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THE USE OF PEDOMETERS AND THE '10,000 STEPS/DAY'-CONCEPT IN THE PROMOTION OF PHYSICAL ACTIVITY

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Samenvatting

Ondanks inspanningen om fysieke activiteit te promoten, haalt een aanzienlijk deel van de Vlaamse volwassen populatie de richtlijn van 30 minuten matig intense beweging per dag niet. Een inactieve levensstijl gaat nochtans gepaard met gezondheidsrisico's. Daarom is er nood aan effectieve interventies ter promotie van (meer) beweging.

Om beweging te promoten, maakten recente interventies in de Verenigde Staten, Australië, en Japan gebruik van stappentellers of pedometers, meestal in combinatie met 'stapdoelen'. In het algemeen bleken deze pedometerinterventies effectief te zijn. Europese gegevens omtrent pedometerinterventies ontbreken echter, evenals informatie omtrent methodologische aspecten van pedometergebruik in Europa. Bijgevolg omvat deze thesis methodologisch onderzoek in verband met pedometergebruik en pedometerinterventies in Europa, meer bepaald Vlaanderen (België).

De eerste methodologische studie ging de validiteit van een goedkope pedometer na. Uit de studie bleek dat de 'Stepping Meter' invalide informatie geeft en dus niet aanvaardbaar is voor gebruik in onderzoek of promotievoering. Twee andere methodologische studies vonden significante correlaties tussen pedometerdata ('stappen') en zelfgerapporteerde fysieke activiteit. Er werd ook aangetoond dat valide pedometers niet alleen wandelen, maar ook matig en zwaar intense fysieke activiteit kunnen meten in verschillende contexten.

Pedometerinterventies werden geïmplementeerd op het micro-, meso-, en macroniveau en toonden veelbelovende resultaten. Een individugerichte pedometerinterventie, al dan niet gebruikmakend van 'ondersteunend materiaal', beïnvloedde het bewegingsgedrag positief. Het materiaal, zoals een informatiebrochure en dagboek, had vooral een positieve invloed op de attitudes in verband met pedometergebruik. Een pedometerinterventie in een bedrijf bleek effectief te zijn bij reeds actieve werknemers: bij hen was de daling in de hoeveelheid beweging, waarschijnlijk veroorzaakt door een seizoensgebonden effect, minder sterk. Onderzoek wees uit dat de campagne "10.000 Stappen Gent" een hoge naambekendheid had, een daling veroorzaakte in de tijd die men zittend doorbracht, en een stijging teweegbracht in de hoeveelheid beweging, in zowel actieve als inactieve individuen. Er werd ook gevonden dat pedometergebruik meer voorkwam bij oudere personen en bij personen die op de hoogte waren van de campagne, terwijl een stijging in het aantal stappen/dag meer voorkwam bij personen met een hoger diploma, bij inactieve personen (<10.000 stappen/dag) en bij pedometergebruikers. Tevens bleek dat pedometergebruik het interventie-effect deels medieert.

Summary

Despite the fact that physical activity has been promoted previously, a considerable amount of adults still do not meet the current health-related physical activity guideline of 30 minutes of moderate to vigorous physical activity per day. However, an inactive lifestyle is related to inverse health outcomes, consequently, effective physical activity interventions are needed.

Recent interventions used step counters or pedometers, mostly in combination with step count goals, to encourage physical activity. In general, the pedometer was found to be an effective intervention tool in the United States, Australia, and Japan. However, no European data on physical activity promotion through pedometer use and step count goals are available. Also information about methodological aspects of pedometer use is missing in Europe. Therefore, the current thesis presents pedometer-related methodological research and pedometer-based intervention studies in Flanders, Belgium (Europe).

The first methodological study evaluated the validity of an inexpensive pedometer. Results showed that the 'Stepping Meter' was unacceptable for research and practice, as it gave invalid information. Two other methodological studies found significant correlations between pedometer-determined step counts and self-reported physical activity, and showed that a valid pedometer is capable of assessing not only walking, but also moderate and vigorous physical activity in different contexts.

Pedometer-based interventions were implemented on the micro-, meso-, and macro-level and showed promising results. It was found that a 3-week individual-based intervention consisting of pedometer use, with or without cognitive and behavioural support materials, increased physical activity in motivated individuals. In this study, support materials, such as an information brochure, and a log to set goals and record steps, had an additional positive effect on attitudes towards pedometer use. A workplace pedometer-based intervention was effective in reducing the decrease in step counts, probably caused by winter time, in already active employees. Two effectiveness studies of the community campaign "10,000 Steps Ghent" showed a high project awareness level, a decrease in sitting time, and an increase in physical activity among both active and inactive individuals. An additional study found that pedometer use was more likely in older participants and in those aware of the campaign. Increased step counts were more likely among higher educated individuals, at-risk persons (baseline step counts below 10,000 steps/day) and those who used a pedometer. Furthermore, it was found that pedometer use partly mediated the intervention effect on step counts.

PART 1: GENERAL INTRODUCTION AND OUTLINE OF THE THESIS

1 Introduction

The overall purpose of the present thesis is to provide insights about physical activity promotion through pedometer use and the '10,000 steps/day'-concept, in adults. It is known that regular physical activity is associated with increased health benefits. However, physical inactivity still is a major public health concern in modern society. Therefore, efforts are needed to promote (more) physical activity.

The original research of the present thesis includes pedometer-related studies. Consequently, the general introduction will include aspects on physical activity, measurement of physical activity, and physical activity promotion, specifically concerning pedometers or step counters.

This general introduction will start with the description of some aspects about physical activity and health in adults, including current health-related physical activity guidelines. Then, attention will be given to physical activity measurement methods. Since it was decided to use a combination of self-administered questionnaires and pedometers in the original research, only self-reports and step counters will be described in detail. It is not within the scope of this thesis to clarify other measurement techniques producing data that can be converted to energy expenditure, such as the method of doubly labelled water (following the difference in elimination rates of the stable isotopes of oxygen and hydrogen in body water after initial labelling of the body water pool) (Bouchard et al, 1994), calorimetry (measuring heat exchange directly or through respirometry that analyzes oxygen uptake and carbon dioxide waste) (Bouchard et al, 1994), or accelerometers (motion-sensing devices with piezoelectric ceramics, recording accelerations of the waist/hip/lower back) (Bassett et al, 2000). A next section of this general introduction will be dedicated to physical activity promotion, again with specific attention for pedometer-based interventions and strategies used in the original studies of the thesis. Finally, a problem analysis and the outline of the thesis will be given.

2 Physical activity and health

2.1 Definitions

In order to avoid confusion, a clear definition of the frequently used terms 'physical activity', 'physical fitness', 'health', and 'health-related physical activity' will be given. In addition, the mutual association between physical activity, physical fitness, and health will be described concisely.

Caspersen and colleagues (1985) defined physical activity as "any bodily movement produced by skeletal muscles that results in energy expenditure". Everyone performs physical activity in order to sustain life and physical activity can be categorized in a variety of ways, for example occupational, leisure time, household or other activities. Also exercise can be a subcategory of physical activity: exercise is physical activity that is planned, structured, repetitive, and purposive with an improvement or maintenance of one or more components of physical fitness as objective. In contrast to physical activity, which is related to movements of individuals, physical fitness is a set of attributes that individuals have or achieve (Caspersen et al, 1985). Components of physical fitness can be health-related (cardio-respiratory endurance, muscular endurance, body composition, and flexibility) or related to skills that pertain more to athletic ability. Furthermore, health can be defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization, 1948). In 1988, the International Consensus Conference on Physical Activity, Physical Fitness, and Health (Bouchard et al, 1994) defined health as "a human condition with physical, social, and psychological dimensions, each characterized on a continuum with positive and negative poles. Positive health is associated with a capacity to enjoy life and to withstand challenges; it is not merely the absence of disease. Negative health is associated with morbidity and, in the extreme, with premature mortality".

Research revealed that physically active people, as contrasted with their sedentary counterparts, develop and maintain higher levels of physical fitness. Furthermore, protective effects were found between physical activity and risk for developing several chronic diseases such as coronary heart disease, hypertension, diabetes mellitus type II, obesity, osteoporosis, colon cancer, and anxiety and depression (US Department *Surgeon General*, 1996). As a result, health-related physical activity refers to the minimum recommendable dose of activity needed to guarantee physiological health effects (Laitakari et al, 1996).

2.2 Health-related physical activity guidelines

To encourage increased participation in physical activity, public health recommendations on the types and amount of physical activity were/are needed (Pate et al, 1995). Traditionally, guidelines prescribed the recommended frequency, duration and intensity of physical activity. However, more recently, step count goals have been introduced.

2.2.1 Physical activity frequency, duration and intensity goals

During the 1970's, researchers believed that health benefits could only be obtained by increasing physical fitness. Consequently, the American College of Sports Medicine (ACSM) made a guideline for the development and maintenance of cardio-respiratory fitness and body composition. The organization recommended healthy adults at least 20 minutes of continuous aerobic activity, using large muscle groups, such as jogging, hiking, and other endurance activities. The exercise training should be performed on 3 to 5 days a week, and this at an intensity of 60 % to 90 % of maximum heart rate reserve, or at 50 % to 85 % of maximum oxygen uptake (ACSM, 1978).

Since the early 1990's, various departments have released public health recommendations for physical activity to achieve health promotion and disease prevention. The focus was no longer on 'exercise and fitness', but on 'physical activity and health', since research revealed that benefits can also be obtained through lower intensity levels (Pate et al, 1995).
In 1993, an expert team convened by the Centers for Disease Control and Prevention (CDC) and the ACSM, stated that every adult should accumulate at least 30 minutes of moderate-intensity activity on most, preferably all, days of the week (Pate et al, 1995). An activity performed at an intensity of 3 to 6 metabolic equivalents (METs) (1 MET is equal to the resting metabolic rate of 3.5 ml/kg/minute), is considered as moderate-intensity activity. Examples are brisk walking, gardening, or bicycling.
The recommendation published in 1996, was part of the US Public Health Service's Surgeon General's Report on Physical Activity and Health (US Department *Surgeon General*, 1996), and stated that men and women of all ages benefit from daily longer sessions of moderately intense activities (such as 30 minutes of brisk walking) as from shorter sessions of more strenuous activities (such as 15-20 minutes of jogging). There, moderate-intensity activity was defined as physical activity that uses 150 kcal/day or 1000 kcal/week, for example swimming laps for 20 minutes, or gardening for 30 to 45 minutes. Some activities can be

performed in a range of intensities, so the suggested duration corresponds to expected intensity of effort. Both guidelines differ from the earlier exercise prescription, by recommending a different activity intensity and duration. Furthermore, the guidelines emphasized that adults can meet the physical activity recommendations by accumulating a variety of shorter activity bouts throughout the day, including sports and exercise, occupational activity, active transport, home and garden activities, or other unstructured physical activity.
Linked to the previous recommendations, is the concept of 'lifestyle physical activity': "the daily accumulation of at least 30 minutes of self-selected activities, which includes all leisure, occupational, or household activities that are at least moderate to vigorous in their intensity and could be planned or unplanned activities that are part of everyday life" (Dunn et al, 1998).

Recently, Haskell and colleagues (2007) updated and clarified the 1995 physical activity recommendation for adults to improve and maintain health (Pate et al, 1995). The expert panel of scientists concluded that to promote and maintain health, all adults between 18 and 65 years, need moderate-intensity aerobic physical activity for a minimum of 30 minutes on 5 days each week, or vigorous-intensity aerobic physical activity for a minimum of 20 minutes on 3 days each week. It is possible to perform combinations of moderate- and vigorous-intensity activity to meet the recommendation. Moderate-intensity aerobic activity accelerates the heart rate and is generally equivalent to brisk walking. The 30 minutes minimum of moderate-intensity activity can be reached by accumulating different bouts lasting at least 10 minutes. Vigorous-intensity activity is exemplified by jogging, and causes a considerable increase in heart rate, and rapid breathing. These moderate- or vigorous physical activities should be done in addition to light intensity routine activities of daily living (e.g. preparing a meal, shopping) or activities lasting less than 10 minutes (e.g. walking around office or home). Furthermore, every adult should perform activities (8-10 exercises using the major muscles) to maintain or increase muscular strength and endurance, at least 2 days each week. Finally, the experts recommend persons who wish to further improve their fitness, reduce their risk for chronic diseases and disabilities, or prevent unhealthy weight gain, to exceed the minimum recommended amount of physical activity (Haskell et al, 2007).

2.2.2 Step count goals

Previous recommendations, mainly expressed as duration goals, require constant timing and summing of scattered bouts of activity during the day, which can be impractical. More recently, alternative goals have been introduced, which are more practical than the minutes/day recommendations and do not require constant tracking of at least moderate-intensity activity time during the day: step count goals.

In Japan, Hatano (1993, 1997) was the first to propose the recommendation of accumulating 10,000 steps/day to gain health benefits in adults. Hatano (1993) estimated that taking 10,000 steps/day equals the expenditure of 300-400 kcal/day, a energy degree which should protect against heart attacks (Paffenbarger et al, 1978). This quantity is double the amount (150 kcal/day) that the US Surgeon General indicated as related to improved health (US Department *Surgeon General*, 1996). The difference in energy expenditure here, can be explained by the fact that the step count goal is a daily recommendation that includes all activity, while the minute-guideline is a recommendation over and above an unidentified minimal level of daily activity (Tudor-Locke and Bassett, 2004). Usual daily activity in healthy adults approximates 6000-7000 steps/day (Tudor-Locke and Bassett, 2004). Different publications (Welk et al, 2000; Wilde et al, 2001; Tudor-Locke, 2002) showed that 30 minutes of moderate intensity walking represented approximately 3100-4000 steps. Consequently, the summation of usual daily activity (6000-7000 steps/day) plus the recommended health-related extra physical activity (30 minutes/day or 3100-4000 steps/day) is more or less 10,000 steps/day.

