, Pensacola, FL, USA), a valid (Plasqui and Westerterp 2007) and reliable (McClain et al. 2007) hip-worn electronic motion sensor. Vertical acceleration is converted into activity counts that increase linearly with the magnitude of the acceleration (i.e. intensity). The movements counts are summed during a user-defined time interval (epoch) and averaged over the total wearing time to indicate the overall physical activity. A SAS-based macro reduced the raw data to mean counts per minute (CPM). Sequences of consecutive zero counts lasting ≥ 60 minutes were interpreted as representing non-wear time and excluded from each individual recording. A valid recording of a participant`s activity level was defined as having at least 10 hours of daily wear time for at least four days.

Demographic and biological variables

Age, sex, height, and weight were self-reported. As reported previously, overall physical activity remained steady with age, until 65 years, after which activity levels declined (Hansen et al. 2012). Age was therefore dichotomised into two age groups (20-64 and 65+ years) before entered into the regression analysis. Body mass index (BMI) was computed as weight (kg) divided by metres squared (m^2) and categorized according to WHO guidelines (World Health Organization. 2000), with overweight and obesity defined as BMIs of 25-30 and >30 kg/m^2, respectively. Because of the small sample size, underweight participants (n=35) were included in the normal-weight category; this did not cause any significant changes in physical activity for the normal weight participants. Participants were asked to rate their perceived health status as very poor, poor, fair, good, or very good.. Because of the low prevalence of poor health (n=104, 3.0%) and very poor health (n=3, 0.1%), the answers were grouped into two categories for the analysis: very poor/poor/fair and good/very good ("not good" vs. "good"). Educational attainment was categorized into four groups: less than high school, high school, less than four years of university, and university for four years or more. Smoking habits, marital status and number of children were reported and dichotomized before the variables were entered into the analysis (smoking vs. not smoking, married vs. not married and children vs. no children, respectively).

Theoretical framework

The theoretical framework used to understand physical activity was the socio-ecological model (McLeroy et al. 1988;Stokols et al. 1996), which describes multiple levels of influence, from the intra-individual level to the community/environmental level. All psychological, social environmental and physical environment variables were derived from previously developed and validated scales.

Psychological variables

The psychological vairables considered likely to be correlates of physical activity were: self-efficacy for physical activity (Bandura 2004;Fuchs and Schwarzer 1994), perceived behavioural control over physical activity (Ajzen and Madden 1986;Norman and Smith 1995), and physical activity identity (Jackson et al. 2003;Lorentzen et al. 2007b). Self-efficacy for physical activity was assessed using a five-item measure, where the participants indicated on a seven-point Likert scale (with “not at all confident” and “very confident” at opposite ends of the continuum) the extent to which they were confident in their ability to perform planned physical activity in the face of potential barriers. A mean score for all the constituent items was computed, with higher scores indicating a greater amount of self-efficacy for physical activity. Only participants with a response rate of 75% or greater for the respective item in each subscale were included when the mean scores were computed (allowance for two missing items). The self-efficacy measure displayed a high degree of internal consistency (Cronbach`s alpha [α] of 0.91). Perceived behavioural control was assessed with items assessing the individual`s perception of his/her personal control over being regularly physically active. The measure showed a relatively high degree of internal consistency (α=0.67). Physical activity identity was assessed with four items, which the participants rated on a five-point scale ranging from 1 (fits badly) to 5 (fits well) of the degree to which different statements described them with respect to physical activity. The measure showed good internal consistency (α=0.91).

Social environmental variables

The social environmental variables likely to correlate with physical activity were social support, from either family or friends. Social support was measured using an 11-item scale divided into two sections, one concerning support received from family, and the other concerning the support received from friends, acquaintances, and co-workers. Participants rated separately how often their family and friends/acquaintances/co-workers had been supportive of their physical activity. The response to each item was based on a five-point scale, ranging from 1 (never) to 5 (very often). The participants could also answer "does not apply to me", which was treated as missing data. A family support measure and a friend support measure comprising five of the 11 items used in the present friend support scale have previously shown acceptable reliability and criterion-related validity (Sallis et al. 1987;Lorentzen et al. 2007a). In the present study, Cronbach`s α was 0.86 for the family support subscale and 0.89 for the friend support subscale. For each scale/subscale, a mean score of all constituent items was computed, with higher scores indicating a greater amount of support for PA, and only participants with a response rate of 75% or greater for the respective item in each subscale were included when the mean scores were computed (allowance for one missing item).

Physical environmental variables

The inclusion of the physical environmental varaibles was guided by the empirical literature on the environmental factors that have been associated with physical activity in various settings and population groups (Brownson et al. 2001;Saelens and Handy 2008;Van Holle et al. 2012). Hence, perceived community attributes was measured with a seven-item measure, in which the participants indicated on a four-point Likert scale the extent to which they agreed or disagreed with statements describing their community (regarding pedestrian street safety, safety of recreation areas/parks, walking/cycling facilities, access to shops, access to physical activity facilities/places and organized offers for physical activity) on a scale ranging from 1 (don`t agree) to 4 (agree) (Saelens et al. 2003;Booth et al. 2000). The measure showed good internal consistency (α=0.79).

Statistical methods

All statistical analyses were performed with PASW Statistics 18 for Windows (IBM Corporation, Somers, NY, USA). Descriptive data are presented as proportions, means and standard deviations (SD) or standard errors of the mean (SE), and 95% confidence intervals (CI) where appropriate. Differences in objectively assessed physical activity and anthropometric data were assessed with analyses of variance with the Bonferroni post hoc test for multiple comparisons.

To analyse the relationships between the outcome variables, CPM and the sets of potential correlates for physical activity, hierarchical regression was applied with the principle of hierarchical ordering of proximal versus distal variables based on a socio-ecological framework (Stokols et al. 1996). Preliminary analyses were conducted to ensure that there was no violation of the assumptions of linear regression. The analysis was built up from consecutive blocks containing categories of variables, in which the order of the blocks were based on their relative proximity to the individual. This approach ensures that increases in the explained variance in overall physical activity between individuals (multiple correlations squared, R^2) added by adding a new block, can be attributed solely to the variables in the added block. Demographic and biological variables were entered as block 1. The inclusion of demographic and biological variables in block 1 was based on their association with physical activity shown in epidemiological studies (Trost et al. 2002) and ensured that the amount of variance explained in the following blocks was independent of these variables. Block 2 contained the psychological variables (self-efficacy, perceived behavioral control, and physical activity identity), reflecting greater proximity to the individual than the more distal social environmental variables (social support from family and friends), which were included in block 3. The physical environmental variables (perceived community attributes) were entered in block 4. Unstandardized coefficients (b) and the individual contribution of each predictor variable to the explained variance (semi-partial correlation squared) are reported.

To investigate the potential moderating effects of the demographic and biological variables on the relationships between the psychological, social environmental and physical environmental variables and physical activity, the interaction terms for the demographic and biological variables and the potential correlates were computed (e.g. sex multiplied by self-efficacy). The potential correlates were mean centred before the interaction terms were computed to avoid the potential bias of multicollinearity. The initial regression analyses were re-run, with block 1 consisting of the demographic and biological variables, excluding the potential moderator being investigated, block 2 containing the potential moderator and the potential correlate being investigated, while the corresponding interaction term was added in block 3. This procedure was repeated for each potential correlate, resulting in six separate regressions for each potential moderator variable. To graphically display and explore the directions and strengths of the significant interactions, the potential correlates were ordered in moderator-split tertiles (tertile 1: low score; tertile 2: moderate score; and tertile 3: high score) and analysis of covariance was then applied to explore the overall physical activity for each tertile, adjusted for the demographic and biological variables.

Results

Descriptive data is provided in Table 1. The mean age (SD) of the sample was 49.1 years (14.9) and the average BMI was 25.5 kg/m^2 (4.0), with 47 % of the study population being either overweight or obese. Women and men did not differ in their overall physical activity levels and activity remained constant with increasing age until 65 years, after which activity levels declined (data not shown).

The mean scores for the psychological and social environmental variables were moderate and relatively high, respectively, while the mean scores for the physical environment variables were high (a mean score of 3.3 of 4.0) (Table 2). Compared with the women, the men reported lower levels of social support from friends (2.5 vs. 2.7, respectively, $p \leq 0.001$), and higher levels of perceived behavioral control (5.1 vs. 4.9, $p \leq 0.001$). No other sex-based differences were observed.

The demographic and biological factors included in the model (block 1) accounted for 11.9% of the variance in overall physical activity ($R^2 = 0.119$, $p \leq 0.001$) (Table 3). Age group, health status, and weight status displayed the largest amount of explanatory power, explaining 4.1 %, 4.4 % and 2.3 % of the variance, respectively ($p \leq 0.001$). The psychological variables of self-efficacy, perceived behavioural control and physical activity identity (block 3) increased the total explained variance to 18.6% ($p \leq 0.001$). Although age group, health status, and weight status remained significant throughout the addition of the blocks of variables, their predictive power changed somewhat. In the fully adjusted model, age group accounted for 4.8% of the explained variance ($p \leq 0.001$), whereas the predictive power of health status and weight status decreased to 1.5% and 1.2%, respectively ($p \leq 0.001$). Each of the psychological correlates individually contributed to increasing the explanatory power of the model, with physical activity identity being the most important factor, individually explaining 3.4% of the variance ($p \leq 0.001$). The social environmental variables (block 3) (perceived social support from family and friends) and the physical environmental variable (block 4) yielded no further significant increases in amount of variance explained by the total set of variables.

Altogether, seven of the 22 interaction terms contributed significantly to increasing the explanatory power of the predictor variables, indicating that these moderated the relationships between the sets of variables now established as correlates, and physical activity. However, the effect sizes were small (Table 4), and visual inspection of the relationships between the correlates and physical activity, split by the potential moderator, indicated that none of the interaction terms altered the relationships sufficiently to have any significant relevance to the predictive power of the correlates in any of the specified subgroups (fig. 1-3).

Discussion

Using a social ecological framework, this study examined correlates of accelerometer-determined overall physical activity in a large population-based sample of Norwegian adults and older people.

The total independent variable set accounted for 18.6% of the explained variance in overall physical activity. Age group (below or above 65 years) was the most important predictor of overall activity level, uniquely explaining 5.0% of the variance in the dependent variable, a finding that is consistent with findings from studies using self-reported measures of physical activity (Trost et al. 2002). Further, in contrast to much of the published literature on levels of physical activity, no sex gradient in overall physical activity was observed (Trost et al. 2002). This is, however, consistent with more recent studies of population levels of objectively measured physical activity (Hagstromer et al. 2010), and might reflect the activity monitors increased ability to capture a broader spectrum of physical activity compared to self-reported measures (Hansen et al. 2012).

Concerning the remaining demographic and biological variables, the results of the current study are in conjunction with other studies. As reported by others, civil status were not associated with physical activity (Brownson et al. 2000;King et al. 2000) and smoking status were inversely related to physical activity (Johnson et al. 1998;Brownson et al. 2000). Overweight and obesity was associated with lower levels of physical activity after controlling for potential demographic confounders, as consistently reported in the literature (Martinez-Gonzalez et al. 1999).

Self-efficacy was a significant independent contributor to overall physical activity in the present study. This finding confirm earlier findings of self-efficacy as a correlate that is positively associated with adoption and maintenance of physical activity (Bandura 1997;Bauman et al. 2012;Sallis et al. 1986). Perceived behavioral control is an individual's perception of the extent to which regularly maintaining the behavior is easy or difficult and may influence behavior directly and through the intentions to act (Ajzen and Madden 1986). A number of studies have found that perceived behavioral control predicts physical activity behavior (Hagger et al. 2002;Jackson et al. 2003), which was also observed in the present study. Physical activity identity was the strongest predictor of all the correlates and yielded a significant independent addition of variance accounted for in physical activity, equal as age group in size. The explanatory power of physical activity identity is supported by others. In a community-based study of 2,336 adults living in Norway, physical activity identity was found to be the strongest predictor of forward transition in the stages of change in physical activity (Lorentzen et al. 2007b). The relevance of activity identity as a correlate of physical activity was also confirmed in earlier studies of self-reported physical activity (Anderson.D.F. and Cychosz 1995), and these earlier findings combined with the results of the current study provide strong evidence for the inclusion of attempts to foster the development of individual`s physical activity identity, in interventions aimed at enhancing physical activity behavior.

According to the literature, social support is a consistent correlate of physical activity (Bauman et al. 2012;Trost et al. 2002). In our model, however, social support neither from friends nor family emerged as a significant contributor to the explanatory power of the model after controlling for demographic and biological variables and psychological correlates. This finding is also observed by others (Hall and McAuley 2010). Further, perceived community attributes did not relate significantly to overall physical activity. A similar finding was reported in a review by Wendel-Vos et al (2007), reporting that availability, accessibility and convenience of recreational facilities were less consistent correlates of physical activity, possibly due to the use of non-validated measures of environments and/or behaviour. The item measuring perceived community attributes in the present study displayed reasonable internal consistency, but the mean score was relatively high and might therefore not be able to discriminate sufficiently between high and low levels of community attributes. Furthermore, the addition of perceived environment measures that assessed multiple features of physical environment would have strengthened the study. Ideally, objective measurement of neighbourhood walkability, street connectivity, population density and sidewalk conditions would be ideal for this purpose, and might yield different results (Wendel-Vos et al. 2007).

There were significant interaction effects of the demographic and biological variables in the relationship between the different correlates and physical activity. However, the size of the interaction effects (as displayed in Table 4 and Figure 1-3) should be considered as relatively modest. Hence, the interaction findings would seem encouraging by indicating that tailoring strategies to increase overall physical activity in the population according to sex, weight or level of education does not seem necessary.

The study is not without limitations. The response rate might be considered low, which increases the risk for selection bias (Sogaard et al. 2004;Van Loon et al. 2003). Hence, it is important to describe the non-responders; however, such analyses are rarely available (Sogaard et al. 2004). Analyses of the non-responders in our study revealed that non-responders were more likely to be either at the younger or older end of the age spectrum, unmarried and with lower educational and income levels, compared to the responders (Hansen et al. 2012), as observed in most population-based surveys (Sogaard et al. 2004;Strandhagen et al. 2010). Further, the prevalence of overweight or obesity and other non-communicable diseases, such as type 2 diabetes, was similar to other national estimates. Therefore, we believe that the results of the current study have a general validity corresponding to similar studies. Another weakness of the study is the inherent inability of cross-sectional studies to establish causality. Lastly, there is emerging evidence on other possible correlates of physical activity, such as genetic and policy related determinants. The inclusion of such factors have the potential to increase our understanding of the correlates of physical activity, but this is beyond the scope of this article.

In spite of these limitations, the present study contributes to the understanding of physical activity and its correlates. The results of the study can serve as an empirical evaluation of a social-ecological model of physical activity and the order of entry of blocks of variables into the hierarchical regression model is of relevance to intervention design. Demographic and biological variables that are not modifiable were entered first, allowing the explained variance (R^2) for the following blocks to serve as a theoretical estimate of change that could be expected by changing variables in the blocks. Although the independent explanatory power of each correlates was relatively modest, they yield important information as there is consistent evidence showing that small increases in physical activity can benefit people`s health significantly (Hill 2009;Levine et al. 2000).

Conclusion

Several correlates that might be important targets for intervention were identified. These variables include self-efficacy, perceived behavioral control and physical activity identity. The observed interaction effects of the demographic and biological variables on the relationships between the correlates and physical activity did not seem to have a sufficient impact to justify interventions that are specific for sex, weight status, or level of education.

List of abbreviations

BMI, Body Mass Index; PA, physical activity; CI, Confidence Interval; CPM, counts per minute

Competing interests

The authors declare that they have none competing interests.

Authors' contributions

BHH was active in the planning of the study and coordinated the practical part of the study, analysed and interpreted the data and drafted the manuscript. IH was involved in the conception and design of the study and the article, contributed particularly in the statistical analyses and interpretation of the data, and reviewed the article critically. SAA was project manager of the study, participated in planning of the study, was involved in the conception and design of the article, discussed the analysis and interpretation of the data, and reviewed the manuscript critically. YO and EK helped planning the study, helped with the analysis and interpretation of the data and reviewed the manuscript critically.

Acknowledgements

The authors thank all the test personnel at the ten institutions involved in the study, for their work during the data collection: Finnmark University College, Hedmark University College, NTNU Social Research AS, Sogn og Fjordane University College, University of Agder, University of Nordland, University of Stavanger, Telemark University College, Vestfold University College, and Norwegian School of Sport Sciences.

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Table 1 Physical activity and anthropometric data for all participants and by sex, Norway (2008-2009).

	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Physical activity[a]	All	(n^b = 3267)	Women	(n = 1747)	Men	(n = 1520)	
Overall PA (counts/min)	338	(2.4)	335	(3.3)	342	(3.6)	ns
Anthropometric data							
Age (yrs)	49.1	(14.9)	48.3	(15.0)	50.0	(15.0)	*
Height (cm)	173.0	(9.1)	166.9	(6.1)	180.1	(6.5)	*
Weight (kg)	76.6	(14.8)	69.3	(12.3)	85.0	(12.8)	*
BMI (kg/m^2)	25.5	(4.0)	24.9	(4.3)	26.2	(3.5)	*
Overweight (%)[b]	35.3		29.7		45.6		*
Obese (%)[d]	11.4		10.9		13.3		*

Values are means (SD), except for overall PA where standard error of the mean (SE) is reported.
[a]Activity variables are adjusted for age and test centre.
[b]Values are presented as proportions (%).
Significant test for women compared with men.
*p<0.001.
NS, non-significant; SD, standard deviation.

Table 2. Psychosocial and socio-environmental variables with Cronbach`s alpha, and examples of scale items, Norway (2008-2009).

	Scale range	Mean (SD)		α
Biological variable				
Weight category: overweight/obese (%)	NA	46.7	NA	NA
Psychological variables				
Self-efficacy	1-7	5.2	(1.4)	0.91
"I am sure that I can perform the planned physical activity even though I am tired"				
Perceived behavioral control	1-7	5.0	(1.3)	0.67
"I control whether I perform regular physical activity or not"				
Physical activity identity	1-5	3.5	(1.0)	0.91
"Being physically active is a part of being the person I am"				
Social environmental variables				
Social support from family	1-5	2.9	(0.9)	0.86
"How often do members of your family change their plans so that they can be physically active with you"				
Social support from friends	1-5	2.6	(0.9)	0.89
"How often do your friends change their plans so that they can be physically active with you?"				
Physical environmental variables				
Perceived community attributes	1-4	3.3	(0.7)	0.79
"To what extent does your community have: safe places where you can walk?"				

NA; not applicable

Table 3. Hierarchical regression analysis of variables of overall physical activity (mean counts per minute), Norway (2008-2009).

Fixed effects	Block 1			Block 2			Block 3			Block 4		
	b	(SE)	Partial r^2	b	(SE)	Partial r^2	b	(SE)	Partial r^2	b	(SE)	Partial r^2
Intercept	300.2	(20.8)***		212.9	(23.8)***		214.7	(24.8)***		210.1	(26.3)***	
Demographic variables												
Age group (20-64 vs. 65-85 yrs)	-73.3	(6.7)***	0.041	-78.1	(6.5)***	0.048	-78.2	(6.5)***	0.048	-78.1	(6.5)***	0.048
Sex (female vs. male)	13.4	(5.0)***	0.002	9.8	(4.8)*	0.001	9.8	(4.9)*	0.001	9.7	(4.9)*	0.001
Have children (yes vs. no)	3.5	(7.0)	0.000	2.6	(6.7)	0.000	2.6	(6.7)	0.000	2.6	(6.7)	0.000
Smoking habits (smoker vs. non-smoker)	36.8	(6.7)***	0.010	20.9	(6.6)**	0.003	21.0	(6.6)**	0.004	21.1	(6.6)**	0.004
Health status (not good vs. good)	68.0	(5.9)***	0.044	39.8	(6.0)***	0.015	39.8	(6.0)***	0.015	39.6	(6.0)***	0.015
Level of education(low vs. high)	-14.1	(5.1)*	0.003	-20.2	(5.0)***	0.006	-20.1	(5.0)***	0.006	-20.3	(2.5)**	0.006
Marital status (married vs. unmarried)	-2.7	(5.4)	0.000	-4.6	(5.2)	0.000	-4.3	(5.2)	0.000	-5.0	(5.3)	0.000
Biological variables												
Weight category[a]	-41.6	(5.1)***	0.023	-29.7	(5.0)***	0.012	-29.7	(5.0)***	0.012	-29.6	(5.0)***	0.012
Psychological variables												
Self-efficacy				4.6	(1.9)*	0.002	4.6	(1.9)*	0.002	4.6	(1.9)*	0.002
Perceived behavioral control				10.2	(2.1)***	0.008	10.2	(2.1)***	0.008	10.2	(2.1)***	0.008
Physical activity identity				27.7	(2.8)***	0.034	27.9	(2.9)***	0.032	27.9	(2.9)***	0.032
Social environmental variables												
Social support from family							-1.5	(3.2)	0.000	-1.3	(3.2)	0.000
Social support from friends							0.4	(3.3)	0.000	0.3	(3.3)	0.000
Physical environmental variables												
Perceived community attributes										1.9	(3.7)	0.000
Explained variance (R^2)	0.119***			0.186***			0.186			0.186		

[a]Weight category code: 1 = normal weight, 2 = overweight/obese
*p<0.05
** p<.01
*** p<.001
b, unstandardized beta coefficient; SE, standard error of the mean.

Table 4. Interaction effects of potential moderators of the relationship between correlates and moderate-to-vigorous physical activity, Norway (2008-2009).

Variables included in block	R^2*100	p-value
Sex and self-efficacy	13.9	
Interaction term: sex × self-efficacy	14.2	0.001
Sex and perceived behavioral control	14.9	
Interaction term: sex × perceived behavioral control	15.0	0.014
Sex and perceived community attributes*	12.1	
Interaction term: sex × perception of community attributes	12.3	0.003
Weight status and self-efficacy	13.9	
Interaction term: weight status × self-efficacy	14.2	0.001
Weight status and perceived behavioral control	14.9	
Interaction term: weight status × perceived behavioral control	15.0	0.016
Level of education and self-efficacy	13.9	
Interaction term: level of education × self-efficacy	14.1	0.004

R^2*100; percentage explained variance in overall physical activity (mean counts per minute)

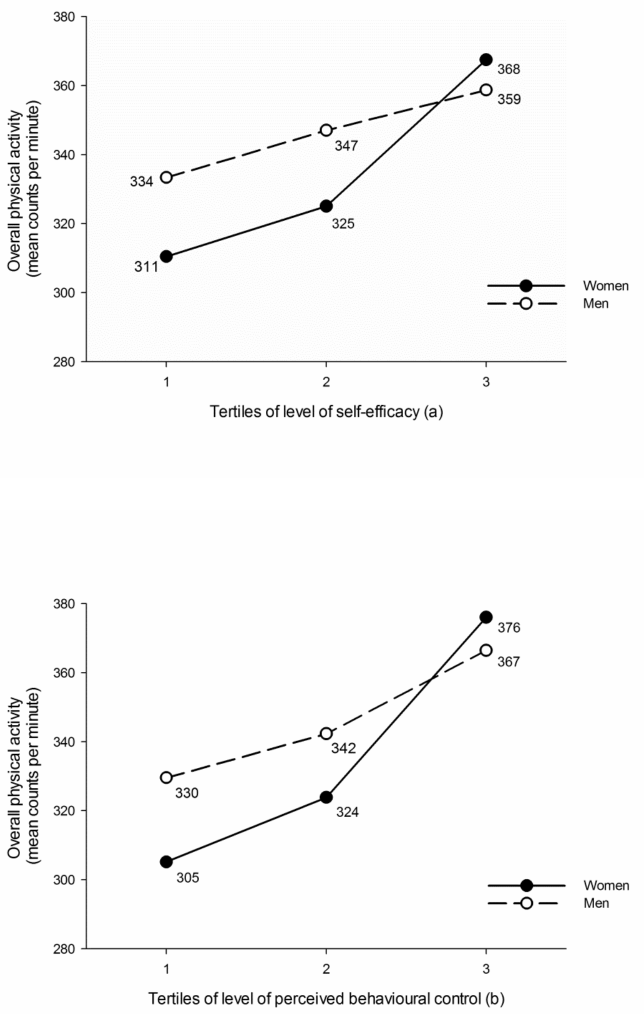

Fig. 1 Relationship between overall physical activity and self-efficacy (a) or perceived behavioral control (b) by sex, Norway (2008-2009)

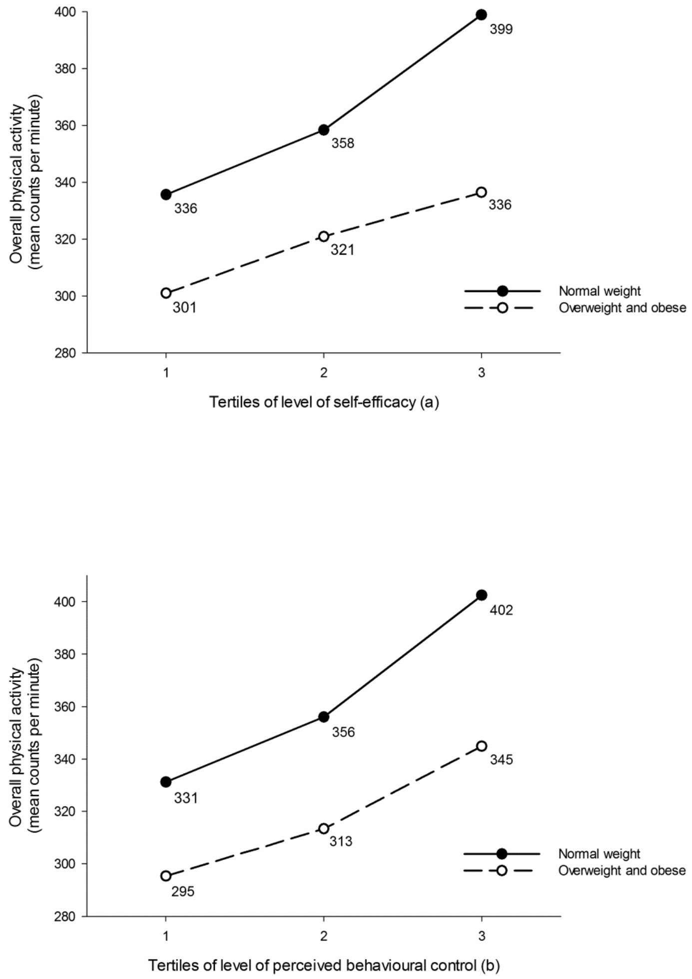

Fig. 2 Relationship between overall physical activity and self-efficacy (a) or perceived behavioral control (b) by weight status, Norway (2008-2009)