The 10,000 steps/day- recommendation is simple, easy to remember, and it provides people with a concrete goal for increasing physical activity. Furthermore it is focused on behaviour, and not on metabolic cost, which makes it relevant for individuals of different body sizes (Hatano, 1993). The step count concept can be used in the recommended active living approach, which stresses the importance of doing moderate activities as a part of daily living (Choi et al, 2007). Moreover, step count goals could be beneficial especially for sedentary individuals who dislike exercise or vigorous physical activity (Welk, 2002). Wilde et al (2001) also support “10,000-steps” as a challenging behavioural target for sedentary women. For many of them, achieving 10,000 steps may be appropriate. However, not all sedentary individuals are “equally inactive”, consequently lower or higher step count targets may be needed. Le Masurier et al (2003) showed that individuals who accumulate 10,000 steps/day are more likely to meet the traditional guideline, however it does not guarantee it.

Tudor-Locke and Bassett (2004), suggested that 10,000 steps/day may not be a sustainable goal for some groups, such as older people and those with chronic diseases, consequently selecting personally relevant step count goals, based on an individual's baseline step level, may be more appropriate (Tudor-Locke, 2002). For example, Hill et al (2003) believed that increasing baseline physical activity by 2000-2500 steps/day, could prevent weight gain and cause health benefits of a more active lifestyle. An increase of 2000 steps/day represents about 1 mile (1.6 km) of walking, takes about 15-20 minutes of walking, and represents an energy expenditure of approximately 80-100 kcal. To conclude, any step count goal selected should be an improvement from the individual baseline step level and should be sustainable for a longer period (Sidman, 2002).

More detailed step count indices for public health have been introduced (Tudor-Locke and Bassett, 2004) and revisited (Tudor-Locke et al, 2008): less than 5000 steps/day can indicate a 'sedentary lifestyle', accumulating between 5000-7499 steps/day corresponds to typical daily activity without sports/exercise and might be considered as 'low active', while accumulating 7500-9999 steps/day likely includes some activities and might be classified as 'somewhat active'. Taking 10,000 steps/day or more, indicates the point that should be used to classify individuals as 'active', and people who take more than 12,500 steps/day are likely to be classified as 'highly active'.

Steps/day are associated inversely with percentage body fat, Body Mass Index (BMI), waist circumference, blood pressure, and components of the metabolic syndrome (Hatano, 1997; Tudor-Locke et al, 2001; Chan et al, 2003; Dwyer et al, 2007; Schmidt et al, 2007). Recently, researchers established preliminary criterion-referenced cut points for adult pedometer-determined physical activity related to weight status defined by BMI (Tudor-Locke et al, 2008). Using a cross-sectional international pedometer dataset, they found that best estimated cut points for normal versus overweight/obesity, ranged from 11,000 to 12,000 steps/day for men, and 8000 to 12,000 for women, with consistently higher numbers for younger age groups: to maintain a normal weight BMI level, the need for steps/day is lower with higher age. The cut point that best predicts group (normal weight versus overweight/obese) classification for men aged 18 to 50.9 years was 12,000 steps/day, while 11,000 steps/day was the best cut point for 51-88 year-old men. For women, the cut points were presented in four age groups: 12,000 steps/day for women aged 18 to 39.9 years, 11,000 steps/day for 40-49.9 year-old women, 10,000 steps/day for 50-59.9 year-old women, and 8000 steps/day for women aged 60 to 94 years.

3 Measuring physical activity

For public health purposes, it is essential to monitor the (changes in) proportions of individuals meeting the health-related physical activity guidelines. Additionally, to investigate associations between health and physical activity, or to measure the effectiveness of physical activity interventions, individuals' amount of physical activity needs to be assessed accurately (Prince et al, 2008). In general, the combination of self-reported ('subjective') and motion-detecting (more 'objective') measures are suggested as a good solution to measure physical activity in free-living populations (Sallis and Saelens, 2000; Tudor-Locke and Myers, 2001b; Tudor-Locke et al, 2002).

3.1 Self-reported measurement methods of physical activity: questionnaires

The most frequently and widely used methods of assessing physical activity are self-report instruments (Sallis and Saelens, 2000). Benefits of these methods (e.g. questionnaires) include the ability to collect data from a large number of people at a low cost. Furthermore, recalls have no influence on the behaviour under study. When people are asked to recall their past physical activity behaviour, they cannot alter or modify behaviour at the moment of recall. Finally, using self-reports, it is possible to assess the type and context of physical activity, e.g. work-related physical activity, gardening activities. Despite the fact that self-reports are popular and practical, various limitations of self-reports need to be considered (Ainsworth et al, 1994). First of all, social desirability can cause over-reporting of physical activity (Adams et al, 2005). Second, since recalling physical activity is a complex cognitive task, recall biases can occur. At last, typical terms e.g. 'physical activity', 'moderate intensity', can be understood or interpreted differently by participants and researchers, which can also cause errors (Sallis and Saelens, 2000). Furthermore, self-report measures do not succeed in assessing accurately the lower end of the continuum of physical activity i.e. lighter intensity activities, walking (Tudor-Locke and Myers, 2001b). Despite their limitations, the use of physical activity questionnaires remains popular because of the previously given benefits.

A well-developed physical activity questionnaire, regularly used to obtain estimates of physical activity, is the International Physical Activity Questionnaire (IPAQ) (http://www.ipaq.ki.se). The purpose of the IPAQ is to provide an instrument that can be used internationally to obtain comparable levels of physical activity in different countries. The IPAQ has been shown to be a valid and reliable instrument for measuring population-based physical activity in many settings and in different languages, also in Europe (Craig et al, 2003), and in Belgium (Vandelanotte et al, 2005). Furthermore, the IPAQ is being used as an evaluation tool in intervention studies. The 'IPAQ short form' assesses three specific types of physical activity, namely walking, moderate, and vigorous physical activity, during the last seven days. The 'IPAQ long form' assesses different types of physical activity undertaken across a comprehensive set of domains such as work (vigorous and moderate physical activity, walking), transport (bicycling, walking), house and garden (vigorous and moderate physical activity in the garden, moderate physical activity inside home), and leisure time (vigorous and moderate physical activity, walking). All questions in both versions assess the frequency (days) and duration (time) of all the types of activities, if they lasted for at least ten minutes. Both versions, which can be interview-based or self-administered, also assess the time spent sitting on a weekday (short and long form) and on a weekend day (only in the IPAQ long form).

3.2 Motion-sensing measurement methods of physical activity: pedometers

As self-report methods of physical activity possess several limitations, more objective motion-sensing devices such as accelerometers and pedometers have become popular. However, accelerometers are relatively expensive (€ 110-375, $ 150-500 per unit) and require computer application for data processing, which makes them inconvenient for studies with a large sample size.

In recent years, step counters or pedometers are regularly being used. With their lower price (€ 15-20, $ 20-25 per unit) and no requirement of extra software or expertise, they are a good alternative for accelerometers (Tudor-Locke and Myers, 2001b; Tudor-Locke, 2002). The pedometer is appropriate to assess total levels of physical activity and aspects not captured through self-reports, such as incidental daily movement or small, incremental changes (Freedson and Miller, 2000; Tudor-Locke and Myers, 2001b). Furthermore, pedometer use does not raise recall biases (Prince et al, 2008). Moreover, with the growing use of step count goals, pedometers have become (more) popular monitoring tools for physical activity in (large) free-living populations (Tudor-Locke and Myers, 2001b; Tudor-Locke, 2002). Below, the pedometer will be described and discussed in detail.

3.2.1 Pedometer device

Pedometers are small, light weight, unobtrusive instruments that are typically worn on the belt or waistband and count movement (Tudor-Locke, 2002). They put a relatively low burden on participants and can be used in populations with language and literacy barriers (Tudor-Locke and Myers, 2001b). The originally used pedometer, was a gear-driven device, using a mechanical system of a pendulum arm. This model however showed problems with reliability and validity, making it unsuitable as research instrument (Galye et al, 1977). Later, electronic pedometers became available, differing in cost and sensitivity (Bassett et al, 1996). Electronic pedometers operate on a horizontal, spring-suspended lever arm that moves up and down with vertical accelerations of the hip. The internal mechanism, with a sensitivity threshold, detects vertical accelerations above a certain force needed to record a step (Tudor-Locke et al, 2002). For example, one brand of pedometer (Yamax Digi-Walker) is not likely to detect forces less than 0.35 g (g = standard gravity) (Hatano, 1997). With each step taken, the lever arm makes an electronic contact, and one step is recorded (Bassett, 2000; Leenders et al, 2001). Electronic pedometers are considered to be more accurate than their mechanical predecessors (Tudor-Locke and Myers, 2001a; Welk, 2002). Furthermore, there are also pedometers using a magnetic reed proximity switch, and pedometers using an accelerometer-type mechanism with a horizontal beam and a piezoelectric crystal (Schneider et al, 2003). From here, the term 'pedometer', will refer to the electronic type of step counters.

A review of Tudor-Locke and Myers (2001b), including different studies using pedometers to assess daily activity in free-living conditions, showed the feasibility of pedometers in large population observation studies. Furthermore, different studies used pedometers to assess the effectiveness of behavioural and environmental lifestyle physical activity programs (Tudor-Locke and Myers, 2001b).

Even though the pedometer has several advantages, the device is not perfect and limitations need to be considered. Compared with the accelerometer mechanism, that is able to track the frequency, intensity, and duration of activity, the technology of the pedometer is less sophisticated. The internal mechanism of the step counter is unable to distinguish between vertical accelerations above a certain threshold. Consequently, the pedometer does not determine the intensity of the activity and no differentiation can be made between walking and running (Freedson and Miller, 2000). Furthermore, pedometers do not reflect the amount of time spent in physical activity. However, some pedometer models count "time in activity" and start a clock when initiating stepping and stop the clock with inactivity (Le Masurier and Tudor-Locke, 2003). Moreover, there are models available that count the number of aerobic steps (a minimum of 10 minutes of continuous walking more than 60 steps per minute). Finally, pedometers do not provide information on non-ambulatory activities like swimming, bicycling or weightlifting (Tudor-Locke and Myers, 2001b). However, walking is one of the most common forms of physical activity (Reis et al, 2008).

3.2.2 Validity and reliability of pedometers

With the increasing popularity of pedometers, several investigators examined the validity and reliability of the device. Step counters have shown evidence of acceptable reliability (Tryon et al, 1991). The reliability within a single pedometer model (Cronbach's alpha) was found to be > 0.80 (Schneider et al, 2003). A review of Tudor-Locke et al (2002) found a great concordance between pedometers and accelerometers (median of reported correlations r = 0.86). Pedometers also correlated well with time in observed activity (median of reported correlations r = 0.82), and somewhat less with different measures of energy expenditure (median of reported correlations r = 0.68). Lowest correlations were found between pedometers and self-reports (median of reported correlations r = 0.33) (Tudor-Locke et al, 2002). More recently, good to moderate correlations were found between pedometer scores and total activity estimated by other instruments such as accelerometers (r = 0.70), heart monitoring (r = 0.40), a physical activity log (r = 0.40), and a questionnaire (r = 0.30) (Macfarlane et al, 2006). The most accurate measurement unit of pedometers is the pure, or raw data i.e. step counts. Less precise are energy expenditure or distance estimates derived from pedometers (Tudor-Locke and Myers, 2001a; Leenders et al, 2001; Crouter et al, 2003).

Notwithstanding previous evidence, certain threats to validity need to be taken into account. First, slow walking speeds may affect accuracy. Research revealed that different pedometers showed increased error at walking speeds < 80 m/minute (Bassett et al, 1996; Crouter et al, 2003; Melanson et al, 2004). A less pronounced vertical acceleration of the waist during slow walking, and consequently not exceeding the threshold required to trigger a step, can explain the incorrectness (Crouter et al, 2003). However, while consistently under-recording at speeds < 54 m/minute (Le Masurier and Tudor-Locke, 2003; Le Masurier et al, 2004), the brand 'Yamax Digi-Walker' showed acceptable accuracy at speeds of 54 m/minute or more (Bassett et al, 1996; Crouter et al, 2003; Le Masurier and Tudor-Locke, 2003; Le Masurier et al, 2004). In addition, such slow speeds of walking (< 54 m/minute) are uncommon in healthy adult populations (Le Masurier and Tudor-Locke, 2003; Swartz et al, 2003), but can cause problems in elderly or obese individuals who ambulate at slower walking speeds (Melanson et al, 2004).

Second, walking surface could threaten accuracy. However, Bassett et al (1996) found that pedometers provided a reasonably accurate estimate of the number of steps taken, regardless of the walking surface.

Third, non-step movements, for example caused by simple agitation while riding in a motorized vehicle, may overestimate actual steps taken. However, the error caused by motorized transport is no more than 2-3% of daily accumulated steps which is considered negligible (Tudor-Locke et al, 2002; Le Masurier and Tudor-Locke, 2003).

Fourth, pedometer step recording may fail in overweight or obese individuals with abdominal fat. The belt may be tilted forward, reducing the vertical acceleration needed to trigger a step. However, BMI, waist circumference, and percentage body fat did not affect pedometers accuracy (Swartz et al, 2003; Le Masurier et al, 2004).

Fifth, since the recommended position of the pedometer is on the belt or waistband at the mid-line of the thigh, oriented vertically (Welk, 2002), positioning the pedometer elsewhere may influence the step counting. Nevertheless, placement on the front, side, or back of the waistband did not affect accuracy for counting steps (Swartz et al, 2003). Also Bassett et al (1996) concluded that it does not matter which side of the body the pedometer is worn on.