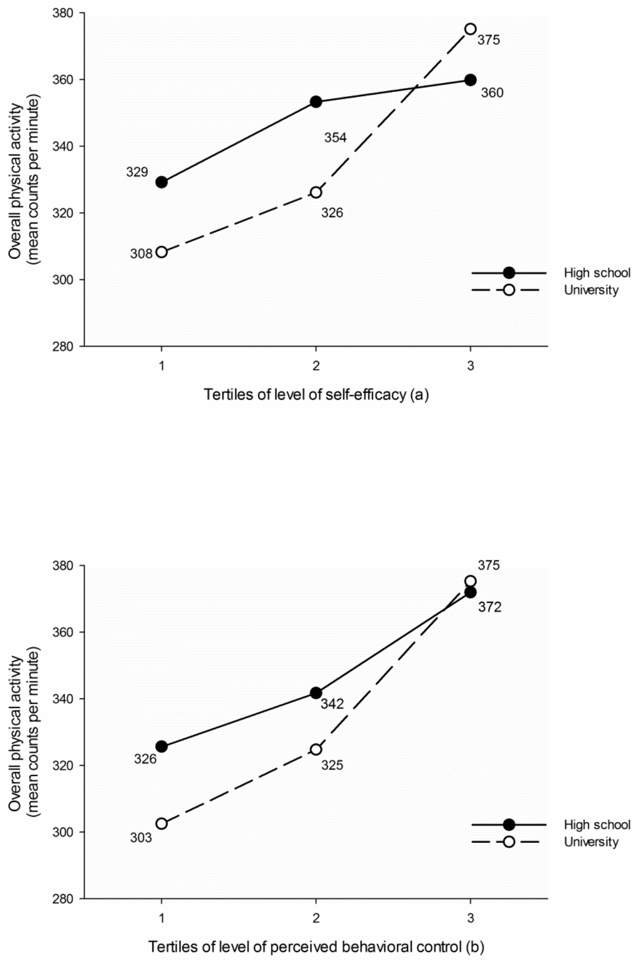

Fig. 3 Relationship between overall physical activity and self-efficacy (a) or perceived behavioral control (b) by level of education, Norway (2008-2009)

Paper IV

Validity of the ActiGraph GT1M during walking and cycling

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Running title: Validity of the ActiGraph GT1M

ABSTRACT

Purpose: The ActiGraph activity monitors have developed and newer versions of the ActiGraph accelerometers (GT1M, GT3X, and GT3X+) are now available. The new monitors include changes in hardware and software compared to the old version (AM7164). This is problematic as most of the validation and calibration work include the AM7164. The aims of the study were to validate the ActiGraph GT1M during level and graded walking and to assess the potential underestimation of physical activity (PA) during cycling. **Methods:** Data were obtained from 20 participants during treadmill walking and ergometer cycling. Energy expenditure (EE) was measured via indirect calorimetry and used as the criterion method. **Results:** Activity counts were highly correlated with energy expenditure during level walking (R^2=0.82) and graded walking at 5% and 8% (R^2=0.82 and R^2=0.67, respectively). There was no linear relationship between CPM and METs during cycling. The average CPM for all data points during cycling was 1,157 (SD=974) and mean EE during cycling was 5.0 METs. **Conclusions:** The GT1M is a valid tool for assessing walking across a wide range of speeds and gradients. However, there is no relationship between CPM and METs during cycling and PA is underestimated by ≈73% during cycling compared to walking.

1.0 INTRODUCTION

Accurate measurement of physical activity (PA) is important for understanding basic characteristics of human movement and the relationship of physical activity to non-communicable diseases such as cardiovascular disease and diabetes type 2 (Chen & Bassett, Jr., 2005). Although much is known of the health benefits of regular physical activity, the specific dose-response relationship between activity and different health outcomes remains unclear (Jørgensen et al., 2009). To better define the dose-response relationship between PA and health, sensitive, valid, and reliable assessments methods are required. This involves recording daily PA patterns individually, a behaviour that vary substantially between individuals (Jørgensen et al., 2009) and is inherently difficult to measure due to its complex nature (Howley, 2001).

Historically, subjective measures (e.g. questionnaires and diaries) have been the most widely used tool for assessing physical activity (Chen & Bassett, Jr., 2005). These methods are prone to recall and social desirability bias, and comparisons between studies are often hampered by inconsistencies in variable definitions and survey methodology (Prince et al., 2008; Sallis & Saelens, 2000; Troiano, 2005). Over the last two decades, the popularity of assessing PA by portable activity monitor have increased, due to the unique combination of validity, increased simplicity and affordability of such devices (Bassett, Jr., 2000).

ActiGraph (Pensacola, FL, USA) introduced the piezoelectric AM 7164 in the 1990s, and since its introduction, it has been widely used in both laboratory and field-based studies to derive energy expenditure (EE) prediction equations (Freedson, Melanson,

& Sirard, 1998; Hendelman, Miller, Baggett, Debold, & Freedson, 2000; Merchant, Dehghan, & Akhtar-Danesh, 2007; Nichols, Morgan, Chabot, Sallis, & Calfas, 2000; Pivarnik, Reeves, & Rafferty, 2003; Swartz et al., 2000) as well as to assess free-living PA in large population studies (Troiano et al., 2008; Hagstromer, Oja, & Sjostrom, 2007). Over the past two decades, newer versions of the ActiGraph accelerometer have been developed, including changes in hardware and firmware (John & Freedson, 2012). The AM 7164 was discontinued in the early 2000s and replaced by the capacitive GT1M. Both the AM 7164 and the GT1M have built-in singe-axis (vertical) accelerometers, but the accelerometers embedded in the two versions differ substantially from each other. The AM 7164 embedded piezoelectric accelerometer while the GT1M uses a Micro-Electro-Mechanical System (MEMs) capacitive accelerometer. In addition, the AM 7164 has a lower sampling frequency (10 vs. 30 Hertz) (John, Tyo, & Bassett, 2009). Although ActiGraph states that the AM 7164 and the GT1M provide comparable output, observations indicate that inter-generation differences exist, at least at certain intensities (Corder et al., 2007; Rothney, Apker, Song, & Chen, 2008; Kozey, Staudenmayer, Troiano, & Freedson, 2009). These finding are problematic, as most of the validation and calibration studies included the AM 7164 (Brage, Wedderkopp, Franks, Andersen, & Froberg, 2003; Ekelund et al., 2001; Freedson et al., 1998; Leenders, Sherman, & Nagaraja, 2006; McClain, Sisson, & Tudor-Locke, 2007; Melanson, Jr. & Freedson, 1995; Welk, McClain, Eisenmann, & Wickel, 2007).

The AM 7164 appears to be valid for estimating EE during a range of speed of locomotion (Brage et al., 2003; Freedson et al., 1998; Melanson, Jr. & Freedson, 1995), but is not able to discriminate between level and graded walking (Montoye et al., 1983; Melanson, Jr. & Freedson, 1995). As graded walking increases EE compared to level walking, this represents a potential source of underestimation of EE. To our knowledge, the validity of the ActiGraph GT1M to discriminate between level and graded walking has not yet been established thoroughly.

Furthermore, the most commonly reported accelerometer output are uniaxial accelerations translated to activity counts and the monitor is most often attached to the hip. As a result of this, activities with little or no vertical acceleration of the hip are poorly registered by the monitor, such as cycling. This might be a concern when used in populations where bicycling is common. For example, daily commuting by bike is about 20% in Denmark (Hallal et al., 2012). Although most studies of accelerometer-derived PA acknowledge this limitation, few have attempted to estimate size of the potential underestimation of PA that occurs during cycling (Treuth et al., 2004).

The aims of the present study was; 1) to validate the ActiGraph GT1M during level and graded walking using EE determined by indirect calorimetry as the criterion method; and 2) to assess the potential underestimation of EE during cycling.

2.0 METHODS

A sample of 20 healthy participants (23-39 years) from Oslo and surrounding areas, with no ambulatory restrictions, were recruited to participate in the study. Participants were given detailed information about study procedures and signed written informed consent documents. The study protocol was reviewed by the Regional Committee for Medical Research Ethics.

2.1 Instrumentation

Participants wore an ActiGraph GT1M activity monitor (Pensacola, FL, USA) secured with an elastic belt over the auxiliary line on the right hip. The GT1M is a small (5.3 x 5.1 x 2.2 cm) and lightweight (27 grams) activity monitor that embeds a Micro-Electro-Mechanical-System (MEMS) accelerometer with on-board filtering. Detailed specifications of the GT1M is published elsewhere (John & Freedson, 2012). The GT1Ms were initialized and downloaded via a USB interface using the ActiLife software (v. 4.1.1). Epoch period was set to 10 seconds. The accelerometer output in counts per minute (CPM) was determined by collapsing the 10 second epoch to 60 second epochs for comparisons with other studies. A total of seven GT1Ms were used in the study. After the data collection, the units were exposed to a standardized set of sinusoidal accelerations in a mechanical setting, and intra-instrument variation was less than 1%.

Oxygen uptake (VO_2 expressed as $ml \cdot kg^{-1} \cdot min^{-1}$) was measured by a metabolic cart (Jaeger Oxycon Pro; Wursburg, Germany) using a Hans Rudolph two-way mouth piece (2700 series; Hans Rudolph Inc., Kansas City, USA). The oxygen and carbon dioxide content of expired air was used for calculation of oxygen uptake (VO_2). The gas analyser was calibrated with standard gases and the flow meter was calibrated for volume before each individual session according to the manufacturer´s recommendations. Heart rate (HR) was assessed by a Polar Electro FT1 heart rate monitor (Kempele, Finland) worn around the chest at the level of the sternum.

2.2 Study protocol

Participants met at the exercise physiology laboratory at the Norwegian School of Sport Sciences at three separate days. On day 1, information of the study was given, the participants were accustomed to the testing equipment, and anthropometrical measures were made. Weight were measured to the nearest 100 g with a digital scale (Seca Model 708, Seca Ltd, Birmingham, UK) and height to the nearest 0.1 cm. Participants were measured in light clothing and without shoes. Waist circumference was measured with anthropometrical tape around the umbilicus. Body mass index (BMI) was computed as weight (kg) divided by meters squared (m^2).

On day 2, participants performed two sessions of treadmill walking. Session one consisted of 5-minute intervals of walking on a motorized treadmill (Woodway, Elg 2, Germany) at 0% inclination at speed of 3, 4, 5, 6, and 7 $km \cdot h^{-1}$. These speeds were selected to reflect the intensity of effort ranging from light to moderate intensity physical activity (Pate et al., 1995). Population studies of accelerometer-determined PA indicate that only a very small proportion of the daily PA of adults and older people consists of vigorous activity (Hansen, Kolle, Dyrstad, Holme, & Anderssen, 2011; Troiano et al., 2008). During session 2, participants completed 5-minute intervals at speeds of 3, 5, and 6 $km \cdot h^{-1}$ at 5% inclination and speeds of 3, 4, and 5 $km \cdot h^{-1}$ at 8% inclination.

On day 3, participants performed one session of treadmill walking at -5% inclination at speeds of 4, 5, and 6 $km \cdot h^{-1}$, and one session of 5-minute intervals at a cycle ergometer (Lode Excalibur Sport, Lode BV, Groningen, the Netherlands) at cadences of 60 and 80 RPM with 40, 60, and 80 watts of resistance.

Before each session, the GT1Ms and heart rate monitors were mounted on the participants. CPM, steady state VO_2 and mean HR was calculated using the final 3 minutes of exercise for each interval. METs were calculated by dividing the steady state VO_2 by 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. An external timepiece was used to synchronize the accelerometer internal clock with the VO_2 output.

2.3 Statistical analysis

T-test for independent samples were used to examine sex-related differences in oxygen uptake and accelerometer output. Linear regression was used to establish the relationship between EE and CPM. Generalized linear models with Bonferroni post hoc test were used to explore differences in CPM and EE with increasing speed and gradient on the treadmill. Paired t-tests were used to compare EE of cycling at different cadences (RPM) and workloads (watts). All statistical analyses were performed using PASW Statistics 18 for Windows (IBM Corporation, Route, Somers, NY, USA) and a two-tailed alpha level of 0.05 was used for statistical significance.

3.0 RESULTS

The mean age of the sample was 28.2 years (SD 3.3) and the mean BMI was 23.7 (SD 3.1). Figure 1AB illustrates the VO_2 (A) and accelerometer data (B) relative to treadmill speeds, for women and men separately. No differences between the sexes in EE or accelerometer counts within speeds were observed and subsequent analyses were performed on the total sample without any adjustments being made. Table 1 presents the CPM, VO_2, and HR values relative to treadmill speed and gradient. Significant differences in all measured variables between consecutive velocities in the 3-7 $km^{.}h^{-1}$ range during level walking were observed (p-values). Increases in treadmill speeds were associated with a linear increase in VO_2 relative to body weight (R^2=0.88, $p \leq 0.001$) and HR (R^2=0.44, $p \leq 0.001$) during level (0%) walking.

Figure 2 illustrates the relationship between CPM and METs during level walking. The relationship was linear (R^2=0.82, $p \leq 0.001$). The variability about the regression line is evident at increasing EE. During graded walking the GT1M was able to discriminate between increased gradients at 3 and 5 $km^{.}h^{-1}$. At 3 $km^{.}h^{-1}$, the mean difference in CPM between level walking and graded walking at 5% was 286 CPM (95% CI: 132, 439, $p \leq 0.001$) and 673 CPM (95% CI: 435, 912, $p \leq 0.001$) at 8% gradient. At 5 $km^{.}h^{-1}$, no differences in CPM were observed between level walking and the 5% gradient walking. However, a significant difference of 966 CPM (95% CI: 638, 1294, $p \leq 0.001$) between level walking and walking at 8% gradient was observed. The relationship between CPM and METs during graded walking differed somewhat from level walking. At 5% grade, the explained variance in metabolic cost due to increases in CPM was similar to level walking (R^2=0.815), compared with a somewhat lower explained variance at 8% gradient (R^2=0.677, $p \leq 0.001$). Although the GT1M appears to discriminate between level and graded walking, the size of the difference in CPM is not large enough to reflect the increased EE observed during graded walking, thus underestimating EE during uphill walking. Furthermore, we observed a reduced EE during walking at -5% grade, while CPM was high, indicating an overestimation of EE during downhill walking (Figure 3).