A final threat to validity can be reactivity, i.e. participants showing a change in behaviour due to being monitored. However, different studies showed that reactivity does not appear to threaten the validity of using pedometer self-monitoring to objectively assess free-living physical activity in healthy adults (Eastep et al, 2004; Matevey et al, 2006; Behrens and Dinger, 2007; Marshall, 2007). Clemes et al (2008) on the other hand, found that reactivity may implicate validity in short-term studies.

As a consequence of the promising research, different pedometers became commercially available. Out of different brands, the Yamax Digi-Walker (Yamax Inc., Tokyo, Japan) was found to be the most accurate (Bassett et al, 1996; Le Masurier et al, 2004). High correlations were found between the Yamax Digi-Walker and different brands of accelerometers (r≈0.80 to 0.90) in field and laboratory settings (Bassett et al, 2000; Leenders et al, 2000; Tudor-Locke et al, 2002). Consequently, the Yamax Digi-Walker is a brand that received the most scientific attention. Also Crouter et al (2003) and Schneider et al (2003) found that the Yamax Digi-Walker pedometer gave step count values within 1 % of the actual steps taken, which is less than the maximum permissible error of miscounting steps (3 %) in controlled conditions, set by the Japanese Ministry of Industry and Trading Regulations (Hatano, 1993, 1997). Furthermore, the intra-model reliability of the Yamax Digi-Walker was very high (> 0.99) (Schneider et al, 2003).

3.2.3 Methodological aspects of pedometer use

Since the pedometer is shown to be a valid and reliable tool for measuring physical activity, it can be used in research. Below, some procedural features of pedometer use will be given.

The gathering of pedometer step counts in free-living populations can be done in various ways. In general, there are two options: researchers record the step counts, or participants submit the results on a daily or weekly basis and return the pedometer by mail. An activity log can be used to record the step counts taken at the end of the day. Also minutes spent biking and/or swimming, common behaviours in Belgium (de Geus et al, 2008), can be reported on the activity log. As stated earlier, these non-ambulatory activities cannot be detected correctly by pedometers. However, Miller and colleagues (2006) suggested to account for these activities: 150 steps extra can be added for every minute spent biking or swimming. The main limitation of using an activity log (just like diaries and self-reports) is the possibility that participants forget to fill in the log, forget (to write down) or overestimate the time spent in bicycling, swimming.

Since pedometer-based physical activity during the weekend tends to be lower compared to weekdays (Tudor-Locke et al, 2004), and physical activity behaviour may vary from day to day, any single day of data collection is not acceptable. Research revealed that a minimum of three days can provide a sufficient estimate of weekly physical activity (Tudor-Locke et al, 2005). It is however recommended to collect pedometer data over a seven-day period for a reliable estimate of monthly activity in adults (Clemes and Griffiths, 2008).

Furthermore, Tudor-Locke et al (2004) suggested to conduct surveillance in spring or fall, because steps taken during summer are higher than those recorded during winter. Finally, Basset et al (1996) believed that for epidemiologic studies, there may be an advantage to models using a plastic cover that can be closed to prevent accidental resetting.

3.3 Pedometer-based physical activity in healthy adults

Even though, as described above, pedometers can have limitations, pedometer-based data are useful to determine the physical activity level in free-living populations. Several international studies have been conducted using a pedometer to collect physical activity data in whole populations. For example, in the United States, a state-wide study in Colorado revealed that adults took on average 6804 steps/day (Wyatt et al, 2005). Adults in South Carolina took on average 5931 ± 3664 steps/day (Tudor-Locke et al, 2004). The average number of steps taken each day in a sample of working Australian adults was 8873 ± 2757 (Miller and Brown, 2004), while the step level of the Western Australian adult population was 10,079 ± 848 steps/day for men and 9169 ± 3800 for women (Mc Cormack et al, 2006). For Tasmanian 25-64 year old adults, the median number of daily steps was 10,062 (Schmidt et al, 2007). In Europe, a Swiss study showed a mean of 10,400 ± 4700 steps/day for men and 8900 ± 3200 for women (Sequeira et al, 1995). A recent review of 42 studies, mostly from the United States or Japan, but some from Europe and Australia, showed an overall average of 9501 ± 2295 steps/day (Bohannon, 2007). In conclusion, for many people, the daily 10,000-step count goal is not normally achievable through routine daily activities. Consequently physical activity promotion is needed.

4 Physical activity promotion

Since physical activity is associated with improved health, there is a growing need for interventions designed to prevent sedentary behaviour and promote physical activity (US Department *Surgeon General*, 1996). Interventions are most effective when they change the underlying variables that influence physical activity (Trost et al, 2002). Therefore, an overview of factors associated with physical activity will be given below. Further, the role of pedometers in physical activity promotion will be described, and different levels of physical activity promotion will be discussed, each with illustrations of pedometer-based interventions.

4.1 Understanding physical activity

In order to develop interventions, it is interesting to know which factors have an influence on physical activity behaviour. A brief summary of the most frequently used theories and models explaining physical activity behaviour and an overview of behavioural correlates and determinants of physical activity will be given below.

4.1.1 Health behaviour theories and models

All theories and models described here are designed as guides to understand and explain behaviour. The first two models address behaviour on the individual level. The Health Belief Model (Rosenstock, 1990) instructed that health-related behaviour depends on four types of beliefs: the perception of the severity of a potential illness (for example health problems caused by inactivity), the perception of the susceptibility to that illness, the perception of the benefits of taking a preventive action, and the perception of the barriers to taking that action. Also cues to action (for example leaving a written reminder to oneself to be active) and the construct of self-efficacy (a person's confidence in his or her ability to successfully perform an action, the perceived ease or difficulty of performing a behaviour) have been incorporated later in the model. However, some researchers believe that exercise or physical activity is a more complex behaviour and that the health belief model is not comprehensive enough to explain it (Marcus et al, 1996).
In the Transtheoretical Model or Stages of Change Model, behaviour change is conceptualized as a five-stage process or continuum related to someone's readiness to change. The five stages are precontemplation (no intention to change to a healthier behaviour), contemplation (considering a change to a healthier behaviour), preparation (preparing or taking steps to change to a healthier behaviour), action (change to a healthier behaviour is made, but for no longer than six months), and maintenance (the healthier behaviour is maintained for more than six months). It is possible that individuals move backwards and forwards between these stages before attaining the goal of maintenance (Prochaska et al, 1992). Those in the early stages of change for example could be unaware of the benefits of physical activity and in need of encouragement to become active (Marcus et al, 1996).

In contrast to the previous models, the following theories operate on the interpersonal level. In the Social Learning Theory/Social Cognitive Theory (Bandura, 1997, 1986), behaviour is identified as an interaction between personal factors, attributes of the behaviour, and the environment. Each may affect or be affected by either of the other two. Central principles are (1) self-efficacy (a person must believe in his or her ability to successfully achieve a behaviour and must perceive an incentive to do so) and (2) the outcome or consequence expectations (belief that performing a behaviour will produce a specific outcome). This theory suggests that enhancing an individual's confidence in their capability to be active is useful to increase physical activity levels. Techniques, based on the Social Cognitive Theory, used to promote changes in physical activity behaviour are goal setting, decisional balance sheets, relapse prevention training, stimulus control strategies, and social support (Marcus et al, 1996).

The Theory of Reasoned Action states that a behaviour is determined by a person's intention to perform the behaviour, which is in turn determined by the person's attitude (instrumental or affective beliefs about the behaviour and the value attached to those beliefs) and the subjective norm (beliefs about what other people think the person should do, social pressure of family, friends, others to perform a behaviour) (Fishbein and Ajzen, 1975). Simply said, the theory states that if an individual believes that physical activity improves health, energy and mood, if they perceive minimal barriers (costs) to being active, and if the individual has support that encourage physical activity, then the individual will form the intention to be active, which will lead to performing the behaviour (Marcus et al, 1996). In the Theory of Planned Behaviour, Ajzen (1985) improved the last theory by adding the concept of perceived control (self-efficacy), which can influence both intention and behaviour and reflects the fact that external factors can influence a person's behaviour.

A combination of the Theory of Reasoned Action and the Social Cognitive Theory is the Attitude, Social influence and self-Efficacy (ASE) model (De Vries et al, 1995). The ASE-model states that behaviour and intention are determined by the attitudes, social influences and self-efficacy. Furthermore, the model indicates that skills and barriers have an influence on the intention-behaviour interaction.

Mainly the previously described psychological models have been used to explain behaviour, however, they alone cannot fully describe certain behaviours. They pay little attention to socio-cultural and physical environmental influence on behaviour (McLeroy et al, 1988). Therefore, a final group of models, commonly referred to as social ecological models, are based on a broad, overarching concept that link several different fields of research. The models integrate behavioural change and environmental enhancement within a wide systems-theoretical framework (Stokols, 1996). Social ecological models state that behaviour is determined by multiple levels of influence such as intrapersonal aspects, interpersonal factors, institutional or organizational factors, the socio-cultural environment, and the physical environment, and their interrelationships. Important aspects are (1) the fact that the environment is considered to have multiple dimensions (social, cultural, physical), and (2) the dynamic interplay between the environmental and personal factors. Otherwise, the models take into account the physical environment and its relationship to the social environment, namely people at intrapersonal, interpersonal, organizational, community, and public policy levels (see Figure 1). Intrapersonal factors can involve an individual's knowledge, attitudes, skills, or intentions; while interpersonal factors are, for example, relationships with family, friends, neighbours, colleagues, or acquaintances, and social norms. As stated previously, a social ecological perspective tends to refocus attention away from strictly intra-individual factors and processes, and focus more towards environmental factors of behaviours, such as the effects of interpersonal relationships. A third level of environmental considerations within social ecological frameworks concerns organizations. Examples of institutional or organizational structures include the workplace policy or management. Organizations can provide incentives, social support, changes in rules and regulations, changes in benefits, or changes in work structure (e.g. time off to participate in physical activities). Another important aspect of the social environment is the community level. The community level includes community resources, neighbourhoods, social and health services, and governmental structures. Finally, public policy (legislations, policies, laws) plays a role in influencing behaviour (e.g. restrictions on smoking in public spaces) (McLeroy et al, 1988; Stokols, 1992; Gregson et al, 2001). Multi-level social ecological models have been widely accepted in both specific (tobacco control) and broad (public health) areas. There is also a great interest in social ecological models in the physical activity field, possibly because physical activity can be done in specific settings and is associated with environmental variables (Elder et al, 2007).

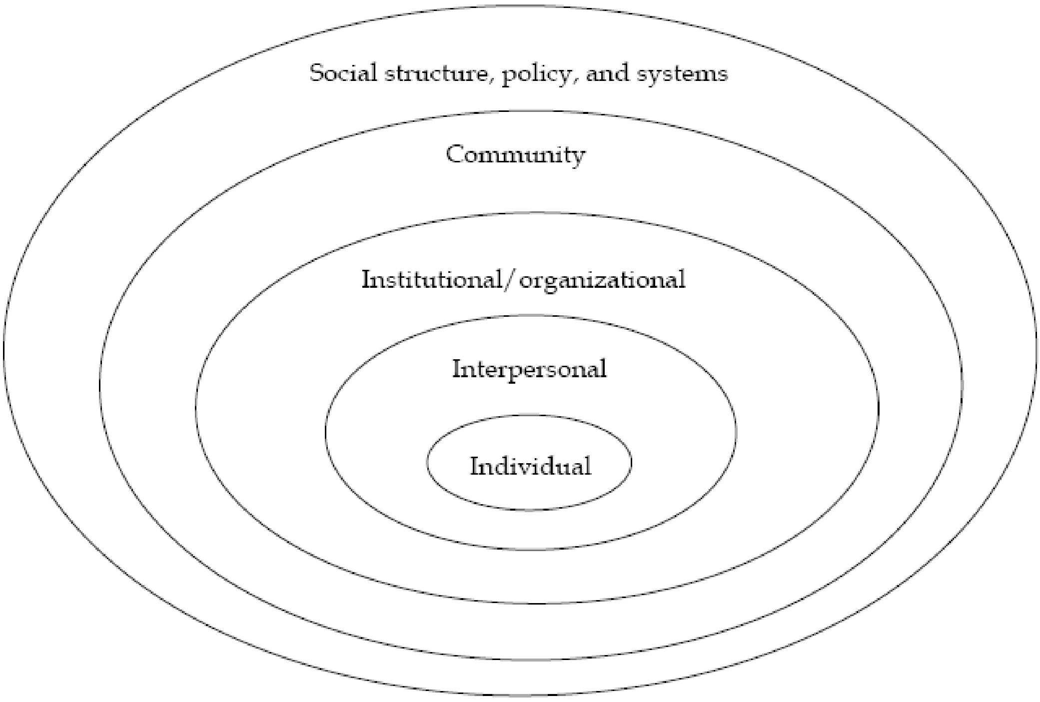

Figure 1: an ecological perspective on health promotion program (McLeroy et al, 1988).

Many of the previously described theories and models are applicable to different ecological levels (Bartholomew et al, 2006). For example, someone may not engage in physical activity due to determinants at different levels: lack of self-efficacy (intrapersonal level), lack of social support from family and friends (interpersonal level), lack of fitness norms and facilities (organizational level), and barriers to physical activity in the built environment (community level) (Bartholomew et al, 2006).

4.1.2 Correlates and determinants of physical activity

The identification of factors associated with physical activity is mostly based on correlational studies, mainly using previous models or theories. However, some variables are not associated with a specific theory, but still related to physical activity (Bauman et al, 2002). The variables associated with physical activity are called ‘correlates’ or ‘determinants’ of physical activity. The term correlate is used for factors found in cross-sectional studies, which are associated or related with a behaviour; while determinants are causal variables showing a cause-and-effect relationship in longitudinal studies (Bauman et al, 2002). In general, most research is based on cross-sectional studies and has revealed that different personal, social, and environmental factors ('correlates') are associated with being physically active or not (Sherwood and Jeffery, 2000; Bauman et al, 2002; Trost et al, 2002).