The metabolic cost of cycling at a low and high cadence with increasing workloads is shown in figure 4. Increases in workloads produced significant increases in metabolic cost at both cadences (60 and 80 RPM) ($p \leq 0.001$) and cycling at 80 RPM yielded higher metabolic costs compared to cycling at 60 RPM at all workloads ($p \leq 0.001$). However, increased workload were not associated with an increase in CPM, either at 60 RPM (R^2=0.00) or 80 RPM (R^2=0.002), as shown in figure 5. Due to the non-linear relationship between increasing EE and accelerometer output, we calculated the average CPM for all data points during cycling, which was 1,157 CPM with a standard deviation of 974 CPM. Correspondently, the average MET-value obtained while cycling was 5.0 METs.

4.0 DISCUSSION

This study examined the impact of increasing workload during treadmill walking (speed and gradient) and cycling (cadence and power output) on uniaxial activity counts from the ActiGraph GT1M activity monitor and its association with EE measured by indirect calorimetry. The data output from the GT1M during levelled walking rose linearly with speed over the walking range (3-7 $km^{.}h^{-1}$) and explained 82% of the variance in energy cost expressed in METs. During inclined walking the GT1M was able to discriminate between increased gradient at 3 and 5 $km^{.}h^{-1}$. Activity counts explained 82% and 68% of the variance in METs at 5% incline and 8% incline, respectively. Increased workload during cycling was not associated with an increase in CPM, either at low (R^2=0.00) or high (R^2=0.002) cadence.

Because the speeds of walking used in the present study ranged from casual to brisk walking, the results indicate that the GT1M can be useful to distinguish different walking speeds on level ground. A linear increase in CPM by speed during level walking is in conjunction with previous studies of the AM 7164, generally reporting high levels of shared variance (R^2=0.82-0.90) (Brage et al., 2003; Freedson et al., 1998; Nichols et al., 2000; Yngve, Nilsson, Sjostrom, & Ekelund, 2003). Although there is a difference in gait and thus detection of bodily movement between treadmill and outside walking (Nichols et al., 2000), one could argue that the results of this study are most applicable to treadmill walking. However, studies indicate good agreement between accelerometer output obtained while walking on treadmill and walking in a free-living setting (Vanhelst et al., 2009). This supports the validity of the GT1M as a valid tool for assessing levels of PA in the general adult population, as a large proportion of an adults´ daily PA is spent in locomotion (Terrier, Aminian,

& Schutz, 2001). The ability to detect changes in ambulatory speeds or intensities are important from a public health perspective, as researchers are often interested in evaluating the intensity and duration of physical activity performed throughout the day (Abel et al., 2008).

Unlike earlier studies of the AM 7164, the GT1M appears to be sensitive to changes in grades. This might be a result of inter-generation differences in the accelerometers and their sampling frequency. The MEMS-based accelerometer in the GT1M samples data at 30 Hertz compared to piezoelectric-based AM 7164 who samples data at 10 Hertz (John et al., 2009). If step length is decreased and step frequency is increased during uphill walking, as shown for uphill running (Padulo, Annino, Migliaccio, D'ottavio, & Tihanyi, 2012), the amount of vertical acceleration performed will increase accordingly (Brage et al., 2003). This might be picked up by the GT1M and not the AM 7164. However, the observed increase in CPM does not seem to reflect the concurrent increase in EE, leading to an underestimation of EE during uphill walking. Interestingly, the results from downhill walking indicate that EE is overestimated during this activity. Thereby it appears as the overestimation of EE during downhill walking evens out the underestimation of EE during uphill walking, and that the limitation of over- and underestimating EE during graded walking is no threat to the validity of the monitor for assessing ambulatory activities in a free-living setting where walking consists of level as well as graded walking.

Uniaxial accelerometer attached to the hip yield significantly fewer counts in cycling than in walking, thus underestimating intensity in cycling. As there was no linear relationship between increased workload and EE while cycling, we calculated the

CPM for all data point while cycling to be 1,157. Correspondently, the average MET-value obtained while cycling were 5.0 METs. During level walking, an EE of 5.0 METs equaled approximately a CPM value of 4300 CPM. Thereby, we calculate the size of the underestimation of CPM during cycling to be 73% ((1,157/4300)*100. However, due to the large variations in CPM values obtained while cycling, this estimate is uncertain. Nevertheless, as cycling is a common activity both for leisure activities as well as for transport, researchers should keep this in mind when assessing physical activity in populations were cycling is a common activities.

Several limitations should be acknowledged. The study sample was small (n=20), which introduce the risk of type II errors. However, the relatively homogenous sample, with regards to age, height and weight and BMI, reduces the risk of the results being affected by extreme values in the sample. Furthermore, we were able to discriminate between speeds and gradients, which suggest that the sample size was adequate for the hypothesis of the study. The use of 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ as the standard resting metabolic rate is debated and ideally it should have been individually measured. However, it is unlikely that this would have affected the relationship between CPM and METs. Strength of the study includes the use of a direct measure of EE and the use of a standardized protocol with interval of sufficient duration to obtain steady state measurements of oxygen uptake.

5.0 CONCLUSIONS

The GT1M discriminates between speeds in the normal walking range (3-7 $km^{.}h^{-1}$) and there is a strong linear relationship between CPM and EE expressed as METs (R^2=0.82) during level walking. Although the GT1M appears to discriminate between level and graded walking, the size of the difference in CPM does not seem to be large enough to reflect the decreased and increased EE observed during downhill and uphill walking, thus overestimating EE during downhill walking and vice versa.

During ergometer cycling, the GT1M yielded significantly fewer counts in during walking, thus underestimating intensity in cycling when calibration equations from treadmill experiments are used. Although the relationship between CPM and METs was non-linear we calculated average CPM and METs during cycling and estimated that CPM is underestimated by 73% during cycling compared to walking.

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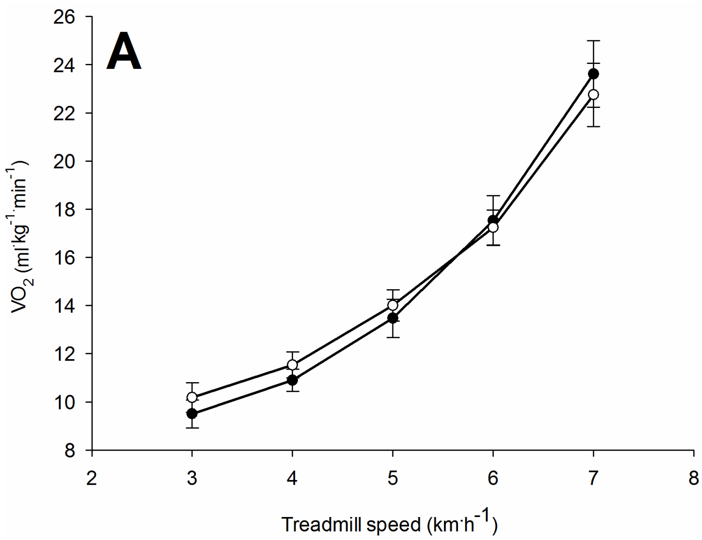
Table 1. CPM, VO_2, and HR during treadmill walking at various gradients (%) and speeds ($km \cdot h^{-1}$) (95% CI).

Grade	**Speed**	**CPM**		**VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)**		**METs**		**HR (bpm)**	
0	3	826	703 to 948	9.8	9.4 to 10.3	2.8	2.7 to 2.9	87	82 to 93
0	4	1888	1687 to 2089	11.2	10.9 to 11.6	3.2	3.1 to 3.3	89	84 to 95
0	5	3070	2830 to 3309	13.7	13.3 to 14.2	3.9	3.8 to 4.1	95	90 to 100
0	6	4303	4047 to 4558	17.4	16.8 to 18.0	5.0	4.8 to 5.2	104	99 to 110
0	7	5496	5187 to 5805	23.2	22.3 to 24.1	6.6	6.4 to 6.9	121	113 to 128
-5	5	3861	3159 to 4153	10.0	9.7 to 10.4	2.9	2.8 to 3.0	86	82 to 91
5	5	3324	2980 to 3669	19.3	18.6 to 20.0	5.5	5.3 to 5.7	109	103 to 115
8	5	4036	3668 to 4403	23.6	22.9 to 24.2	6.7	6.5 to 6.9	120	112 to 127



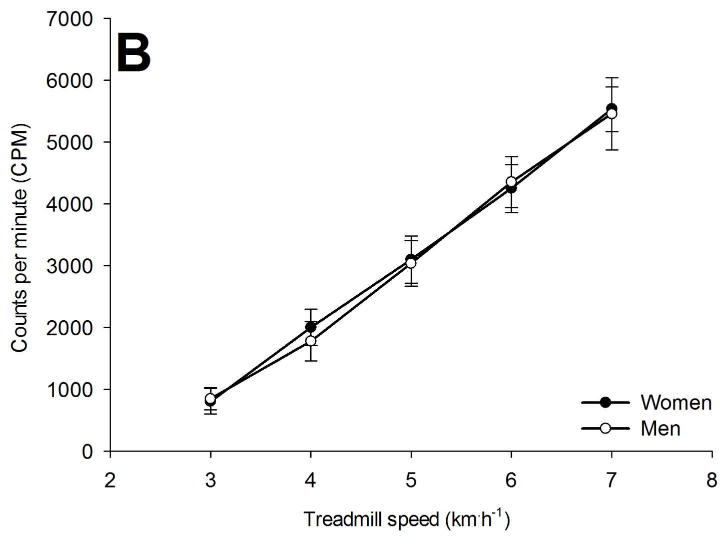


Figure 1AB. The relationship between treadmill speeds (km·h^{-1}) and oxygen consumption (VO_2) (A), and treadmill speed (km·h^{-1}) and CPM (B). Error bars represent 95% CI.

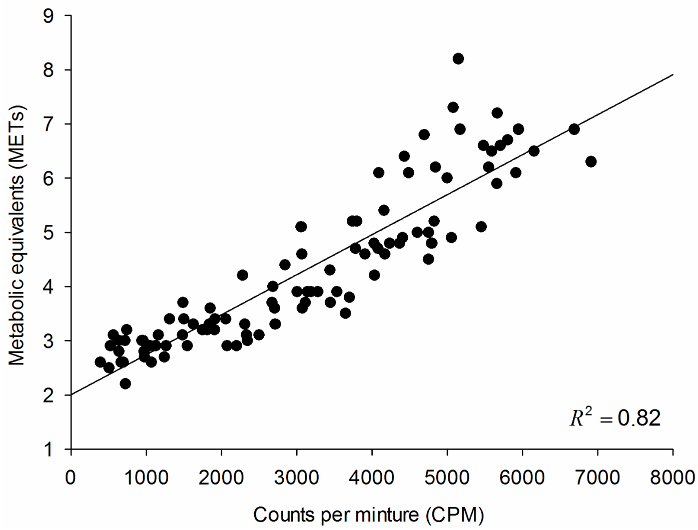


Figure 2. Energy expenditure (METs) as a function of CPM during levelled walking (n=20, each individual contribute with 7 data points). The solid line is the least squares regression line.

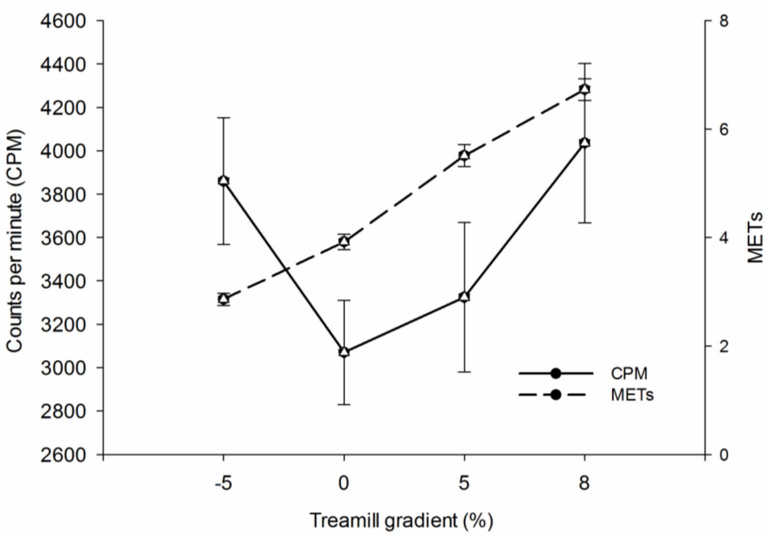


Figure 3. CPM and energy expenditure (METs) during downhill (-5%), level (0%) and uphill walking (5% and 8%) at 5 km·h^{-1}. The dotted line represents METs (right y-axis) and the solid line represents CPM (left y-axis).

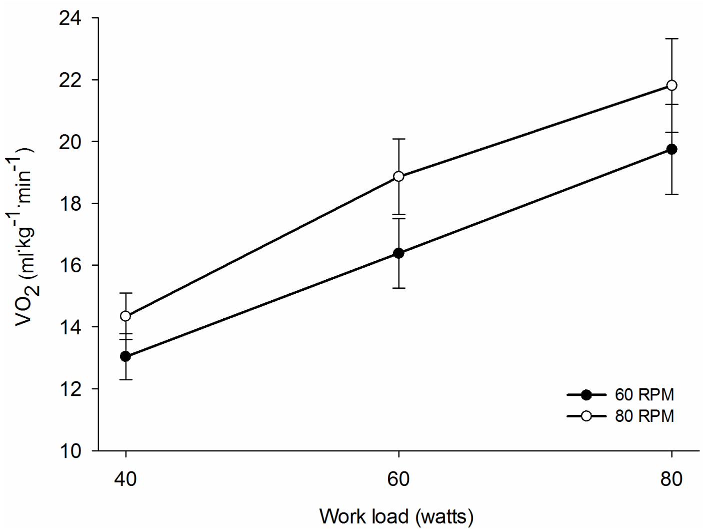


Figure 4. Oxygen consumption (VO_2) as a function of work load (watts) during cycling. Error bars represent 95% CI.