Of the demographic and biological factors, age and gender are the two most consistent, followed by socioeconomic variables such as income, occupation, and education. Physical activity participation is found to be consistently higher in men than in women, and inversely associated with age and positively with socioeconomic status. Overweight or obesity shows a negative association with physical activity. For example, a European study found that individuals in the upper quintile for leisure physical activity were about 50 % less likely, than those in the lowest quintile, to be categorized as obese (Martínez-González et al, 1999).
Of the psychological, cognitive, and emotional factors, self-efficacy is the most consistent correlate of physical activity. Also enjoyment of exercise, expected benefits, intention to exercise, perceived health or fitness, self-motivation, self-schemata for exercise, and stage of change are positively associated with physical activity. In contrast, barriers to physical activity, for example lack of time, and mood disturbance, have a negative influence on physical activity participation.
Past exercise behaviour and dietary habits are behavioural attributes and skills related to physical activity. Smoking behaviour is inversely associated with physical activity.
Other correlates of physical activity, are social and cultural factors, with social support, for example from friends, peers, partner or family, being a consistently important positive correlate of physical activity.
Several physical environmental factors have also been identified as positive correlates of physical activity. These include individual level influences, such as exercise equipment at home, access to facilities, satisfaction with facilities, and some community level influences, such as neighbourhood safety, hilly terrain, regular observation of others engaging in physical activity, and enjoyable scenery. Furthermore, more leisure time physical activity was reported by adults in urban areas than individuals in rural regions (Trost et al, 2002; Bauman et al, 2002). Martin et al (2005) believe that urban-rural differences can be explained by other known social and cultural determinants of physical activity such as race/ethnicity, gender, education, and income level. Also 'walkability' (the extent to which characteristics of a neighborhood may or may not be conducive to walking behaviour, based on residential density, street connectivity, and land use mix), may play a role in the association (Leslie et al, 2005). A more recent review (Wendel-Vos et al, 2007) found that important environmental correlates of physical activity were social support (socio-cultural environment), the

availability of physical activity equipment, having a companion for physical activity (socio-cultural environment), and connectivity of trails.
Despite the advantages of prospective study designs (e.g. less dependent of the moment of measuring) compared to cross-sectional designs, limited research used longitudinal data to examine 'determinants' of physical activity (Trost et al, 2002; Wendel-Vos et al, 2007). However, the findings of these studies did not differ from the results of cross-sectional research. Consistent results were found for age, gender, income, socioeconomic status, intention to exercise, perceived health or fitness, self-efficacy (except in one study), self-motivation, stage of change, past exercise behaviour, social support, and the environmental factors found in the review of Wendel-Vos and colleagues (2007).

A Flemish study has shown that the relative contribution of different psychosocial correlates, such as social variables, self-efficacy, perceived benefits and perceived barriers varies by age and sex groups (De Bourdeaudhuij and Sallis, 2002). Social variables (social norm, modelling, social support) provide the most unique explanatory information, and 'having someone to accompany them' was an important correlate in almost all subgroups. Self-efficacy was also a generalized correlate in all age and gender subgroups. A significant perceived benefit was competition for young men, and health for young women. Among older adults, health concerns were perceived barriers to participation in physical activity.
Another Flemish study examined specific environmental correlates of physical activity (De Bourdeaudhuij et al, 2003) and found that walking and moderate physical activity were associated with quality of sidewalks and accessibility of shopping and public transportation. Vigorous physical activity was associated with the presence of activity supplies in the home and convenient activity facilities outside the home.
A final study including Flemish data, showed that the variance explained by psychosocial factors was higher than that explained by environmental factors (De Bourdeaudhuij et al, 2005). Social support from family and/or friends, and the walkability and walking facilities in the neighbourhood were associated with walking and cycling. Recreational physical activity was influenced by social support, self-efficacy, and perceived benefits and barriers.

The success of intervention strategies will depend to some degree on a good understanding of the factors that explain or influence physical activity. Therefore, it is important to categorize variables into two groups, namely those that cannot be modified (age, gender) and those that are modifiable. Due to their susceptibility to change, modifiable factors are most important to identify, namely behavioural and personal characteristics, and environmental circumstances. Successful interventions take into account the individual needs, personal level of fitness, readiness for a change in behaviour, perceived personal control of the activity and its outcome, and social support from family, peers and communities (Seefeldt et al, 2002). Sherwood and Jeffery (2000) also highlight the importance of (1) understanding and assessing different motivations for physical activity, (2) self-efficacy as a predictor of physical activity and a target for intervention, (3) assessing readiness for physical activity change, (4) addressing prominent barriers to physical activity such as time and access, and (5) enhancing social support for physical activity.

4.2 Promoting physical activity

Behavioural sciences are being used to understand and explain physical activity. In addition, behavioural science theories and models are also being used as a conceptual and knowledge base for the promotion of health-related physical activity. The previously described theories and models are effective or promising for intervening with physical activity (Marcus et al, 1996). Different interventions are designed and implemented to promote physical activity. Interventions can be defined as specific strategies or programs developed to address a particular problem or issue, for example an inactive lifestyle.

In a systematic review, evaluating the effectiveness of various physical activity programs, interventions were categorized by their approach: informational (cognitive skills, education), behavioural and social, or environmental and policy approaches (Kahn et al, 2002). Effective results were found in two informational studies (“point-of-decision” prompts to encourage stair use, and community-wide campaigns), in three behavioural and social interventions (school-based physical education, social support in community settings, and individually-updated health behaviour change) and in one environmental and policy intervention (enhanced access to places for physical activity combined with informational outreach activities) (Kahn et al, 2002).

Another way to categorize interventions, is the level on which they operate. Intervention strategies can be designed to intervene at the micro-level, meso-level or macro-level. The level-classification here is based on the context in which the intervention is implemented, and not on the intervention strategies. Interventions at the micro-level are designed to reach individual persons with the aim to support individuals in changing their behaviour. Meso-level interventions are implemented in different settings, this to reach more individuals at once. A 'setting' is a physical structure with defined borders wherein people are connected and interact with each other, for example schools, workplaces, churches (Harting et al, 2007). Finally, macro-level interventions are delivered to a total population, for example a community population (such an intervention is here called 'a community intervention'). A 'community' is an aggregate of individuals in a geographic location and consists of environmental and social factors, and their interrelationships (Economos and Irish-Hauser, 2007). At each level, different intervention strategies or theoretical concepts can be used to promote physical activity.

Interventions on the micro-level approach individual correlates or determinants of physical activity. In a one-on-one relation (face-to-face contact, telephone, or mail), cognitive behavioural techniques are used to change a behaviour. Examples of behavioural management approaches are self-monitoring, feedback, reinforcement, contracting, incentives and contests, goal setting, skills training to prevent relapse, behavioural counselling, prompts or reminders, and social support. Research revealed that previous techniques have been used with mixed results. Where effects have been demonstrated, they have often been small (US Department *Surgeon General*, 1996).

Another way of approaching individual behaviour change, is through interventions implemented at the meso-level. Meso-level refers to a setting where (a group of) individuals spend a lot of their waking time, for example schools for children and adolescents, and workplaces and churches for adults. The advantage of such interventions is the ability to reach a large(r) percentage of a population. Furthermore, in workplaces for instance, there is easy access to employees and supportive social networks, and the opportunity exists to change the worksite environment (Shephard, 1996). By combining behavioural models, which are individually- and interpersonally-focussed, and social ecological approaches, using broader organizational and environmental strategies, worksite interventions can increase physical activity (Dishman et al, 1998). Also Marshall (2004) suggested multi-strategy worksite interventions that incorporate individually-tailored behaviour change techniques, mass reach approaches, social support strategies, and management support and integration with the organizational structure. A review by Dishman et al (1998) indicated that typical worksite interventions for increasing physical activity yielded a small positive effect. A later review (Proper et al, 2003), showed strong evidence for a positive effect of worksite programs on physical activity and musculoskeletal disorders. Limited evidence was found for a positive effect on fatigue, and inconclusive evidence for a positive effect on specific health outcomes such as cardio-respiratory fitness, muscle flexibility, muscle strength, body weight, body composition, blood serum lipids, and blood pressure. Overall, workplace interventions have shown favourable outcomes, especially in short-term studies using individually tailored theory-based materials and/or environmental prompts (Marcus et al, 2006).

To reach a whole population, interventions can be designed and implemented at the macro-level, for example community interventions, which focus on reaching an entire community population. By focusing on the community, the likelihood of influencing a greater proportion of the underactive population increases, and also the likelihood of reaching the most sedentary part of the population increases (King, 1994). Interventions at the macro-level can focus on one or more, or a combination of personal, environmental, social, cultural, political, and economic factors. Examples of strategies used for physical activity promotion in the community are the sponsoring or supporting of physical activity by community organizations or institutions (e.g. park and recreation departments, local public health departments), mass media to increase awareness and knowledge related to physical activity, environmental strategies to increase safety and enhance environmental support for (un)structured physical activity, legislative and regulatory policies (e.g. zoning and building legislation that encourage stair use), and professional training for physicians, nurses, psychologists, other health professionals, physical education instructors (King, 1994). Focusing on one aspect, for example only mass media campaigns, does not result in population increases in activity. Therefore, broader multi-strategic programs with inter-sectoral approaches are more recommended (Cavill and Bauman, 2004).

Many of the previous multi-strategy interventions at the macro-level focused on a range of health behaviours, including smoking, high blood pressure, cholesterol, obesity, and physical activity, to reduce cardiovascular disease (US Department *Surgeon General*, 1996). One of the first major health intervention programs at the macro-level was the “*North Karelia Project*” in the 1970’s in Finland. The comprehensive educational and service-oriented program showed decreases in different risk factors (Puska et al, 1989). Ever since the 1980’s, the “*Minnesota Heart Health Program*” (Crow et al, 1986), the “*Pawtucket Heart Health Program*” (Eaton et al, 1999), the “*Stanford Five-City Project*” (Young et al, 1996), the “*Bootheel Heart Health Project*” (Brownson et al, 1998) were community interventions in the United States, using for example physical activity education, creating awareness and knowledge about physical activity, and organizing walking events and worksite exercise programs. However, all interventions showed modest effects on physical activity (Crow et al, 1986; Luepker et al, 1994; Young et al, 1996; Eaton et al, 1999; Browson et al, 2005). Soon after, a European health intervention "*Hartslag Limburg*", encouraging community inhabitants to become more active, eat healthier, and give up smoking, showed reduced cardiovascular risk factors (Schuit et al, 2006).

Later, interventions at the macro-level began to focus exclusively on physical activity, mostly through programs guided by social ecological models of health behaviour (Mummery and Brown, 2008). For example in Australia, *"Concord, a Great Place to be Active"*, aimed to increase physical activity levels of 20-50 year-old women in Sydney, through a local social marketing campaign, walking events, and council capacity-building strategies. A 6.4 % reduction in the proportion of sedentary women was found (Wen et al, 2002). More recently, *"Wheeling Walks"*, a theory-based mass media campaign in West Virginia, promoting walking among sedentary 50-65 year-old adults, resulted in a 23 % increase in the number of walkers in Wheeling (Reger et al, 2002). The program *"Agita São Paulo"* promotes messages about the health benefits of physical activity and coordinates activities and interventions for broader physical activity opportunities in the Brazilian state. Inactive physical activity levels decreased from 9 % to 4 % and active levels increased from 54 % to 64 % over a 1-year period (Matsudo et al, 2006). Finally, the Norwegian project *"Romsås in Motion"* included physical activity, communication, environmental, and participatory components. A favourable intervention effect was found on stages of change (Lorentzen et al, 2007).

A quantitative synthesis of Dishman and Buckworth (1996) showed that interventions employing principles of behaviour modification, delivered to healthy people in a community, are associated with large effects (effect size: $r \geq 0.50$), particularly when the interventions are delivered to groups using media approaches or when the physical activity is unsupervised, emphasizing leisure physical activity of low intensity, regardless of the duration or frequency of participation. Also Dunn et al (1998) showed that lifestyle physical activity interventions are effective in increasing and maintaining levels of physical activity.

In the past few decades, there has been a shift in emphasis from individually oriented behaviour change interventions to environmentally based intervention strategies. Physical activity interventions trying to directly influence individual behaviour will often fail because appropriate opportunities and support are not available. An alternative approach is the development and implementation of interventions based on social ecological frameworks that treat the local area and not the individual per se. From a social ecological perspective, physical activity promotion is viewed not only in terms of the specific behaviour of the individual, but more broadly as a dynamic interaction between the individual and groups and their physical and social environment. The underlying idea of a social ecological approach is that interventions are most effective if they include multiple levels of appeal. The social ecological concept emphasizes the advantages of multi-level interventions that combine behavioural and environmental factors. Thus, environmental interventions are implemented to support changes in individuals behavioural. For example, a workplace program that encourages employees to improve their diet and physical activity level may be facilitated by media campaigns in the community to promote heart-healthy lifestyles, in addition to regulatory interventions to enhance food quality and safety, and the provision of physical fitness and recreational facilities in work environments and residential areas. The social ecological approach suggests that multi-strategy interventions that incorporate environmental and behavioural components and span multiple settings are more likely to be effective in promoting personal and public health than are those more narrow in scope (Stokols, 1996; Cochrane and Davey, 2008).

4.3 Pedometer-based interventions

The purpose of pedometer-based interventions is to achieve an active lifestyle, wherein physical activity should become a part of daily living. According to Choi et al (2007), the key to increasing the daily steps is to “get off the chair or couch”. Pedometer-based programs make it possible to meet a step count goal either by going for one long walk or by accumulating steps throughout the day. Pedometer-based interventions are flexible and popular as the individual can incorporate physical activity whenever convenient (Richardson et al, 2008). Using a pedometer to encourage an accumulation of daily steps appears to be appealing, as ‘time’ is often found to be the biggest barrier to physical activity in adults (Trost et al, 2002).