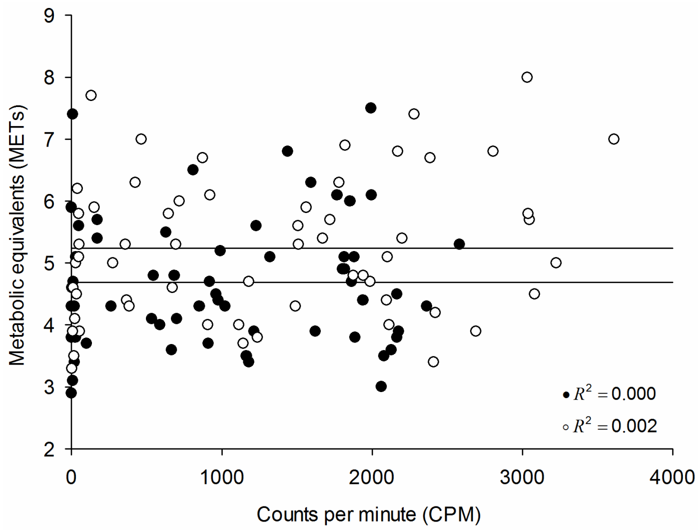


Figure 5. Energy expenditure (METs) as a function of CPM during cycling (n=20, each individualcontributes with 4 data points) at cadences of 60 (●) and 80 (○) RPM. The solid line is the least squares regression line.

Appendix I:

Approval letters from the Regional Committees for Medical Research Ethics

and

Approval letter from the Norwegian Social Science Data Services

UNIVERSITETET I OSLO

DET MEDISINSKE FAKULTET

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Dato: 11.02.08
Deres ref.:
Vår ref.: S-08046b

S-08046b Kartlegging av fysisk aktivitetsnivå, helserelatert fysisk form og determinanter for fysisk aktivitet hos voksne og eldre i Norge [6.2008.142]

Søknad mottatt 08.01.08 med følgende vedlegg: Protokoll; informasjonsskriv med samtykkeerklæring; spørreskjema; følgebrev til REK Sør-Øst datert 7. januar 2008.

Komiteen behandlet søknaden i sitt møte den 31. januar 2008. Prosjektet er vurdert etter lov om behandling av etikk og redelighet i forskning av 30. juni 2006, jfr. Kunnskapsdepartementets forskrift av 8. juni 2007 og retningslinjer av 27. juni 2007 for de regionale komiteer for medisinsk og helsefaglig forskningsetikk.

Forskningsetisk vurdering
Denne studien er todelt, og vil kartlegge status for fysisk aktivitetsnivå, determinanter for fysisk aktivitet, fysisk form og variabler relatert til fysisk form blant den voksne og eldre delen av den norske befolkningen. Komiteen ser ingen etiske betenkeligheter ved denne studien, forutsatt at den direkte målingen av fysisk form/aerob kapasitet i undersøkelsens Del 2 gjennomføres slik den er beskrevet i prosjektbeskrivelsen (dvs. at screening foretas før testen og at akuttmedisinsk hjelp er tilgjengelig under testen).

Vi ber imidlertid prosjektgruppen om å revurdere utvalgsstørrelsen som ligger til grunn for undersøkelsens Del 1. Styrkeberegningene som ligger til grunn for Del 1 (og for Del 2) synes å hvile på et solid grunnlag. Vi ser imidlertid at prosjektgruppen forventer at hele 2/3 deler av de 6000 personene som blir forespurt sier seg villige til å delta i del 1 av studien. Dette synes svært optimistisk med utgangspunkt i at prosjektgruppen henviser til at responsraten ved nylig gjennomførte landsdekkende undersøkelser i regi av FHI har vært på om lag 50 %. Det at deltagerne bes om å bære et akselerometer i en periode på syv dager vil nok neppe bidra til å øke responsraten. Komiteen ønsker en refleksjon omkring hvorvidt dette er realistisk.

I prosjektets Del 2 foreslås det å utelate aldersgruppen 20-30 år pga. økonomiske hensyn. Et av prosjektets mer langsiktige målsetninger er å studere utviklingstrender innen ulike aldersgrupper, gjennom å gjenta undersøkelsen med jevne mellomrom. At den yngste aldersgruppen utelates er bekymringsfullt da dette vil gjøre det problematisk å studere endringer i de yngste aldergruppene over tid. Siden potensialet for forebygging sannsynligvis er størst i nettopp de yngste aldersgruppene, vil utelatelsen redusere undersøkelsens verdi som redskap for forebygging. Vi ber prosjektgruppen om å vurdere på nytt om ikke også denne aldersgruppen bør inkluderes.

Informasjonsskriv/samtykkeerklæring
1. Informasjonsskrivet må påføres logo.
2. I andre avsnitt på første side må det informeres at testen av fysisk form kan påføre enkelte noe ubehag da deler av denne skal utføres under høy intensitet (flytt dette fram fra kapittel A).

3. Det må opplyses om at prosjektet er godkjent av Regional komité for medisinsk og helsefaglig forskningsetikk Helseregion Sør avdeling B, REK Sør B.
4. I kapittel A og B kan begrepsbruken være litt vanskelig å forstå. "Akselerometer" foreslås byttet ut med "aktivitetsmåler". Videre bør det forklares hva som ligger i at "eventuell utgifter for deltakerne i undersøkelsens del 2 vil bli dekket".
5. Dato for sletting av data/kode må angis.
6. "Dette vil ikke få konsekvenser for din videre må behandling" må utgå da personene som deltar i dette prosjektet ikke er til behandling som er knyttet til deltakelsen.

Vedtak
Prosjektet godkjennes under forutsetning av at de merknadene som er anført ovenfor blir innarbeidet før prosjektet settes i gang. Revidert informasjonsskriv og samtykkeerklæring må sendes komiteen til orientering.

Komiteens avgjørelse var enstemmig.

Komiteens vedtak kan påklages (jfr. Forvaltningslovens § 28) til Den nasjonale forskningsetiske komité for medisin og helsefag. Klagen skal sendes til REK Sør-Øst B (jfr. Forvaltingslovens § 32). Klagefristen er tre uker fra den dagen du mottar dette brevet (jfr. Forvaltningslovens § 29). Det bes presisert hvilke vedtak/vilkår som påklages og den eller de endringer som ønskes. Se informasjon om klageadgang og partsinnsynsrett på http://www.etikkom.no/REK/klage

Med vennlig hilsen

Tor Norseth
Leder

Jorunn Lindholt
Jorunn Lindholt
Sekretær

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

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Dato: 29.04.08
Deres ref.:
Vår ref.: S-08046b

S-08046b Kartlegging av fysisk aktivitetsnivå, helserelatert fysisk form og determinanter for fysisk aktivitet hos voksne og eldre i Norge [6.2008.142]

Vi viser til brev datert 18.03.08 vedlagt revidert informasjonsskriv og spørreskjema.

Komiteen tar revidert informasjonsskriv og spørreskjema til orientering.

Vi ønsker lykke til med prosjektet!

Med vennlig hilsen

Tor Norseth
Leder

Julianne Krohn-Hansen
Sekretær

Norsk samfunnsvitenskapelig datatjeneste AS
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0806 OSLO

Vår dato: 24.04.2008 Vår ref: 18886 / 2 / SF Deres dato: Deres ref:

TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 14.03.2008. Meldingen gjelder prosjektet:

18886	*Kartlegging av fysisk aktivitetsnivå, helserelatert fysisk form og determinanter for fysisk aktivitet hos voksne og eldre i Norge*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Sigmund A. Anderssen*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/forsk_stud/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/prosjektoversikt.jsp.

Personvernombudet vil ved prosjektets avslutning, 31.12.2020, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Bjørn Henrichsen

Sølve Fauskevåg

Kontaktperson: Sølve Fauskevåg tlf: 55 58 25 83
Vedlegg: Prosjektvurdering

Personvernombudet for forskning

Prosjektvurdering - Kommentar

18886

BAKGRUNN
Prosjektet er et samarbeid mellom institusjonene:
- Norges idrettshøgskole
- Høgskolene i Finnmark, Bodø, Sogn og Fjordane, Vestfold, Telemark og Hedmark
- Universitetene i Stavanger og Agder, samt NTNU

Norges idrettshøgskole (NIH) er koordinerende aktør og databehandlingsansvarlig for prosjektet. Prosjektleder, ved NIH, er daglig ansvarlig. Det inngås databehandleravtaler mellom samarbeidspartene i henhold til personopplysningsloven § 15.

FORMÅL
Formålet med undersøkelsen er å øke kunnskapen om fysisk aktivitetsnivå, fysiske aktivitetsvaner, samt determinanter for fysisk aktivitet i den voksne delen av den norske befolkningen.

Undersøkelsen iverksettes på initiativ fra Sosial- og helsedirektoratet. Det kan bli aktuelt å gjennomføre oppfølgingsundersøkelser om fem og/eller ti år, og det kan være aktuelt å utvide datagrunnlaget med registerdata. Eventuelle nye oppfølginger og/eller utvidelser meldes ombudet i god tid før iverksetting.

UTVALG, INFORMASJON OG SAMTYKKE
Utvalget er et tilfeldig utvalg av cirka 8000 personer. Utvalget trekkes fra Folkeregisteret og av EDB Business Partner basert på tillatelse fra Skattedirektoratet.

Utvalget sendes informasjonsskriv og kan samtykke skriftlig til deltakelse.

DATAMATERIALET
Datamaterialet innhentes ved hjelp av spørreskjema, aktivitetsmåler og fysiske tester og målinger. Datamaterialet inneholder blant annet navn, personnummer, kjønn, alder, etnisk bakgrunn, yrke, inntekt og utdanningsnivå, kommune, røyking og snus, medlemskap i idrettslag/foreninger, kosthold og bruk av TV og PC, fysisk form (balanse, styrke, bevegelighet og koordinasjon), høyde, vekt, livvidde, hoftevidde, kroppssammensetning, blodtrykk samt resultatene fra aktivitetsmåler (akselerometer) som utvalget skal gå med i syv dager.

REGISTRERING, OPPBEVARING OG UTLEVERING
Navn, fødselsår, adresse, fødekommune og fødeland, sivilstatus og antall barn trekkes fra Folkeregisteret. Informasjonsskriv sendes det trekte utvalget. Det kan gjøres en purring til personer som ikke har svart på første forespørsel.

Alle registrerte opplysninger tilknyttet den delen av utvalget som ikke samtykker, anonymiseres umiddelbart etter at svarfristen på purringen har utløpt.

Prosjektleder vil ha tilgang til hele datamaterialet. De lokale koordinatorene har tilgang til den delen av datamaterialet som de er ansvarlige for å samle inn. Prosjektets styringsgruppe vil ikke ha tilgang til datamaterialet.

Prosjektet forventes avsluttet med rapport 31.01.2009. Datamaterialet skal deretter oppbevares til 31.12.2020 med tanke på eventuelle oppfølgings- eller utvidede undersøkelser. Innen 31.12.2020 anonymiseres datamaterialet. Anonymisering innebærer at direkte og indirekte personidentifiserende opplysninger slettes eller omskrives (grovkategoriseres), samt at koblingsnøkkel slettes.

ANDRE TILLATELSER
Prosjektet er godkjent av Regional komité for medisinsk forskningsetikk Midt-Norge (REKs ref. S-08046b).

Skatteetaten har gitt tillatelse til å trekke utvalget inkludert noen bakgrunnsopplysninger fra Folkeregisteret (Skatteetatens ref. 2008/167522 /SKDRESF/GTE /341).

KOMMENTAR
Personvernombudet finner at prosjektet kan gjennomføres med hjemmel i personopplysningsloven (pol) §§ 8, første ledd og 9 a), samtykke.

Informasjonsskrivet per 23.04.2008 er godt utformet og redegjør for alle sider ved prosjektet forutsatt at dato for anonymisering av data tilføyes, jf. e-post samme dag.

Trekking og førstegangskontakt med utvalget kan hjemles i personopplysningsloven §§ 8 d) og 9 h). Det vises til at undersøkelsen er på oppdrag fra Sosial- og helsedirektoratet og tar sikte på å fremskaffe ny representativ kunnskap om aktivitet og helse. Trekking og kontakt med et representativt utvalg kan vanskelig gjøres på mer skånsom måte enn via Folkeregisteret. Ulempene for de registrerte er minimale da de informeres om trekkingen, og registrerte opplysninger anonymiseres umiddelbart for de som ikke samtykker innen svarfrist for purringen har utløpt.

Appendix II:

Study information and informed consent form

Kan1
Kartlegging aktivitet Norge

Forespørsel om deltakelse i Kan1

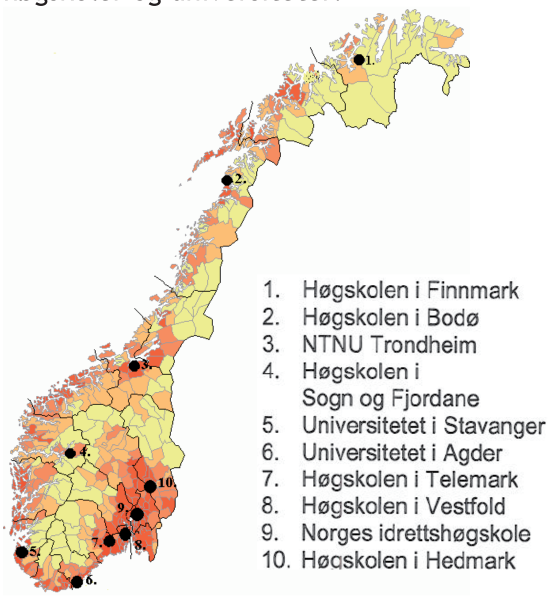
– en **kartleggingsundersøkelse** av fysisk aktivitet og fysisk form blant **voksne** og **eldre**

NTNU Samfunnsforskning AS

Norges idrettshøgskole

Helsedirektoratet

Hva er Kan1-undersøkelsen?
Kan1 er en landsomfattende kartlegging av befolkningens aktivitetsnivå og fysiske form. Vi har i dag ikke tilstrekkelig informasjon på dette feltet til å kunne beskrive utviklingstrekk i befolkningsgrupper og geografiske områder og forskjeller mellom dem. Denne undersøkelsen er ett ledd i Helsedirektoratets Handlingsplan for fysisk aktivitet, hvor et av hovedmålene er å etablere et system for kartlegging av det fysiske aktivitetsnivået i befolkningen. Undersøkelsen gjennomføres over hele landet i løpet av 2008 og 2009 og utføres av følgende høgskoler og universiteter:



Hva innebærer deltakelse i undersøkelsen for deg?
Deltakelse i undersøkelsen innebærer at du svarer på et spørreskjema og går med en aktivitetsmåler i syv dager. Aktivitetsmåleren er et lite og lett apparat som bæres i et elastisk belte rundt livet (se bilder neste side). Du går med måleren i 7 dager og returnerer den deretter sammen med spørreskjemaet i vedlagt returkonvolutt (Fase 1). I etterkant av Fase 1 vil om lag ¼ av deltakerne bli tilfeldig trukket ut og invitert til å gjennomføre en tilleggsundersøkelse av fysisk form (Fase 2). Du kan delta i den første delen av undersøkelsen, og si nei til videre deltakelse.

KAN du delta?
Velger du å delta i Kan1-undersøkelsen bidrar du med viktig og ny kunnskap om aktivitetsnivå og fysisk form i befolkningen.

Alle kan delta, uansett om man ser på seg selv som fysisk aktiv eller ikke.

Hensikten med undersøkelsen er å kartlegge et utvalg som representerer hele befolkningen, ikke bare den delen som er mest aktiv.

Fordeler og ulemper
Ved deltakelse i undersøkelsen vil du i etterkant motta en detaljert tilbakemelding på eget aktivitetsnivå. Du vil blant annet se hvorvidt du oppfyller Helsedirektoratets anbefalinger for fysisk aktivitet. Dersom du blir invitert til videre deltakelse i Fase 2, vil du få tilbakemelding på egen fysisk form. Test av fysisk form i Fase 2 kan påføre deltakere noe ubehag, da man skal utføre enkelte øvelser med høy intensitet.

Hva skjer med informasjonen om deg?
All informasjon som samles inn om deg, vil bli behandlet i henhold til gjeldende lover og forskrifter. Alle medarbeidere involvert i undersøkelsen har taushetsplikt, og opplysningene som samles inn, vil kun bli brukt til godkjente forskningsformål. Se avsnittet om personvern på neste side for mer informasjon.

Frivillig deltakelse
Det er frivillig å delta i undersøkelsen. Du kan når som helst trekke deg uten å oppgi noen grunn. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side.

Kriterier for deltakelse
Kriterier for deltakelse er at man er over 20 år, bor i Norge og er norsk statsborger.

Tidsplan
I perioden april til november 2008 sendes spørreskjema og aktivitetsmåler til deltakeren. Denne delen av undersøkelsen skjer kun per post og kalles Fase 1. Et tilfeldig utvalg av deltakerne i Fase 1 (omtrent ¼) vil bli invitert til en undersøkelse av fysisk form (Fase 2). Fase 2 vil finne sted to til seks måneder etter hovedundersøkelsen. Det er fullt mulig å si nei til deltakelse i Fase 2, selv om man har deltatt i Fase 1.

Mulige bivirkninger
Det er ingen kjente bivirkninger ved deltakelse i undersøkelsen. Test av fysisk form i Fase 2 kan påføre deltaker noe ubehag idet man skal utføre enkelte øvelser med høy intensitet. Eventuelle reiseutgifter for deltakere som blir invitert til deltakelse i Fase 2, vil bli dekket av undersøkelsen.

Personvern
Undersøkelsen er godkjent av Regional komité for medisinsk og helsefaglig forskningsetikk Helseregion Sør avdeling B, REK Sør B. Undersøkelsen er tilrådd av personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste A/S.

Opplysninger som registreres om deg, er personalia som alder, kjønn, sivil status og etnisitet, i tillegg til opplysninger om blant annet aktivitet, kosthold og helse. Du kan være trygg på at informasjonen du bidrar med til undersøkelsen, vil bli behandlet med respekt for personvern og privatliv, og i samsvar med lover og forskrifter.

Innsamlede opplysninger oppbevares slik at navn er erstattet med en kode som viser til en atskilt navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av undersøkelsen når disse publiseres.

Rett til innsyn og sletting av opplysninger om deg og sletting av prøver
Hvis du sier ja til å delta i undersøkelsen, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har videre rett til å få korrigert eventuelle feil i de opplysningene vi har registrert. Dersom du trekker deg fra undersøkelsen, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner.

Det kan bli aktuelt å innhente opplysninger om deg fra nasjonale helseregistre: Skade-, kreft-, dødsårsaks-, og reseptregisteret. Vi ber om din tillatelse til å innhente tilleggsinformasjon fra de nevnte registre. Alle innsamlede opplysninger anonymiseres senest innen 31.12.2020, med mindre vi innen da har kontaktet deg med forespørsel om noe annet.

Økonomi og Helsedirektoratets rolle
Undersøkelsen er finansiert og initiert av Helsedirektoratet.

Bilde 1 og 2. Aktivitetsmåleren i bruk

Kan1

Samtykke til deltakelse i undersøkelsen

Dette eksemplaret underskrives og returneres i vedlagt svarkonvolutt.
Den returnerte samtykkeerklæringen vil bli oppbevart på ett nedlåst sted.

Jeg er villig til å delta i undersøkelsen

Vennligst fyll ut opplysningene nedenfor:
(skriv tydelig, helst med blokkbokstaver)

Fornavn:

....

Etternavn:

....

....
(Signer her)

Jeg bekrefter å ha gitt informasjon om undersøkelsen

Sigmund Anderssen
....

Professor Sigmund Alfred Anderssen
Prosjektleder
Seksjon for idrettsmedisin
Norges idrettshøgskole

kartlegging **aktivitet** Norge
2008

Appendix III:

Instructions for use of the activity monitor

Bruk av aktivitetsmåleren

Ta på deg aktivitetsmåleren **morgenen etter** at du mottok den i posten. Den skal sitte på **i sju hele dager,** fra du står opp til du legger deg. Du behøver ikke slå den av eller på, alt går automatisk.

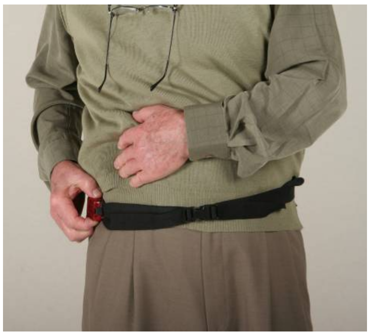
Ta på deg måleren på følgende måte:

- Fest beltet rundt livet slik at måleren sitter på **høyre hoftekam** (se bilder). Det er viktig at du er nøyaktig med plasseringen av måleren
- Pass på at siden merket med "Opp" peker oppover
- Måleren skal være godt festet og ikke henge og slenge

Det er kun i følgende situasjoner at måleren **ikke** skal sitte på:

- Når du sover (om natten)
- Når du dusjer, svømmer eller bader (den er ikke vanntett)

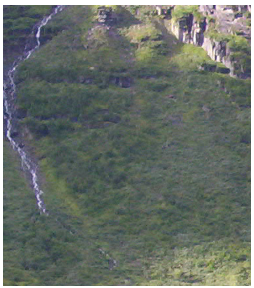
Måleren tåler daglig bruk, og du behøver ikke være redd for at den skal gå i stykker. Måleren må imidlertid ikke åpnes, vaskes eller lånes bort. Gå med måleren så vel til hverdag som til fest, dersom den sjenerer kan du gjemme den under klærne. Måleren koster 2500 kr. Du er ikke økonomisk ansvarlig for måleren, men pass godt på den. Returner måleren i vedlagt returkonvolutt (sammen med Hoved- og Tilleggsskjema) etter at du har gått med den i sju dager.



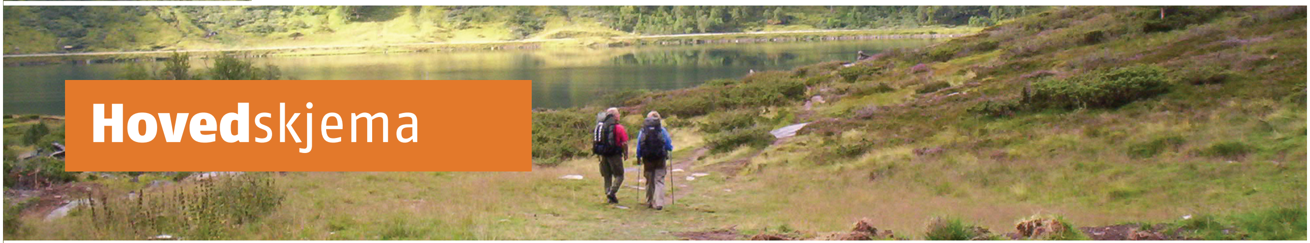
Se www.nih.no/kan for mer info og videosnutt

Appendix IV:

Main questionnaire and additional questionnaire



Kan1
Kartlegging aktivitet Norge



Hovedskjema

Kjære Kan1 deltaker,

Ved hjelp av besvarelsen fra deg og andre deltakere vil vi få økt kunnskap om det fysiske aktivitetsnivået i den norske befolkning. I tillegg vil vi få bedre forståelse for hvilke forhold som er knyttet til fysisk aktivitet blant voksne og eldre.

Du har selvsagt anledning til å unnlate å svare på enkeltspørsmål. Det er imidlertid viktig at du gir ærlige svar. Informasjonen i dette spørreskjemaet behandles konfidensielt og ditt navn vil verken forekomme i datafiler eller i skriftlig materiale.

Det tar 20-30 minutter å fylle ut spørreskjemaet.
Vennligst følg instruksene underveis.

Skjemaet skal leses ved hjelp av en datamaskin. Bruk sort eller blå penn ved utfylling. Det er viktig at du fyller ut skjemaet riktig:

- Ved avkrysning, sett ett kryss innenfor rammen av boksen ved det svaralternativet som passer best

X Riktig

X Galt

Om du krysser av i feil boks, retter du ved å fylle boksen slik

- Skriv tydelige **tall** innenfor rammen av boksen

7 4 Riktig

7 4 Galt

- Bruk **blokkbokstaver** hvis du skal skrive A B C D E F

På forhånd takk for hjelpen!

T T

Bakgrunnsinformasjon

1) Kjønn: ☐ Kvinne ☐ Mann

2) Fødselsår: 19 ☐☐

3) Høyde: ☐☐☐ cm

4) Vekt: ☐☐☐, ☐ kg

5) Hvilken utdanning er den høyeste du har fullført? (Sett ett kryss)

- ☐ Mindre enn 7 år grunnskole
- ☐ Grunnskole 7-10 år, framhaldsskole eller folkehøgskole
- ☐ Realskole, middelskole, yrkesskole, 1-2 årig videregående skole
- ☐ Artium, økonomisk gymnas, allmennfaglig retning i videregående skole
- ☐ Høgskole/universitet, mindre enn 4 år
- ☐ Høgskole/universitet, 4 år eller mer

6) Hva er din hovedaktivitet? (Sett ett kryss)

☐ Yrkesaktiv heltid	☐ Hjemmeværende
☐ Yrkesaktiv deltid	☐ Pensjonist/trygdet
☐ Arbeidsledig	☐ Student/militærtjeneste

7) Hvor høy var husholdningens samlede bruttoinntekt siste år? (sett ett kryss)
Ta med alle inntekter fra arbeid, trygder, sosialhjelp og lignende

☐ Under 125.000 kr	☐ 401.000 – 550.000 kr	
☐ 125.000 – 200.000 kr	☐ 551.000 – 700.000 kr	
☐ 201.000 – 300.000 kr	☐ 701.000 – 850.000 kr	
☐ 301.000 – 400.000 kr	☐ Over 850.000 kr	☐ Ønsker ikke svare

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8) Hvor mange innbyggere er det i din bostedskommune? (sett ett kryss)

☐ Under 1000 ☐ 20.001 – 30.000
☐ 1001 – 5000 ☐ 30.001 – 100.000
☐ 5001 – 10.000 ☐ Mer enn 100.000
☐ 10.001 – 20.000

9) Hvordan vurderer du din egen helse sånn i alminnelighet? (sett ett kryss)

☐ Meget god ☐ God ☐ Verken god eller dårlig ☐ Dårlig ☐ Meget dårlig

10) I hvilken grad begrenser din helse dine hverdagslige gjøremål? (sett ett kryss)

☐ I stor grad ☐ I noen grad ☐ I liten grad ☐ Ikke i det hele tatt

11) Mener du at fysisk aktivitet er viktig for å kunne vedlikeholde egen helse? (sett ett kryss)

☐ Ja, meget viktig for meg
☐ Egentlig tenker jeg ikke så mye på det
☐ Nei, det er ikke så viktig for meg

12) Har du, eller har hatt: (sett gjerne flere kryss)

☐ Astma ☐ Allergi
☐ Kronisk bronkitt/emfysem/KOLS ☐ Psykiske plager du har søkt hjelp for
☐ Hjerteinfarkt ☐ Sukkersyke (diabetes type I)
☐ Angina Pectoris (hjertekrampe) ☐ Sukkersyke (diabetes type II)
☐ Hjerneslag/hjerneblødning (”drypp”) ☐ Benskjørhet/osteoporose
☐ Kreft ☐ Revmatiske lidelser
☐ Spiseforstyrrelser
☐ Annet: ______________________________

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Fysisk aktivitet

De neste spørsmålene omhandler fysisk aktivitet. Fysisk aktivitet omfatter både:

- fysisk aktivitet i hverdagen (i arbeid, fritid og hjemme, samt hvordan du forflytter deg til og fra arbeid og fritidssysler)
- planlagte aktiviteter (gå på tur, svømming, dansing)
- trening (for å bedre kondisjon, muskelstyrke og andre ferdigheter)

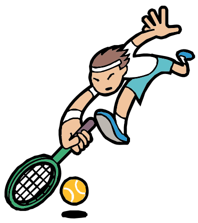
Det er flere nesten like spørsmål - det er meningen

13) Er du *aktivt medlem* av et idrettslag eller en idrettsklubb? (sett ett kryss)

☐ Ja

☐ Nei, men jeg har vært medlem før

☐ Nei, jeg har aldri vært medlem (gå til spm 15)



14) Når ble du medlem for første gang?