While pedometers have been shown to be appropriate measurement instruments, they also appear to have utility as a motivational and behaviour modification tool (Freedson and Miller, 2000). First, the pedometer can be used as a (self-)monitoring device, continuously tracking current physical activity, and increasing cognitive awareness of the level of physical activity. Second, the pedometer provides immediate and direct feedback to the user. Due to the feedback received from a pedometer, the user can monitor their physical activity level easily. This is an important aspect in the light of the goal-setting theory (consistent with Social Cognitive Theory) as performance enhancement through goal setting is gained only with immediate confirmation of the extent to which goals have been attained (Locke and Latham, 2002). Goal-setting, whether personalized or not, has been suggested as vital to the success of pedometers (Tudor-Locke and Myers, 2001a). A pedometer allows the user to easily set (short-term) goals. Baker et al (2008) found that the instant feedback gained from checking the pedometer aided participants in achieving their goals, allowing them to adjust the level and direction of their effort. In summary, pedometers facilitate self-monitoring, personal goal-setting and feedback, all theoretical principles of the Social Cognitive Theory (Tudor-Locke et al, 2001). Furthermore, the pedometer serves as an environmental cue, a reminder to be more active (Tudor-Locke, 2002; Schneider et al, 2003; Wyatt et al, 2004). Together with a calendar, diary, or daily log to keep record of and reflect on the amount of physical activity, the pedometer can be used to effectively increase daily physical activity (Tudor-Locke and Myers, 2001a; Tudor-Locke, 2002). In addition, Health and Human Services stated that pedometers can be effective to increase walking, and should be considered as a successful tool for combating the obesity epidemic (Melanson et al, 2004).

Behavioural concepts used during pedometer-based interventions can be various, such as strategies based on the Social Cognitive Theory, stages of change, attitudes, and social support. Research revealed that pedometer users had higher coping self-efficacy and higher outcome expectations than those who did not own one. It is possible that using a pedometer made one think more about the benefits of physical activity, thus increasing outcome expectations (Berry et al, 2007). Rooney et al (2003, 2005) and Clarke et al (2007) also found that a pedometer-based intervention resulted in significant improvements in self-efficacy. Furthermore, participants were more aware of their own level of activity (Rooney et al, 2003; 2005). In contrast, an earlier study of Speck and Looney (2001) found that self-efficacy scores decreased after a pedometer-based intervention (maybe due to the increased subject awareness of their physical activity from daily recording), while other conceptual model variables (barriers, outcome expectations, value expectations, family support, friend support) remained the same. Dinger et al (2007) and Winett et al (2007) did not find changes in self-efficacy, while all other constructs of the Transtheoretical Model (motivational readiness or stage of change, decision balance) positively changed (Dinger et al, 2007).

In the past, pedometers, in combination with step count goals, record-keeping, and other strategies have been used in lifestyle physical activity interventions in different populations, in controlled and free-living conditions, and this at different levels. A recent systematic review (Bravata et al, 2007) showed that pedometer users increased their physical activity by 26.9 % over baseline after an intervention. An important predictor of increased step counts was having a step goal, such as 10,000 steps/day. Furthermore, BMI and systolic blood pressure significantly decreased in pedometer users (Bravata et al, 2007). Another recent review examined the effect of pedometer-based walking interventions on weight loss (Richardson et al, 2008). The review showed that pedometer-based walking programs (median duration of 16 weeks), without a dietary intervention component, resulted in a modest amount of weight loss (pooled estimate of weight change = -1.27 kg). A final review (Ogilvie et al, 2007), assessed the effects of different interventions designed to promote walking. Three of the seven pedometer interventions, with follow-up periods of up to three months, showed significant net increases in self-reported walking or in step counts. In the three studies with longer follow-up periods, the significant net increases in step counts after 4-16 weeks could not be sustained at 24 weeks or 12 months. Below, examples of pedometer-based physical activity interventions at different levels will be given.

4.3.1 Pedometer-based interventions at the micro-level

The first pedometer-based interventions were delivered to clinical populations, for example obese diabetes patients (Yamanouchi et al, 1995; Tudor-Locke et al, 2001; Tudor-Locke et al, 2004), chronic obstructive pulmonary disease patients (Puente-Maestu, 2000; de Blok et al, 2006), hypertensive patients (Iwane et al, 2000), postmenopausal women with borderline to stage 1 hypertension (Moreau et al, 2001), and overweight/obese adults (Van Wormer, 2004; Schneider et al, 2006) or overweight and/or obese women (Swartz et al, 2003). Also in primary care, pedometer interventions have been implemented, and showed to be effective: adding pedometer use and daily record use to brief physician counselling resulted in increased daily step counts and a higher frequency of short walking trips (Stovitz et al, 2005).

Next to clinical settings, pedometer-based physical activity interventions were also conducted in the general healthy population (see table 1).
The first '10,000 Steps' program was an 8-month, mail-based program designed for 35-50 year-old adults, using pedometers, personal action planners, a step log, and motivational cards (Lindberg, 2000). Results showed significant increases in step counts, concluding that pedometer use with support materials may be successful to support individuals or groups in becoming more physically active (Lindberg, 2000). Furthermore, when menopausal women were encouraged to increase physical activity through a 24-month intervention, including exercise and daily pedometer registrations, daily step counts increased significantly and the profile of serum lipids improved (Sugiura et al, 2002). Also an email-delivered, pedometer-based intervention showed to be effective in impacting walking and most Transtheoretical Model scores among insufficiently active women (Dinger et al, 2007). Sedentary women also increased their step counts by using pedometers with a step count goal. There was no difference between the group who aimed for 10,000 steps/day and the group who had set a personal step count goal (Sidman et al, 2004). Hultquist and colleagues (2005) showed that previously inactive women walked more when they used a pedometer and were told to take 10,000 steps/day, compared with those instructed to take a brisk 30-minute walk. A 6-weeks intervention in healthy women (35-65 year) as well, showed that physical activity can be increased with the aid of pedometers and individualized, specific target goals in steps (Glazener et al, 2004). Even a minimal intervention of 12 weeks of daily record keeping (step counts) resulted in greater activity levels in women (Speck and Looney, 2001). Another study in women, has shown that the combination of setting goals, keeping a log of steps, and wearing a pedometer all the time, were indicators most likely to predict improvements in level of awareness and amount of physical activity, self-efficacy, and other physical improvements, such as increased energy, being ill less often, and weight loss (Rooney et al, 2003). Wearing a pedometer and being encouraged to walk 10,000 steps/day for 12 weeks, improved physical activity attitudes, self-efficacy and activity level among healthy families (Rooney et al, 2005). Healthy adults, advised to increase walking by 2000 steps/day, also increased step counts and estimated energy expenditure (Koulouri et al, 2006). In conclusion, several studies proved the effectiveness of pedometer-based interventions at the micro-level in increasing physical activity levels and some health outcomes.

Table 1. Overview of recent (since 2000) pedometer-based interventions in healthy adults.

AUTHORS (YEAR) CONTINENT	PARTICIPANTS / AGE STUDY DESIGN	INTERVENTION	DURATION	RESULTS
Interventions at micro-level				
Lindberg (2000) United States	Adults 35-50 year Intervention n=92 No comparison Pilot study	"10,000 Steps" mail-based program: - pedometer use - personal action planner - step count log - motivational cards	8 wk- 32 wk	After 8 weeks: - 81% found the program assisting to ↗ PA - 76% indicated improvement in readiness to engage in PA - 66% found program excellent to improve confidence level for ↗ PA - sign ↗ in steps at start, wk 4, wk 8 After 8 months: - 50% continued to use pedometer ≥ 2d/wk - 94% found program somewhat to very motivating to ↗ PA - 90% found program moderate to excellent to maintain new level of PA - 100% would recommend the program to a friend
Sugiura et al (2002) Asia	Women 40-60 year Intervention n=14 Comparison n=13 Randomized trail Pre-post test	- weekly 90-minutes physical education class - daily step count log	24 mo	Intervention group: - step counts ↗ sign from 6740 to 8500 steps/d - improved serum lipids
Dinger et al (2007) United States	Inactive women 25-54 years Intervention1 n=24 Intervention2 n=32 Randomized trial Pre-post test	- intervention1: pedometer use + step log + set goal + weekly email reminder - intervention2: pedometer use + step log + set goal + weekly email reminder + strategies based on Transtheoretical Model (TTM) to increase PA	6 wk	Both intervention groups: - daily steps increased from 6419 to 7984 steps/d - weekly walking minutes increased (+90 minutes) - moved forward at least one stage - increased all TTM variables except self-efficacy
Sidman et al (2004) United States	Sedentary women 20-65 year Intervention n=92 No comparison Quasi-experimental pre-post test	Pedometer use + daily step count log +group1: 10,000 step/d as goal group2: personal step count goal (baseline + 1000 to 3000 steps)	3 wk	Step counts ↗ in both groups

n = number d = day wk = week mo = month PA = physical activity sign = significant ↗ = increase ↘ = decrease

Hultquist et al (2005) United States	Women 33-55 years Intervention1 n=27 Intervention2 n=31 Randomized trial Pre-post test	- intervention1: goal = 30 minute walk - intervention2: goal = 10,000 steps/d + pedometer use + daily step log	4 wk	- intervention1 (8270 steps/d) sign less step counts than intervention2 (10,159 steps/d) - intervention1: goal reached = 9505 steps - intervention2: goal reached = 11775 steps
Glazener et al (2004) United States	Women 35-65 year Intervention n=7 Comparison n=7 Randomized trial Pre-post test	Intervention and control group: pedometer use in both groups Intervention group: individual step count goal (20% increase from baseline)	1 wk	Sign ↗ in step counts in intervention group
Speck & Looney (2001) United States	Women 20-57 year Intervention n=25 Comparison n=24 Randomized trial Pre-post test	Daily recording of PA on calendar page	12 wk	Daily step counts intervention group (9251) sign higher than in comparison group (7103)
Rooney et al (2003) United States	Women ± 42 year Intervention n=400 No comparison Pre-post test	- purchasing pedometer - 10,000 steps/d instruction - encouraged to keep log of progress	8 wk	- 56% set daily step goals - 63% kept log - 43% wore the pedometer all the time → setting goals, keeping log and wearing pedometers = indicators of sign improvements in level of awareness and amount of PA, self-efficacy and other physical improvements.
Rooney et al (2005) United States	Families Intervention1 n=112 (30 families) Intervention2 n=104 (28 families) Comparison n=100 (29 families) Randomized trial Pre-post-follow-up test	- intervention1: pedometer use + 10,000 steps/d goal + step log + 6 sessions of education - intervention2: pedometer use + 10,000 steps/d goal + step log	12 wk	3 months: intervention groups - self-efficacy parents improved - attitudes about PA improved significantly - 68% of the children and 91% of parents felt the pedometer increased their activity level 9 months follow-up: - 8% of children and 11% of parents wore pedometer all the time - no/little effect on activity level, BMI, weight
Koulouri et al (2006) Europe	Adults ± 28 year Intervention n=12 No comparison Pre-post test	Pedometer use + daily step log + advice to increase walking by 2000 steps/d	2 wk	- sign ↗ in step counts (+2667 steps/d) - sign ↗ in energy expenditure (+100 kJ/d)

n = number d = day wk = week mo = month PA = physical activity sign = significant ↗ = increase ↘ = decrease

Interventions at meso-level				
Croteau (2004) United States	College employees 23-64 years Intervention n=37 No comparison Pre-experimental one-group pre-post test	*"Healthy Steps"*: - pedometer use: feedback + self-monitoring + daily log - counselling session - tailoring: personal action plan - goal setting (baseline 8000-10,000: +5% baseline < 8000: +10%) - emails: education and motivation	8 wk	- sign ↗ in step counts from 8565 to 10,568 steps/d - sign ↗ in perceptions of physical activity survey - sign ↗ in physical activity survey
Chan et al (2004) North America	Sedentary working volunteers (± 43 years) Intervention n=106 (5 workplaces) No comparison Pre-post test	*"Prince Edward Island-First Step Program"* Adoption phase - contact with facilitator - goal setting - pedometer use + log: self-monitoring Adherence phase - pedometer use + log: self-monitoring	12 wk	- sign ↗ in step counts from 7029 to 10,480 steps/d - sign ↘ in BMI, waist girth, resting heart rate
Thomas & Williams (2006) Australia	Volunteer staff 25-55 years Intervention n=859 No comparison Pre-post test	*"Ten Grand Steps"*: - pedometer use: self-monitoring + dairy - goal setting: 10,000 steps/d - train-the-trainer model - education: information booklet - motivation: regular email reminder	4 wk	- 70% increased their level of walking - sign ↗ in step counts from 8501 to 9374 steps/d 3 months follow-up: - 97% found program worthwhile - 63% maintained or increased level of walking - 65% changed daily life to increase PA
Behrens et al (2007) United States	Voluntary city employees Intervention n=640 No comparison Descriptive cross-sectional design	- goal setting: 10,000 step/d - team competition (1 team=10 people) - pedometer use: self-monitoring on team intranet page once a week - incentive: certificate from city mayor	12 wk	- sign ↗ in step count from baseline to wk 6-8: baseline total sample: 545,175 steps/wk wk 6-8 total sample: 594,905 - 601,789 steps/wk
Green et al (2007) United States	Adult voluntary employees of a health care system Intervention n=565 (10 facilities) No comparison Pre-post test	*"Active for Life"*: - pedometer use: self-monitoring + log - goal setting: minutes of PA - incentives: team prize and individual awards - team competition	10 wk	- sign ↗ PA + % meeting guidelines from 34% to 48% - sign ↗ in % exercising till sweat from 76% to 91% - sign ↘ in % sedentary from 23% to 6% - sign ↗ in exercise metabolic equivalents (+27%) 6 months follow-up: - no sign differences from baseline except at follow-up 83% exercising till sweat

n = number d = day wk = week mo = month PA = physical activity sign = significant ↗ = increase ↘ = decrease