Jeg ble medlem da jeg var ☐ år gammel

15) Dersom du er fysisk aktiv, hvilke aktiviteter driver du vanligvis med:
(Sett gjerne flere kryss)

☐ Turgåing	☐ Ballspill	☐ Padling/roing
☐ Dans	☐ Stavgang	☐ Sykling/spinning
☐ Golf	☐ Svømming	☐ Jogging
☐ Langrenn	☐ Vanngymnastikk	☐ Skøyter/bandy/hockey
☐ Yoga/pilates	☐ Alpint/snowboard	☐ Trening til musikk i sal
☐ Tennis	☐ Kampsport (karate, judo ol)	☐ Squash/Badminton/Bordtennis

☐ Treningsstudio (styrketrening, tredemølle, ergometersykkel, elipsemaskin ol)

☐ Annet,

hva:____

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16) Hvor ofte trener du på de måtene som er nevnt under?
(Sett ett kryss for hvor ofte du er aktiv på hver måte)

	Aldri	Sjelden	1-3 g/mnd	1 dag/uke	2-3 dag/uke	4-6 dag/uke	Daglig
I idrettslag………………..	☐	☐	☐	☐	☐	☐	☐
På treningssenter………	☐	☐	☐	☐	☐	☐	☐
På jobben eller skolen…	☐	☐	☐	☐	☐	☐	☐
Hjemme…………………….	☐	☐	☐	☐	☐	☐	☐
I nærmiljøet……………..	☐	☐	☐	☐	☐	☐	☐
I svømmehall……………	☐	☐	☐	☐	☐	☐	☐
Sykler…………………….	☐	☐	☐	☐	☐	☐	☐
Danser…………………....	☐	☐	☐	☐	☐	☐	☐
Skitur……………………..	☐	☐	☐	☐	☐	☐	☐
Fottur……………………..	☐	☐	☐	☐	☐	☐	☐

17) **Hvor mange timer den siste uken har du vært i fysisk aktivitet i hjemmet eller i tilknytning til hjemmet?** Det er kun aktiviteter som varer i minst 10 minutter i strekk som skal rapporteres

	Ingen	< 1 time	1-2 timer	3-4 timer	> 4 timer
Lett aktivitet - ikke svett/andpusten………..	☐	☐	☐	☐	☐
Hard aktivitet - svett/andpusten…………….	☐	☐	☐	☐	☐

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18) **Angi bevegelse og kroppslig anstrengelse i din fritid. Hvis aktiviteten varierer meget f.eks mellom sommer og vinter, så ta et gjennomsnitt.**
Spørsmålet gjelder bare det siste året (sett ett kryss i den ruta som passer best)

- Lese, ser på fjernsyn eller annen stillesittende beskjeftigelse?............................ ☐
- Spaserer, sykler eller beveger deg på annen måte minst 4 timer i uka? (Her skal du regne med gang eller sykling til arbeidsstedet, søndagsturer mm)… ☐
- Driver mosjonsidrett, tyngre hagearbeid e.l? (Merk at aktiviteten skal vare minst 4 timer i uka)…………………………………… ☐
- Trener hardt eller driver konkurranseidrett regelmessig og flere ganger i uka……. ☐

Når du svarer på spørsmålene 19 - 22:

Meget anstrengende – er fysisk aktivitet som får deg til å puste *mye mer* enn vanlig
Middels anstrengende – er fysisk aktivitet som får deg til å puste *litt mer* enn vanlig

Det er kun aktiviteter som varer **minst 10 minutter i strekk** som skal rapporteres

19a) **Hvor mange dager i løpet av de siste 7 dager har du drevet med *meget anstrengende* fysiske aktiviteter som tunge løft, gravearbeid, aerobics eller sykle fort?** Tenk bare på aktiviteter som varer *minst 10 minutter i strekk*

☐ Dager per uke

☐ Ingen (gå til spørsmål 20a)

19b) **På en vanlig dag hvor du utførte *meget anstrengende* fysiske aktiviteter, hvor lang tid brukte du da på dette?**

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke

20a) **Hvor mange dager i løpet av de siste 7 dager har du drevet med *middels anstrengende* fysiske aktiviteter som å bære lette ting, sykle eller jogge i moderat tempo eller mosjonstennis?** Ikke ta med gange, det kommer i neste spørsmål.

☐ Dager per uke

☐ Ingen (gå til spørsmål 21a)

T T

20b) På en vanlig dag hvor du utførte *middels anstrengende* fysiske aktiviteter, hvor lang tid brukte du da på dette?

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke

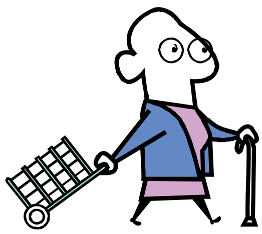
21a) Hvor mange dager i løpet av de siste 7 dager, *gikk du minst 10 minutter* i strekk for å komme deg fra ett sted til et annet? Dette inkluderer gange på jobb og hjemme, gange til buss, eller gange som du gjør på tur eller som trening i fritiden

☐ Dager per uke

☐ Ingen (gå til spørsmål 22)

21b) På en vanlig dag hvor du *gikk* for å komme deg fra et sted til et annet, hvor lang tid brukte du da totalt på å gå?

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke



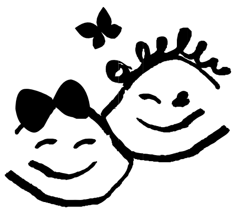
22) Dette spørsmålet omfatter all tid du tilbringer i ro (*sittende*) på jobb, hjemme, på kurs, og på fritiden. Det kan være tiden du sitter ved et arbeidsbord, hos venner, mens du leser eller ligger for å se på TV.

I løpet av de siste 7 dager, hvor land tid brukte du vanligvis totalt på å sitte <u>på en vanlig hverdag</u>?

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke

23) Nedenfor følger en rekke grunner for å drive med fysisk aktivitet. Vennligst sett ett eller flere kryss for den (de) grunnen(e) som er viktige for deg.

- ☐ Forebygge helseplager
- ☐ Holde vekten nede
- ☐ For å se veltrent ut
- ☐ Øke prestasjonsevnen
- ☐ Gjøre fritiden trivelig
- ☐ For å ha det gøy
- ☐ Føler jeg må
- ☐ Komme i bedre form
- ☐ Anbefalt av lege, fysioterapeut eller liknende
- ☐ Fysisk og psykisk velvære
- ☐ For å treffe og omgås andre mennesker
- ☐ Oppbygging etter sykdom/skade
- ☐ Oppleve spenning/utfordring
- ☐ For å få frisk luft



24) Nedenfor følger en rekke grunner for å *ikke* drive med fysisk aktivitet. Vennligst sett ett eller flere kryss for den (de) grunnen(e) som er viktig(e) for deg.

- ☐ Har ikke tid
- ☐ Har ikke råd
- ☐ Transportproblemer
- ☐ Negative erfaringer
- ☐ Bevegelsesproblemer
- ☐ Tror ikke jeg får det til
- ☐ Orker ikke
- ☐ Synes jeg er for gammel
- ☐ På grunn av min fysiske helse
- ☐ Har ingen å være fysisk aktiv sammen med
- ☐ Tidspunktet passer meg ikke
- ☐ Kjenner ikke til noe tilbud
- ☐ Engstelig for å gå ut
- ☐ Mangel på tilbud innen mine interesseområder
- ☐ Redd for å bli skadet (falle, forstue)
- ☐ Vil heller bruke tiden min til andre ting
- ☐ Andre grunner, hva: ______________________________

T T

Transport aktiviteter

De neste spørsmålene handler om dine vaner knyttet til transport og omfatter dine vanlige måter å komme fra et sted til et annet, inkludert hvordan du kommer deg til og fra jobb, butikker, kino, fritidssysler og så videre.

Merk at du skal angi dine transportvaner separat for sommer og vinter.

25a) Hvor mange dager *i en vanlig uke* reiser du med et motorisert transportmiddel som tog, buss, bil eller trikk?

Om sommeren

☐ Dager per uke

Om vinteren

☐ Dager per uke

25b) På *en vanlig dag* hvor du reiser med motorisert transportmiddel, hvor lang tid bruker du da totalt i transportmiddelet?

Om sommeren

☐ Timer ☐ Minutter

Om vinteren

☐ Timer ☐ Minutter

26a) Hvor mange dager i *en vanlig uke* sykler du *minst 10 minutter i strekk* for å komme fra et sted til ett annet?

Om sommeren

☐ Dager per uke

Om vinteren

☐ Dager per uke

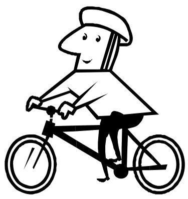
26b) På *en vanlig dag* hvor du *sykler* for å komme deg fra et sted til ett annet, hvor lang tid bruker du da totalt på å sykle?

Om sommeren

☐ Timer ☐ Minutter

Om vinteren

☐ Timer ☐ Minutter



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27a) Hvor mange dager i *en vanlig uke* går du *minst 10 minutter i strekk* for å komme fra et sted til ett annet?

Om sommeren

☐ Dager per uke

Om vinteren

☐ Dager per uke

27b) På *en vanlig dag* hvor du går for å komme deg fra et sted til ett annet, hvor lang tid bruker du da totalt på *å gå*?

Om sommeren

☐ Timer ☐ Minutter

Om vinteren

☐ Timer ☐ Minutter

28) Dersom du er yrkesaktiv, hvordan kommer du deg vanligvis til og fra arbeid?

- ☐ Bil/motorsykkel
- ☐ Offentlig transport (tog, buss, og liknende)
- ☐ Sykkel
- ☐ Til fots
- ☐ Ikke aktuelt

TV, PC og søvnvaner

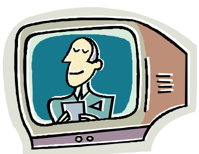
De neste spørsmålene handler om dine vaner knyttet til bruk av **TV og PC utenom jobb.** I tillegg vil vi kartlegge dine søvnvaner

29) Utenom jobb: Hvor mange timer ser du vanligvis på TV og sitter med PC på en hverdag? (Sett ett kryss)

- ☐ Mindre enn 1 time
- ☐ 1 - 2 timer
- ☐ 2 - 3 timer
- ☐ 3 - 4 timer
- ☐ 4 - 5 timer
- ☐ Mer enn 5 timer

30) Utenom jobb: Hvor mange timer ser du vanligvis på TV og sitter med PC på en helgedag? (Sett ett kryss)

- ☐ Mindre enn 1 time
- ☐ 1 - 2 timer
- ☐ 2 - 3 timer
- ☐ 3 - 4 timer
- ☐ 4 - 5 timer
- ☐ Mer enn 5 timer



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31) Hvor mange timer i døgnet sover du vanligvis på en hverdag?
(Sett ett kryss)

☐ Mindre enn 3 timer ☐ 8 - 10 timer
☐ 3 - 5 timer ☐ 10 timer eller mer
☐ 5 - 8 timer

32) Hvor mange timer i døgnet sover du vanligvis på en helgedag eller fridag?
(Sett ett kryss)

☐ Mindre enn 3 timer ☐ 8 - 10 timer
☐ 3 - 5 timer ☐ 10 timer eller mer
☐ 5 - 8 timer

Kosthold, røyk og alkohol

I denne delen av spørreskjemaet er det fokus på kosthold og dine røyke- og alkoholvaner. Vi er klar over at kostholdet varierer fra dag til dag. Prøv derfor så godt du klarer å ta ett gjennomsnitt av dine spisevaner og ha det siste året i tankene når du svarer.

33) Har du røykt/røyker du daglig? (sett ett kryss)

☐ Ja, nå ☐ Ja, tidligere ☐ Aldri (Gå videre til spørsmål 36)

34) Hvis du har røykt daglig tidligere, hvor lenge siden er det du sluttet?

☐☐ år

35) Hvis du røyker daglig nå eller har røykt tidligere:

Hvor mange sigaretter røyker eller røykte du vanligvis daglig?

☐☐ Antall sigaretter

Hvor gammel var du da du begynte å røyke?

☐☐ Alder i år

Hvor mange år til sammen har du røykt daglig?