Haines et al (2007) United States	Middle-aged college faculty and staff Intervention n=120 One-group pre-post test	*"Virtual Walking and Wellness Program"* - pedometer use: self-monitoring + log - goal setting: +10% until 10,000 steps/d - education: walking manual - computer educational program - motivation: weekly emails	12 wk	- sing ↗ in step counts from 42,797 to 58,859 steps/wk - sign ↘ in BMI from 29.06 to 28.76 kg/m^2 - ↘ in blood glucose from 96.71 to 91.44 mg/ml - ↘ total cholesterol from 184.68 to 178.81 mg/ml - moderate effect on fitness level, mood, health awareness, nutritional habits and health status
Naito et al (2008) Asia	Middle-aged employees Intervention n=1077 (5 companies) Comparison n=1852 (5 companies) Pre-post test	*"HIPOP-OHP"*(high risk and population strategy for occupational health promotion) - pedometer use: self-monitoring + diary - education: posters, website, newspaper - organizational changes - environmental changes: walking path	5 yr	- sign ↗ in daily walking in intervention group - sign difference in change in serum level of HDL-cholesterol between intervention (+2.7 mg/dL) and comparison group (-0.6 mg/dL) - no change in BMI
Faghri et al (2008) United States	Volunteering, sedentary employees Intervention n=206 (2 workplaces) No comparison Pre-post test	Progressive walking program: - pedometer use at work + self-monitoring + logs - motivation (based on TTM): weekly emails + website - goal setting - team competition - maps of worksite walking routes	10 wk	- sign ↗ in step counts from 4185 to 5300steps/d at wk 8 - sign ↗ in % reporting to be active (+33%) - sign movement in stage of change for PA, dietary habits, and stress management - sign↘ in blood pressure - no sign effect on body weight
Gemson et al (2008) United States	Volunteering, middle-aged hypertensive employees Intervention n=47 Comparison n=94 Quasi-experimental pre-post test	- Intervention: BMI, blood pressure, body fat measurements + education (brochure) + pedometer use (self-monitoring) + goal setting (10,000 steps/d) + motivation (poster, messages) - Comparison: BMI, blood pressure measurement + education (brochure)	1 yr	- sign greater decline in blood pressure in intervention group than comparison group - sign difference in change in BMI between intervention (-1.0) and comparison group (+0.2) - no sign difference in self-reported ↗ in PA between intervention and comparison group - educational brochure worked motivating for 91.4% in intervention and for 44.7% in comparison group - intervention group: 38.3% reported undertaking vigorous PA = 100% ↗ - intervention group: sign ↗ in pedometer use from 8.5% to 27.7% - intervention group: sign higher motivation to exercise than comparison group

n = number d = day wk = week mo = month PA = physical activity sign = significant ↗ = increase ↘ = decrease

Clarke et al (2007) United States	Low income overweight/obese mothers 18-45 year Intervention n=93 Comparison n=31 non-overweight/obese pre-post test	Weekly lessons including PA, healthful eating, behaviour modification in community centers. PA: class discussion + 30 minutes exercise classes + pedometer use	8 wk	Intervention group: - sign ↗ in exercise self-efficacy - sign ↗ in step counts from 5969 to 9757 steps/d - sign ↗ in energy expenditure (+224 kcal/d) - sign ↘ in body weight, % body fat, waist circumference
Winett et al (2007) United States	Intervention1 n=310 (5 churches) Intervention2 n=334 (5 churches) Comparison n=291 (4 churches) Group-randomized trial Pre-post test	*Guide to Health* (GTH) internet intervention delivered in churches, focusing on nutrition and PA: PA: step count goal (baseline+500 steps/d) - intervention1: GTH - intervention2: GTH with church-based support	28 wk	- both intervention groups improved nutrition at post-test - intervention2 decreased weight at post-test - intervention2 improved PA (+1500 step counts) and nutrition at post-test and follow-up (16 mo)
Whitt-Glover et al (2008) United States	Sedentary, black adults 20-83 years Intervention n=87 (4 churches) No comparison Pre-post test	Pedometer use + step log + advised to take 10,000 steps/d + 8 group sessions including discussion of PA, PA session, weekly incentives to promote PA	12 wk	- sign ↗ in step counts from 4822 to 6148 steps/d - ↘ in proportion of sedentary participants from 36% to 32% - ↗ in proportion of somewhat active participants from 20% to 28% - sign ↗ in self-reported moderate (+ 66 minutes) and vigorous (+ 43 minutes) PA
Wyatt et al (2004) United States	Employees n=503 (6 work sites) Church members n=232 (6 churches) No comparison Non randomized trial Pre-post test	"*Colorado on the Move*": - pedometer use + step log - increase walking by 2000 steps/d - team competitions - incentives	14 wk	- sign ↗ in step counts in work sites from 7669 to 10,417 steps/d - sign ↗ in step counts in churches from 5896 to 8471 steps/d
Interventions at macro-level				
Brown et al (2006) Australia	Community inhabitants 18-60+ years Intervention n=1242 Comparison n=1236 Quasi-experimental pre-post test	"*10,000 Steps Rockhampton*" - pedometer use - marketing strategies - PA promotion by health professionals - environmental support for PA	18 mo	Comparison community: -6.4%↘ 'active' participants Intervention community: - no change in total % 'active' participants (+5% in ♀) - 95% aware of project - 4% ↗ in % receiving advice from health practitioner - 18% used pedometer

n = number   d = day   wk = week   mo = month   PA = physical activity   sign = significant   ↗ = increase   ↘ = decrease

Craig et al (2006, 2007) North America	Adult inhabitants of Canada Study sample n=9755 No comparison Pre-post test	*"Canada on the Move"* - distribution of pedometers - mass media campaign: "add 2000 steps", "keep it simple" - website use	12 wk	- sign positive overall gradient for awareness of the campaign and its specific messages - sign ↗ in pedometer ownership (10% owns pedometer) - message recall and pedometer ownership were associated with ↗ odds of self-reported walking
Merom et al (2007) Australia	Inactive adults 30-65 years Intervention1 n=102 Intervention2 n=105 Comparison n=107 Randomized trial Pre-post test	*"Step-by-Step"* - intervention1: self-help walking program by mail with weekly diaries - intervention2: self-help walking program by mail with weekly diaries + pedometer use + step log	12 wk	- sign ↗ of self-reported walking in both intervention groups, but changes were greatest in intervention2 - sign ↗ of self-reported sports in intervention2 - intervention2: ↗ in step counts (+1820)
Baker et al (2008) Europe	Community inhabitants 18-65 years Intervention n=32 Comparison n=32 Randomized trial Pre-post test	*"Walking for Well-being in the West"* - PA consultations - pedometer-based walking program	12 wk	Intervention group: - sign ↗ in step counts (+3175), walking (+57.5 minutes), positive affect (feelings, emotions) - sign ↘ in sitting time (-1680 minutes/ wk) - no changes in health outcomes

n = number   d = day   wk = week   mo = month   PA = physical activity   sign = significant   ↗ = increase   ↘ = decrease

4.3.2 Pedometer-based interventions at the meso-level

The most obvious meso-level setting for adult physical activity promotion is the workplace. Recently, different workplace interventions using pedometers as intervention tool, have been implemented (see table 1). Strategies and techniques used to change employees' physical activity behaviours included counseling, tailoring, goal setting, self-monitoring, feedback, education, motivation, incentives, team competitions, contact with a facilitator, or focusing on organizational and environmental changes. The majority of these studies, which took mainly place in the United States, Canada, Australia and Japan, reported significant increases in step counts, self-reported physical activity and/or health parameters. However, most of these pedometer-based workplace interventions were of short duration (4-12 weeks), and the studies had problematic designs and did not include a control group.
Other settings at meso-level include churches or community centers (see table 1). Different pedometer-based interventions, such as a physical activity and dietary program, a tailored, social cognitive "*Guide to Health Internet*" intervention, a program to self-monitor ambulatory activity, and "*Colorado on the Move*", showed considerable step count increases after interventions of various durations (Clarke et al, 2007; Winett et al, 2007; Whitt-Glover et al , 2008, Wyatt et al, 2004).

4.3.3 Pedometer-based interventions at the macro-level

Macro-level interventions aim to reach a great proportion of the population, for example a community population. Interventions at the macro-level using pedometers are limited (see table 1). One of the first multi-strategy projects in a community setting was the Australian intervention *"10,000 Steps Rockhampton"*(2002-2003) (Brown et al, 2003). The physical activity promotion strategies used during this 18-month pedometer-based intervention were based on social ecological frameworks. The first strategy consisted of a local media campaign (print, radio, and TV media) to raise awareness of the low levels of physical activity in the community and to profile the project theme ('10,000 steps/day' and 'every step counts') and community role models, and to promote associated activities. Secondly, physical activity was promoted through general practice and other health services using evidence-based protocols and materials, such as posters, brochures, pedometers. Thirdly, social support among disadvantaged groups was improved by working with a range of community partners to initiate group-based activity programs. A fourth strategy was to attempt to change policy and the environment, focusing on infrastructure (key footpaths, sings, maps) and safety.

Finally, community initiatives, such as community competitions for micro-project funding, were established (Brown et al, 2003). The results of the quasi-experimental study showed significant project reach and awareness among Rockhampton adults. Furthermore, the downward trend in physical activity seen in the comparison community (48.3 % categorized as 'active' to 41.9 % 'active'), was not evident in Rockhampton (41.9 % categorized as 'active' to 42.8 % 'active') (Brown et al, 2006).

In 2004, the campaign *"Canada on the Move"* promoted walking through pedometer use among all Canadian adults. The focus on encouraging pedometer usage and walking, was supported by a public-private partnership with Kellogg's Canada, distributing step counters with mass media advertisements via cereal boxes. The specific messages were 'add 2000 steps' and 'donate your steps to health research' (Craig et al, 2006, 2007). Proximal effects of the campaign were that it raised awareness of the campaign message, that pedometer ownership increased, and that awareness of the messages was associated with pedometer use (Craig et al, 2006). Distal results showed that those who were aware of the campaign and its general message ('add 2000 steps'), and those who owned a pedometer, had a higher prevalence of sufficient walking, than those who were unaware and did not own a pedometer respectively (Craig et al, 2007).

In the *"Step-by-Step"* program, a community sample of inactive healthy adults was encouraged to increase their walking, using a mailed theoretically based self-help booklet and weekly diaries. One group also received a pedometer and step diaries. Only participants who received a pedometer were significantly more likely to meet the regular leisure time physical activity criterion. Furthermore, the group that used a pedometer showed the greatest magnitude of change, suggesting that pedometers enhanced the effects of the self-help walking intervention (Merom et al, 2007).

The *"Walking for Well-being in the West"* is a multi-dimensional community intervention which aims to promote and maintain increased walking. This 12-week program in the United Kingdom used physical activity consultations, based on the Transtheoretical Model, and a pedometer-based walking program, encouraging an increase of 3000 steps above baseline value. Significant increases were found for step counts, leisure walking time, and positive affect (an individual's feelings and emotions), while sitting time decreased significantly. The intervention group reported significantly more leisure time, occupational, and total walking, and less sitting than the comparison group. The campaign had no effect on health outcomes such as body mass, BMI, fat, waist and hip circumference, blood pressure, and cholesterol (Baker et al, 2008).

5 Problem analysis and outline of the thesis

The research reported in this thesis is a collection of seven articles that are published in international scientific journals, and one article that is under review for publication. The first three papers of the original research are pedometer and/or step count-related methodological studies, while the other papers report the results of pedometer-based intervention studies. The final part of the present thesis (part 3: general discussion) will give an overall conclusion, practical implications and directions for future research.

In recent years, the pedometer has become a popular monitoring and motivational tool in physical activity research and promotion (Tudor-Locke and Myers, 2001b). Pedometers of different types and brands became available on the market. However, research revealed a considerable variation in pedometer validity, reliability, and accuracy between different types and brands (Crouter et al, 2003; Schneider et al, 2003). The Yamax Digi-Walker was found to be one of the best pedometers with regard to accuracy and reliability for counting steps (Bassett et al, 1996; Bassett et al, 2000; Leenders et al, 2000; Tudor-Locke et al, 2002; Crouter et al, 2003; Schneider et al, 2003; Le Masurier et al, 2004). However, also less expensive and/or free pedometers, often given as marketing gadgets, became accessible to the public and the validity of these inexpensive pedometers is questionable. Therefore, the aim of chapter 2.1.1 is to evaluate the validity of an inexpensive pedometer, namely the 'Stepping Meter', in free-living conditions in adults. The criterion pedometer used in this study was the Yamax Digi-Walker SW-200.

Despite the fact that pedometers became popular measuring devices for public use and research, one could wonder what the pedometer actually measures. What is the 'meaning' of pedometer step counts? Which dimensions of physical activity are exactly being determined by pedometers? Do step counts only represent ambulatory behaviour, i.e. walking, or can pedometers also be used to assess overall physical activity throughout the day? In the United States and Canada, the focus is mainly on measuring walking. However, Europe has a different culture with other environmental (e.g. more cycle paths available, mild climate) and socioeconomic characteristics (e.g. governmental health regulation), which can reflect in other physical activity patterns. Consequently, it is interesting to know what pedometers measure: only walking or also other aspects besides walking? In chapter 2.1.2 pedometer step counts are compared with physical activity data from four validated different

questionnaires (one interview and three self-administered questionnaires) in order to investigate what pedometer counts represent. Associations between step counts and physical activity, i.e. walking, moderate physical activity and vigorous physical activity, reported in the questionnaires are being evaluated.
Moreover, in the study in chapter 2.1.2 different step count thresholds (7500 steps/day, 10,000 steps/day, and 12,500 steps/day) are compared with the current health-related physical activity recommendation of 30 minutes/day of moderate to vigorous physical activity. Previous research assessing whether step count standards are corresponding to the 30 minutes standard, was only done in women and in non-European countries. This study explored whether Flemish adult men and women reaching the different step count goals, also reached 30 minutes of physical activity, based on self-reports.