☐☐ Antall år

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36) Bruker du snus? (sett ett kryss)

☐ Ja, daglig ☐ Av og til ☐ Aldri

37) Hvor ofte drikker du alkohol? (Sett ett kryss som stemmer best med dine vaner)

☐ Aldri

☐ Månedlig eller sjeldnere

☐ 2 - 4 ganger pr måned

☐ 2 - 3 ganger per uke

☐ 4 ganger i uken eller oftere

38) Når du drikker alkohol, hvor mange "drinker" tar du vanligvis?
En "drink" tilsvarer en ½ liter pils, ett glass vin, ett drammeglass
(Dersom du ikke drikker alkohol skal du ikke krysse)

☐ 1 - 2 ☐ 3 - 4 ☐ 5 - 6 ☐ 7 - 8 ☐ 9 eller mer

39) Hvor mange enheter med frukt og grønnsaker spiser du i gjennomsnitt hver dag?
(Med enhet menes for eksempel 1 frukt, 1 glass juice, 2-3 poteter, 1 skål bær, 1 porsjon grønnsaker, 1 porsjon salat)

☐☐ Antall porsjoner frukt

☐☐ Antall porsjoner grønnsaker

40) Hvor ofte pleier du å spise følgende måltider i løpet av en uke?
(Sett ett kryss for hvert måltid)

	Aldri/ Sjelden	**1 g/uke**	**2 g/uke**	**3 g/uke**	**4 g/uke**	**5 g/uke**	**6 g/uke**	**Hver dag**
Frokost…….	☐	☐	☐	☐	☐	☐	☐	☐
Lunsj……….	☐	☐	☐	☐	☐	☐	☐	☐
Middag…….	☐	☐	☐	☐	☐	☐	☐	☐
Kveldsmat…	☐	☐	☐	☐	☐	☐	☐	☐

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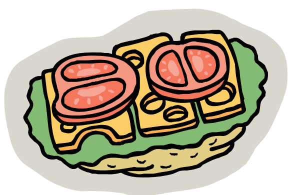
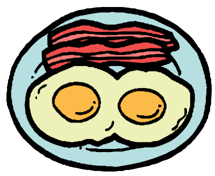
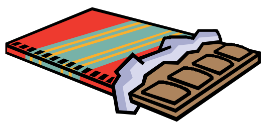
41) Hvor ofte spiser du vanligvis disse matvarene?
(Sett ett kryss per linje)

	0-1 g/mnd	2-3 g/mnd	1-3 g/uke	4-6 g/uke	1-2 g/dag
Poteter (kokte, stekte, potetmos)………………..……	☐	☐	☐	☐	☐
Pasta/ris………………………………………………	☐	☐	☐	☐	☐
Kjøtt (reint kjøtt av storfe, lam, svin, vilt)…………….	☐	☐	☐	☐	☐
Kvernet kjøtt (pølser, hamburger, kjøttdeig, kjøttkaker)	☐	☐	☐	☐	☐
Kylling………………………………………………	☐	☐	☐	☐	☐
Grønnsaker (ikke poteter)……………………….....	☐	☐	☐	☐	☐
Frukt og bær………………………………………	☐	☐	☐	☐	☐
Mager fisk (torsk, sei, ol)…………………………	☐	☐	☐	☐	☐
Fet fisk (laks, ørret, makrell, sild, kveite, uer, ol)…….	☐	☐	☐	☐	☐
Grovt brød……………………………………………	☐	☐	☐	☐	☐
Salt snacks (potetgull, saltstenger, ol)………………	☐	☐	☐	☐	☐
Godteri/sjokolade…………………………………	☐	☐	☐	☐	☐
Kaker/kjeks…………………………………………..	☐	☐	☐	☐	☐







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42) Hvor mye drikker du vanligvis av følgende? (Sett ett kryss for hver linje)

	Sjelden/ aldri	1-3 glass pr mnd	1-3 glass pr uke	4-6 glass pr uke	1-3 glass pr dag	4-6 glass pr dag	>7 glass pr dag
Helmelk…………	☐	☐	☐	☐	☐	☐	☐
Lettmelk…………	☐	☐	☐	☐	☐	☐	☐
Ekstra lett melk…	☐	☐	☐	☐	☐	☐	☐
Skummet melk…	☐	☐	☐	☐	☐	☐	☐
Juice………………..	☐	☐	☐	☐	☐	☐	☐
Vann………………	☐	☐	☐	☐	☐	☐	☐
Brus med sukker…	☐	☐	☐	☐	☐	☐	☐
Brus uten sukker…	☐	☐	☐	☐	☐	☐	☐
Kaffe………………	☐	☐	☐	☐	☐	☐	☐
Te…………………	☐	☐	☐	☐	☐	☐	☐
Pils………………	☐	☐	☐	☐	☐	☐	☐
Vin…………………	☐	☐	☐	☐	☐	☐	☐
Brennevin…………	☐	☐	☐	☐	☐	☐	☐

Holdninger til fysisk aktivitet

I denne siste delen er det fokus på dine holdninger til fysisk aktivitet. Du nærmer deg slutten av skjemaet. **Hold ut** ☺

43) Tenk deg alle former for fysisk aktivitet. Ta stilling til påstanden: *Jeg er sikker på at jeg kan gjennomføre planlagt fysisk aktivitet selv om*:

	Ikke i det hele tatt 1	2	3	4	5	Veldig sikker 6	7
Jeg er trett………………………………	☐	☐	☐	☐	☐	☐	☐
Jeg føler meg nedtrykt…………………..	☐	☐	☐	☐	☐	☐	☐
Jeg er bekymret…………………………..	☐	☐	☐	☐	☐	☐	☐
Jeg er sint på grunn av noe……………	☐	☐	☐	☐	☐	☐	☐
Jeg føler meg stresset…………………	☐	☐	☐	☐	☐	☐	☐

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44) Tenk på alle former for fysisk aktivitet. For hver påstand, angi i hvilken grad du er enig/uenig. (Sett ett kryss for hver påstand)

	Helt enig 1	2	3	4	5	6	Helt uenig 7
Om jeg er regelmessig fysisk aktiv eller ikke er helt opp til meg…………………………………………………………………….	☐	☐	☐	☐	☐	☐	☐
Hvis jeg ville, hadde jeg ikke hatt noen problemer med å være regelmessig fysisk aktiv……………………………………	☐	☐	☐	☐	☐	☐	☐
Jeg ville likt å være regelmessig aktiv, men jeg vet ikke riktig om jeg kan få det til ………………………………………………	☐	☐	☐	☐	☐	☐	☐
Jeg har full kontroll over å være regelmessig fysisk aktiv…….	☐	☐	☐	☐	☐	☐	☐
Å være regelmessig fysisk aktiv er vanskelig for meg…………	☐	☐	☐	☐	☐	☐	☐

45) I hvilken grad beskriver disse påstandene deg som person?
(Sett ett kryss for hver påstand)

	Passer dårlig 1	2	3	4	Passer bra 5
Jeg ser på meg selv som en person som er opptatt av fysisk aktivitet…………………………………………………………………….	☐	☐	☐	☐	☐
Jeg tenker på meg selv som en person som er opptatt av å holde seg i god fysisk form……………………………………………….....	☐	☐	☐	☐	☐
Å være fysisk aktiv er en viktig del av hvem jeg er …………………..	☐	☐	☐	☐	☐

46) Har familien din (medlemmer i husstanden):
(Sett ett kryss for hver påstand)

	Aldri	Sjelden	Noen få ganger	Ofte	Veldig ofte	Passer ikke
Oppmuntret deg til å være fysisk aktiv……......	☐	☐	☐	☐	☐	☐
Diskutert fysisk aktivitet sammen med deg….	☐	☐	☐	☐	☐	☐
Forandret planene sine slik at dere kunne drive fysisk aktivitet sammen…………………	☐	☐	☐	☐	☐	☐
Overtatt oppgaver for deg, slik at du fikk mer tid til å være fysisk aktiv………………………..	☐	☐	☐	☐	☐	☐
Sagt at fysisk aktivitet vil være bra for helsen din………………………………………………..	☐	☐	☐	☐	☐	☐
Snakket om hvor godt de liker å være fysisk aktive…………………………………………….	☐	☐	☐	☐	☐	☐

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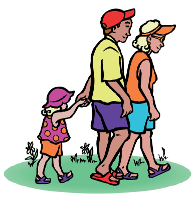
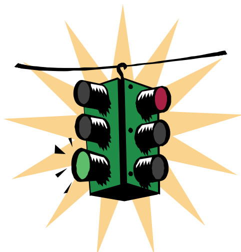
47) Har vennene dine/bekjente/familiemedlemmer utenfor husstanden:
(Sett ett kryss for hver påstand)

	Aldri	Sjelden	Noen få ganger	Ofte	Veldig ofte	Passer ikke
Foreslått at dere skulle drive fysisk aktivitet sammen………………………………………	☐	☐	☐	☐	☐	☐
Oppmuntret deg til å være fysisk aktiv…………	☐	☐	☐	☐	☐	☐
Gitt deg hjelpsomme påminnelser om fysisk aktivitet som: "Skal du mosjonere i kveld?"…..	☐	☐	☐	☐	☐	☐
Forandret planene sine slik at dere kunne drive fysisk aktivitet sammen…………………..	☐	☐	☐	☐	☐	☐
Sagt at fysisk aktivitet vil være bra for helsen din………………………………………….	☐	☐	☐	☐	☐	☐
Snakket om hvor godt de liker å være fysisk aktive………………………………………………	☐	☐	☐	☐	☐	☐

48) Er det i ditt nærmiljø:
(Sett ett kryss for hver påstand)

	Helt uenig	Litt uenig	Litt enig	Helt enig
Trygge steder å gå (park/friområde, turvei, fortau) som er tilstrekkelig opplyst……………………………………………………………………….	☐	☐	☐	☐
Mange steder der du kan være fysisk aktiv (utendørs, svømmehall etc.)……………………………………………………………………………	☐	☐	☐	☐
Flere tilrettelagte tilbud om trening og fysisk aktivitet (som kunne være aktuelle for deg)……………………………………	☐	☐	☐	☐
Greit å gå til butikker (10-15 min å gå, fortau langs de fleste veiene)………………………….	☐	☐	☐	☐
Lett tilgang til gang- eller sykkelveier…………………………………….	☐	☐	☐	☐
Så mye trafikk i gatene at det er vanskelig eller lite hyggelig å gå……	☐	☐	☐	☐
Fotgjengeroverganger og lyssignal som gjør det enklere å krysse veien…………………………………………………………………………….	☐	☐	☐	☐





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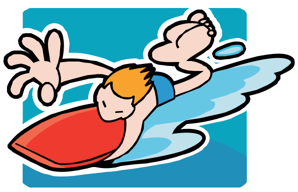
49) Omtrent hvor lang tid vil det ta deg å gå hjemmefra til:
(Sett ett kryss for hver linje)

	1-5 min	6-10 min	11-20 min	21-30 min	> 30 min	Vet ikke
Butikk for dagligvarer…………………	☐	☐	☐	☐	☐	☐
Et friområde/park/turvei………………	☐	☐	☐	☐	☐	☐
Helsestudio/treningssenter/svømme-hall/idrettshall/utendørs idrettsanlegg	☐	☐	☐	☐	☐	☐
Skog/mark/fjell…………………………	☐	☐	☐	☐	☐	☐

50) I hvilken utstrekning mener du at daglig fysisk aktivitet kan ha gunstig effekt for å forebygge følgende sykdommer: (Sett ett kryss for hver linje)

	Stor effekt	Liten effekt	Ingen effekt	Vet ikke
Hjerte- og karsykdom…………………	☐	☐	☐	☐
Muskel- og skjelettlidelser…………	☐	☐	☐	☐
Diabetes type 2………………………	☐	☐	☐	☐
Kreft………………………………….….	☐	☐	☐	☐
Høyt blodtrykk…………………..….….	☐	☐	☐	☐
Psykiske lidelser……………………	☐	☐	☐	☐
Overvekt og fedme…………………	☐	☐	☐	☐
Mage-/tarmsykdommer……………....	☐	☐	☐	☐
Astma og allergi……………………...	☐	☐	☐	☐
KOLS…………………………………	☐	☐	☐	☐



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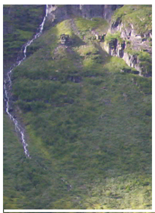
Etter at du har fylt ut spørreskjemaet og gått med aktivitetsmåleren i 7 dager, legger du skjemaet og aktivitetsmåleren i den vedlagte konvolutten og returnerer den til oss.

Tusen takk for hjelpen



Kan1

kartlegging **aktivitet** Norge

2008

Kan1
Kartlegging aktivitet Norge

Tilleggsskjema

Informasjon om måleperioden

Dette tilleggsskjemaet fylles ut etter at du har gått med aktivitetsmåleren i sju dager.

1) Beskriv i hovedtrekk hvordan været og underlaget var i de sju dagene du gikk med aktivitetsmåleren:

	VÆRET			UNDERLAGET		
	Opphold	**Skiftende**	**Nedbør**	**Isete**	**Vått/sølete**	**Tørt**
Dag 1	☐	☐	☐	☐	☐	☐
Dag 2	☐	☐	☐	☐	☐	☐
Dag 3	☐	☐	☐	☐	☐	☐
Dag 4	☐	☐	☐	☐	☐	☐
Dag 5	☐	☐	☐	☐	☐	☐
Dag 6	☐	☐	☐	☐	☐	☐
Dag 7	☐	☐	☐	☐	☐	☐

2a) Hvor mange dager i måleperioden har du tatt av deg aktivitetsmåleren for å drive med svømming?

☐ Dager ☐ Ingen (gå videre til spm 3)

2b) På en dag hvor du drev med svømming, hvor lenge varte aktiviteten i gjennomsnitt?

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke

3a) Hvor mange dager i måleperioden har du syklet eller drevet med spinning/ergometersykkel?

☐ Dager ☐ Ingen (hopp over siste spørsmål)

3b) På en dag hvor du syklet, hvor lenge varte aktiviteten i gjennomsnitt?

☐ Timer ☐ Minutter ☐ Vet ikke/husker ikke