In the past, valid pedometers have been used to collect physical activity data in free-living populations. However, population-based step counts have only been collected in a limited number of countries, mostly outside Europe (Wyatt et al, 2005; Tudor-Locke et al, 2004; Brown and Miller, 2004; Mc Cormack et al, 2006; Schmidt et al, 2007; Sequeira et al, 1995). In the recent literature, no pedometer-based data can be found for European countries, while physical activity levels may differ from other continents, due to different environmental and socioeconomic characteristics. Therefore, the pilot study in chapter 2.1.3, will provide pedometer-based physical activity data in Flemish adults, and evaluate comparisons between sexes, age groups, employment status, and days of monitoring.
It was already found that pedometers are able to discriminate between sitting, standing, and moderate effort categories in a European sample (Sequeira et al, 1995). However, it remains unclear whether pedometer-based data provide enough information to sufficiently describe differences in various domains of physical activity. Consequently, a second aim of the study in chapter 2.1.3 was to compare step counts with physical activity data (at work, during transport, at home, and during leisure time) assessed by the valid IPAQ (Craig et al, 2003).

The modern way of living, including automation of occupation and domestic tasks, creates a sedentary and inactive lifestyle. Currently, physical inactivity is one of the most important modifiable risk factors for chronic disease, together with smoking. Furthermore, an inactive lifestyle may contribute significantly to total mortality in Western countries (US Department *Surgeon General*, 1996). Despite numerous attempts to promote exercise, voluntary or leisure time physical activity or exercise remains unpopular (Sherwood and Jeffrey, 2000). For example, only 15 % of adults in the United States engage regularly in vigorous physical activity during leisure time (US Department *Surgeon General*, 1996). In Belgium, this figure is no more than 12 % (Bayingana et al, 2006). Fortunately, lifestyle physical activity of moderate intensity have been shown to have health benefits (Pate et al, 1995). Still, the majority of American (60 %) (US Department *Surgeon General*, 1996), Australian (43 %) (Bauman et al, 2003), and European (43-87 %) (Varo et al, 2003) adults do not meet the current health-related physical activity guideline, which recommend 30 minutes of moderate-intensity physical activity (Haskell et al, 2007). In Belgium, 66 % of the population is not sufficiently active enough to achieve health benefits (Bayingana et al, 2006).

Consequently, easy accessible physical activity interventions, targeting the individuals most at risk, are needed. One way to do this, is through pedometer-based physical activity interventions. Pedometers have the potential to reach individuals who might not otherwise participate in structured exercise (Merom et al, 2007). Furthermore, recent pedometer-related reviews have found promising results and showed that pedometer-based interventions can increase physical activity, decrease BMI and blood pressure (Bravata et al, 2007), and can result in a modest amount of weight loss (Richardson et al, 2008). However, most pedometer-based studies have been conducted in the United States, Canada, Australia, or Japan, leaving a gap concerning the effectiveness of pedometer-based interventions in European countries, which have different environmental and socio-cultural characteristics than other parts of the world. Therefore, the papers in the second part of the original research, will present pedometer interventions in a European country, namely Belgium. Even though Belgium is not representative for the whole of Europe (as within this continent, there are different cultures, climates, environments), and not all East-Flemish study samples are representative for Belgium, it can be said -with some caution- that the present studies represent preliminary pilots for Europe. Specially since no earlier pedometer-based studies have been implemented in Europe and since this continent clearly differs from the United States and Australia.

Previous international pedometer-based interventions were implemented on different levels, resulting in mixed effects, sometimes based on research with a poor study design (see table 1). The studies in the present thesis were however controlled, and also implemented on the micro (individual)-, meso (workplace)-, and macro (community)-level.

As stated earlier, to be effective, interventions should focus on correlates or determinants that influence physical activity. Most consistent modifiable factors are self-efficacy, stage of change, social support, time constraints, and access to facilities (Sherwood and Jeffrey, 2000).

Studies have already shown that through self-monitoring, goal-setting and feedback from pedometer use, self-efficacy and stage of change can positively evolve (Rooney et al, 2003; Rooney et al, 2005; Clarke et al, 2007; Dinger et al, 2007). Furthermore, the concept of pedometer use and step count goal-setting is flexible and not time-consuming. Consequently, these principles will be used in the different interventions. Furthermore, the intervention at the meso- and macro-level will use a social ecological approach to facilitate more social support and environmental changes.

Chapter 2.2.1 describes the effects of a pedometer-based physical activity intervention at the *micro-level*. In this study, physical activity was promoted through pedometer use in combination with cognitive and behavioural support materials. This study aimed to demonstrate that the combination of pedometer use with support materials has a positive effect on physical activity and attitudes towards pedometer use. Furthermore, this study investigated how familiar a Flemish sample was with pedometers and the '10,000 steps/day' guideline.

In chapter 2.2.2, an intervention at the *meso-level* is described. The aim of the study was to evaluate a 20-week pedometer-based intervention in a workplace, including educational approaches (emails), program feedback (pedometer use, email), motivational aspects (email tips), environmental approaches (staircase use promotion, walking circuit), and components of the Social Cognitive Theory such as self-monitoring (pedometer use), goal setting (10,000 steps/day), and social support (worksite step competition).

Another intervention, based on social ecological models (McLeroy et al, 1988; Stokols, 1992; Gregson et al, 2001), was implemented at the *macro-level*. Chapter 2.2.3 presents the effects of the community intervention "*10,000 Steps Ghent*" on physical activity levels, while the effects on sitting time are evaluated in chapter 2.2.4. A final study (chapter 2.2.5) aimed to examine which individual characteristics and intervention exposure variables of intervention participants in Ghent were associated with (1) pedometer use, and (2) increased step counts. The third aim of that final study was to evaluate the mediational effect of pedometer use on step count change.

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PART 2: ORIGINAL RESEARCH

PART 2 ORGINAL RESEARCH

2.1 PEDOMETER-RELATED METHODOLOGICAL RESEARCH

CHAPTER 2.1.1

VALIDITY OF THE INEXPENSIVE 'STEPPING METER' IN COUNTING STEPS IN FREE LIVING CONDITIONS: A PILOT STUDY

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British Journal of Sports Medicine 2006, 40(8): 714-716

SHORT REPORT

Validity of the inexpensive Stepping Meter in counting steps in free living conditions: a pilot study

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Objectives: To evaluate if inexpensive Stepping Meters are valid in counting steps in adults in free living conditions.

Methods: For six days, 35 healthy volunteers wore a criterion Yamax Digiwalker and five Stepping Meters every day until all 973 pedometers had been tested. Steps were recorded daily, and the differences between counts from the Digiwalker and the Stepping Meter were expressed as a percentage of the valid value of the Digiwalker step counts. The criterion used to determine if a Stepping Meter was valid was a maximum deviation of 10% from the Digiwalker step counts.

Results: A total of 252 (25.9%) Stepping Meters met the criterion, whereas 74.1% made an overestimation or underestimation of more than 10%. In more than one third (36.6%) of the invalid Stepping Meters, the deviation was greater than 50%. Most (64.8%) of the invalid pedometers overestimated the actual steps taken.

Conclusions: Inexpensive Stepping Meters cannot be used in community interventions as they will give participants the wrong message.

With the continued publicity of the "10 000 steps/day" recommendation, pedometers have become very popular. They are used as a monitoring and motivational tool in the promotion of physical activity, and the "10 000 steps" concept has previously been shown to be effective in increasing lifestyle physical activity.[1 2]

The Department of Movement and Sports Sciences of Ghent University was preparing a large community based physical activity intervention based on, and in cooperation with, "10 000 steps Rockhampton".[3] The Yamax Digiwalker, used in 10 000 steps Rockhampton, was not on the market in Belgium, and, as this type of pedometer is relatively expensive, less expensive alternatives were explored. In Belgium, pedometers gained popularity very recently, and there are some inexpensive models on the market—for example, the Stepping Meter (€1 or $1.2 each) distributed by Blokker Belgium. It was thought that the 10 000 steps/day campaign in Ghent would be strengthened if these inexpensive pedometers were widely accessible or possibly handed out free. However, before use, their validity needed evaluation. Considering the health related purpose of the pedometer—that is, measurement of needed physical activity—validation was considered essential. Several step counters have been tested for validity and reliability, and it was found that there is considerable variation in accuracy between different brands and types.[4–8] Therefore the purpose of this pilot study was to evaluate if the inexpensive Stepping Meter is valid in counting steps in adults in free living conditions.

METHODS

Participants and instruments

A convenience sample of 35 healthy adults (nine men, 26 women; 20–60 years of age) volunteered to participate. The body mass index of the total sample was 19.9–26.6 kg/m^2. The Stepping Meter (fig 1) has a display and reset button on the front and a clip on the back. The validity of this inexpensive pedometer was tested against the Yamax Digiwalker SW-200, one of the best pedometers with regard to accuracy and reliability for counting steps.[5–8]

Procedures and data analysis

At the start of the study, volunteers were given 30 Stepping Meters, one Yamax Digiwalker, a step count log, and information on correct pedometer use—that is, to be worn on belt or waist band and reset only in the morning. Participants were asked to wear the Yamax Digiwalker and five other Stepping Meters every day. Three pedometers were randomly worn on the right of the front of the body and three on the left. Every evening, the volunteers recorded the number of steps registered on the six pedometers for that day. This procedure was repeated for six days until all the Stepping Meters had been tested. When subjects returned the pedometers and step count log, they were asked if they had any remarks about the pedometer use.

After data collection, the researchers calculated the differences in step counts from the Yamax Digiwalker and the Stepping Meter and expressed them as deviations (%) from the counts from the Digiwalker. The criterion for validity was a maximum deviation of 10%.[8] A positive deviation reflects an overestimation, and a negative deviation an underestimation.

RESULTS

Because of damage to the display, reset button, or clip before first use, 26 of the 1000 Stepping Meters purchased could not be tested. Figure 2 shows that 25.9% of the Stepping Meters met the criterion of a maximum deviation of 10% from the Yamax Digiwalker counts, whereas 74.1% (721) appeared to give invalid information. About 65% (467) overestimated the step count (mean (SD) overestimation 48.9 (70.5)%; maximum overestimation 1034%). The other 254 pedometers (35.2%) underestimated the step count (mean (SD) underestimation −56.1 (34.18)%; maximum underestimation −100%). In more than one third (36.6%) of the invalid Stepping Meters, the deviation was 50% or more. The magnitude of error, expressed as absolute percentage error (regardless of direction), was 51.4 (60.4)%.

Participants noticed that the Stepping Meter also registered non-stepping movements such as sitting on a chair, twisting the hip, bending over, and kneeling. Furthermore, some participants complained that the Stepping Meter could be unintentionally reset during the day by accidentally pushing the reset button.

Figure 1 The Stepping Meter.

DISCUSSION

The results of this pilot study illustrate that the inexpensive Stepping Meters provide incorrect information on step counts, which makes them inappropriate for physical activity promotion targets. Only a quarter of the Stepping Meters tested met the criterion of 10% maximum deviation, whereas the other 75% over-counted or under-counted the steps and made a mean absolute error of at least 51.4%. The large range of deviation without any consistency is problematic, as pedometers are used as a device to monitor physical activity. For example, an error of 20% in a 10 000 step day is 2000 steps, so either 8000 or 12 000 steps/day are recorded, which significantly changes the activity level of the user. If the results showed a consistent direction of error—that is, overestimation or underestimation—an adjustment of the recommendation would be sufficient to solve the validity problem. However, the findings show random underestimation.

The choice of a criterion of 10% may be one reason why only 25% of the pedometers tested were valid. However, this criterion was proposed in earlier studies in which different models of pedometers were compared in free living conditions.[5 8] The positioning of the Stepping Meter can also be questioned. In this study, six pedometers had to be worn at one time, so only two could be worn right above the knee. However, there is no variation in accuracy for different placements of the Yamax Digiwalker.[5 7] Finally, any concerns about pedometer inaccuracy in obese people are not relevant because none of the volunteers in this study were obese. Consequently, there must be other explanations for the large differences in step counts.

Most of the Stepping Meters over-counted the steps. As in previous studies,[5 7 8] assumptions can be made that the sensitivity of the internal mechanism is the main cause of inaccuracy. The threshold needed to trigger a step may be too sensitive and also receptive to non-stepping movements. This overestimation of steps is not consistent, however, as about one third of the Stepping Meters under-counted the steps. An explanation of the underestimations may be inadvertent use of the unprotected reset button of the Stepping Meter. In contrast, the Yamax Digiwalker has a cover to prevent accidental resetting.

Because of the validity problem, the Stepping Meters will not be used for the 10 000 steps/day campaign in Ghent. A pedometer that overestimates the actual steps would incorrectly indicate a healthy lifestyle when 10 000 steps/day are achieved. Using a pedometer that is inaccurate may lead to frustration and potentially low compliance. One may argue that the low validity is not a problem when only the baseline activity level is used. An increase of 2000 steps/day is also protective against chronic diseases.[9] However, it is not known whether the Stepping Meters are reliable or not. Another type of inexpensive pedometer, McDonald's Stepometer, was previously found to be inaccurate and also inconsistent in step counting.[10] Furthermore, accurate judgment of the baseline steps and a correct comparison with international classifications[11] would be impossible.

The wide accessibility of pedometers needs encouragement, but, because of validity problems, the use of an untested inexpensive pedometer is not recommended. The introduction of a quality label given to all valid, accurate, and reliable pedometer types and brands would be useful for researchers and individual users.

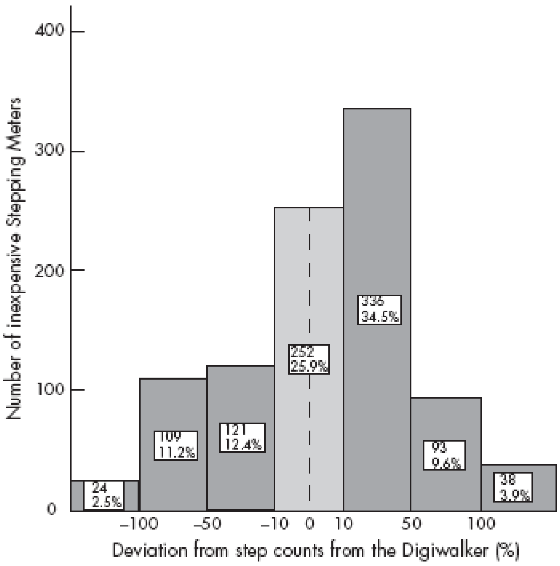

Figure 2 Percentage deviation of step counts of the Stepping Meters from the Yamax Digiwalker SW-200 step counts.

What is already known on this topic

- Pedometers have become very popular as a monitoring and motivational tool in the promotion of physical activity in adults
- Several pedometers have been tested for validity and reliability and there is considerable variation in accuracy between different types and brands of step counters

What this study adds

- The validity of a large number of inexpensive pedometers in counting steps in adults was evaluated in free living conditions
- The use of inexpensive pedometers should not be recommended because of considerable validity problems, which may damage any investment in good quality pedometers for physical activity health promotion

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CHAPTER 2.1.2

WHAT DO STEP COUNTS REPRESENT? A COMPARISON BETWEEN PEDOMETER DATA AND DATA FROM FOUR DIFFERENT QUESTIONNAIRES

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What do pedometer counts represent? A comparison between pedometer data and data from four different questionnaires

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Abstract

Objectives: To compare physical activity (PA) reported through pedometer registrations (step counts) with PA reported in four different questionnaires; to compare step count thresholds (7500, 10000 and 12500 steps/d) with the PA guideline of 30 min of moderate to vigorous PA (MVPA) per day.
Subjects: A sample of 310 healthy adults, mean age 38·7 (SD 11·9) years, volunteered to participate. Forty-seven per cent was male and 93 % of the sample was employed.
Methods: PA was assessed by interview (Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ)), three self-administered questionnaires (long version and short version of the International Physical Activity Questionnaire (long-form IPAQ, short-form IPAQ), Baecke questionnaire) and seven consecutive days of pedometer registration.
Results: Step counts correlated positively with questionnaire-based PA. The strongest correlations were found between step counts and total PA reported in the long-form IPAQ ($r_s = 0{\cdot}37$), moderate PA reported in the short-form IPAQ ($r_s = 0{\cdot}33$), total and moderate PA reported in the MLTPAQ ($r_s = 0{\cdot}32$), and the total and leisure-time PA indices (excluding sport) reported in the Baecke questionnaire ($r_s = 0{\cdot}44$). According to step counts, 22·6 % of the participants were somewhat active, 18·7 % active and 39·4 % highly active. As assessed by the long-form IPAQ, short-form IPAQ and MLTPAQ, the guideline of 30 min MVPA/d was reached by respectively 85·4 %, 84·8 % and 68·0 % of participants.
Conclusion: Pedometer-based data offer adequate information to discriminate between levels of PA. Caution is needed when comparing active samples based on different PA recommendations.

Keywords
Step counter
Survey
Health guidelines
IPAQ

The amount of usual physical activity (PA) accumulated by an individual is strongly related with all-cause morbidity and mortality risk[1]. Healthy adults should accumulate 30 min or more of moderate-intensity aerobic PA on 5 d each week or a minimum of 20 min of vigorous-intensity aerobic activity on 3 d each week[2]. The use of step count recommendations as useful behavioural PA targets has been suggested in the past[3,4]. These step count thresholds are more practical than the 30 min MVPA/d guideline since they do not imply constant time tracking and summing of at least moderate-intensity activity during the day, which is impractical for PA assessment on individual and population levels. Additionally, more detailed pedometer-based indices for public health (sedentary: <5000 steps/d; low active: 5000–7499 steps/d; somewhat active: 7500–9999 steps/d; active: 10000–12499 steps/d; highly active: ≥12500 steps/d) have been introduced by Tudor-Locke and Bassett[5].

Being able to accurately quantify the amount of PA accrued during daily life is necessary for researchers and health professionals to better understand PA behaviour and to develop successful programmes to increase activity levels in various populations. Traditionally, PA has been measured through questionnaires, the strengths and limitations of which are well known[6]. Recognized benefits are the possibility to assess different dimensions of PA, the ability to collect data from a large number of people at low cost, and the unobtrusiveness of the instrument[7]. However, there are limitations in subjects' recall ability and social desirability bias can cause over-reporting of PA[7]. Recently, more attention has been given to objective instruments to assess PA, e.g. accelerometers and pedometers. Pedometers have been shown to provide a valid and accurate measure of ambulatory activities in free-living conditions[8,9]. They are simple to use, more objective than surveys, and less expensive (approximately $US 20–50) compared with accelerometers (approximately $US 150–500). Despite their limitations such as variability between different brands, insensitivity to non-ambulatory activities (i.e. cycling, swimming) and increased errors at slow walking speeds (<60 m/min)[8], pedometers have become popular devices for public use and for researchers. Moreover, step counts have proved to be useful in PA studies in free-living populations[8]. However, the question remains of which exactly dimensions of PA are measured by pedometers. Several researchers[8,10] report that pedometer step counts are an appropriate measurement of the distance walked, while others believe that pedometers also enable the quantification of ambulatory behaviour during occupational, leisure-time, household and transportation activity[11,12]. In addition, one could wonder if step counts are simply a measure for walking or if they can also be associated with self-reports of PA that encompass intensity (other moderate and vigorous PA, besides walking). Therefore, the first purpose of the present study was to compare pedometer data with data from questionnaires, the most commonly used[7] and practical method for PA assessment in large-scale studies[13]. The objective was to evaluate the associations between step counts and PA (walking, moderate PA, vigorous PA) reported in four different validated questionnaires: the interviewer-administered Minnesota Leisure Time Physical Activity Questionnaire[14] (MLTPAQ), the self-administered long version and self-administered short version of the International Physical Activity Questionnaire[15] (long-form IPAQ, short-form IPAQ), and the self-administered Baecke Questionnaire[16]. Additionally, questionnaire-based PA was compared between the five 'step count groups' based on the pedometer health indices of Tudor-Locke and Bassett[5].

A third objective of the present study was to compare step count thresholds (7500, 10 000 and 12 500 steps/d) with the guideline of 30 min of moderate to vigorous PA (MVPA) per day. Wilde *et al.*[17] found that sedentary women who added a 30 min walk to their daily habits accumulated approximately 10 000 steps. Another study[18] also revealed that on days when women took a 30 min walk, their average step count was close to 10 000. Other researchers[19] found that women who took 10 000 steps/d were more likely to meet the current MVPA guideline, compared with those not accumulating as many steps. Miller and Brown[20] found only a moderate level of agreement between meeting 10 000 steps/d and 150 min or more of PA over five or more sessions per week. However, no research could be located in either gender or in a European sample assessing whether step count thresholds are corresponding to the 30 min MVPA/d guideline. Therefore, the present study explored whether adults reaching 7500, 10 000 and 12 500 steps/d also reached 30 min MVPA/d, based on self-reports.

Methods

Participants and procedures

A convenience sample of 310 volunteers (146 men) living in Flanders, Belgium participated in the present study. Participant characteristics are shown in Table 1. No gender differences were found for the proportions of employed participants, mean ages and average daily step counts.

All participants were visited at home by research assistants for the completion of the MLTPAQ. After this interview, participants were asked to complete the self-administered long-form IPAQ, the self-administered short-form IPAQ and the Baecke questionnaire. Then, participants were asked to register pedometer-based step counts for seven consecutive days. They were instructed to wear the pedometer on their waistband or belt during waking hours. All participants were asked to carry on their usual activities, to remove the pedometer only while swimming, bathing or showering, and to complete an activity log at the end of each day. All participants provided written informed consent and the study was approved by the Ethical Committee of Ghent University. Research assistants (masters-level graduates, native speakers) were given 2 h of training and interview practice.

Instruments

Pedometers

The Yamax Digiwalker SW-200 (Yamax, Tokyo, Japan) was used in the present study as it is known to be a valid, reliable and accurate instrument for counting steps in adult populations[21].

Table 1 Characteristics of the study participants: healthy adult volunteers, Flanders, Belgium

	Total group		Male		Female		
	n	%	*n*	%	*n*	%	Gender comparison
Gender	310	100·0	146	47·1	164	52·9	$\chi^2 = 1{\cdot}05^{NS}$
Employed	288	92·9	139	95·2	149	90·9	$\chi^2 = 0{\cdot}35^{NS}$
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	38·7	11·9	39·1	12·5	38·3	11·4	$t = 0{\cdot}56^{NS}$
Daily step counts	12 087	4888	12 452	4983	11 762	4792	$t = 1{\cdot}24^{NS}$

NS, $P > 0{\cdot}05$.

Activity log

Based on procedures of Tudor-Locke *et al.*[22], participants were asked to keep daily activity records in an activity log during the seven consecutive days of pedometer registration. They were requested to record the date, the number of steps recorded at the end of the day, and the type and duration of non-ambulatory activities (e.g. 20 min of biking/swimming). Following established guidelines[23,24], 150 steps were added to the daily total for every minute of reported biking and/or swimming. The average daily step count was 9981 (SD 3455) without adding the equivalent for biking/swimming and 12 087 (SD 4888) with the added steps for biking/swimming. Of the total sample, 152 people (49·0%) reported biking/swimming during the week of pedometer registration (mean: 7·6 (SD 15·1) min/d).

MLTPAQ

A structured interview was used to solicit detailed information on leisure-time PA over a 1-year period. A Dutch version of the validated MLTPAQ, developed for the Belgian Physical Fitness Study, was used[6,14,25]. Participants' engagement in different activities was queried, together with the number of months per year, the monthly frequency and the duration of the activity. Activities were classified as walking (structured walking for transport or in leisure time), moderate-intensity PA (MPA) or vigorous-intensity PA (VPA), based on their energy requirements (MPA: 3–6 MET; VPA: >6 MET; MET = metabolic energy equivalent task)[26].

Long-form IPAQ

The self-administered long-form IPAQ was used to assess PA at work, transport-related PA, domestic and gardening activities, and PA during leisure time in a usual week. Total times engaged in walking, MPA and VPA, all expressed in min/week, were computed according to the guidelines (www.ipaq.ki.se). The IPAQ has been shown to be a valid and reliable instrument for measuring PA in Europe[15] and in Flanders, Belgium[27].

Short-form IPAQ

PA was assessed using the self-administered short-form IPAQ, which provides information on the time spent walking, in MPA and in VPA (min/week) in a usual week. This version of the IPAQ has been found to be valid and reliable[15].

Baecke questionnaire

In the Baecke questionnaire[16], responses were scored on a five-point scale and resulted in three different indices reflecting PA during work (work index), PA during leisure time excluding sport (LT index) and PA during sport activities (sport index). The summation of the three indices was defined as the overall PA index (total PA index). Good validity of the Baecke questionnaire for the assessment of PA was found in the past[28,29].

Data analysis

Analyses were carried out using the SPSS for Windows statistical software package version 12·0 (SPSS Inc., Chicago, IL, USA). Average daily steps were calculated and values above 20 000 steps/d were recorded as 20 000 steps/d to limit unrealistically high average step counts[30]. Because of the non-normal distributions in PA data, Spearman correlation coefficients (r_s) were calculated to assess the relationship between step counts and questionnaire-based PA. The same technique was used to assess the correlations between PA data derived from the different questionnaires. Correlations were interpreted as low (<0·30), moderate (0·30–0·50) or high (>0·50). Differences in questionnaire-based PA between the five step count groups based on the pedometer indices[5] were evaluated with multivariate ANOVA. First, the skewed questionnaire outcomes were log-transformed to approximate normal distributions. Parametric analyses were performed on the log-transformed data and adjusted for age, gender and employment status. F values, P values and partial η^2, as a measure of the effect size, are reported. For reasons of clarity and comparability, the means and standard deviations of the non-transformed data are used in Table 3. Finally, cross-tabulations of the number of participants (not) reaching the step count thresholds of 7500, 10 000 and 12 500 steps/d and/or the guideline of 30 min MVPA/d were performed, and the percentages of agreement between the different PA recommendations were calculated based on the cross-tabulations. A P value $\leq$0·05 was considered as statistically significant.

Results

The correlations between step counts and questionnaire-based PA are shown in Table 2. Step counts correlated moderately with total PA ($r_s = 0{\cdot}37$) and MPA ($r_s = 0.31$), and lowly with walking ($r_s = 0{\cdot}19$) and VPA ($r_s = 0{\cdot}25$), reported in the long-form IPAQ. Low correlations were found between step counts and total PA ($r_s = 0{\cdot}28$), walking ($r_s = 0{\cdot}15$) and VPA ($r_s = 0{\cdot}20$) reported in the short-form IPAQ, except for MPA ($r_s = 0{\cdot}33$). A low correlation was found between step counts and walking ($r_s = 0{\cdot}10$) and VPA ($r_s = 0{\cdot}16$) reported in the MLTPAQ; total PA ($r_s = 0{\cdot}32$) and MPA ($r_s = 0{\cdot}32$) reported in the MLTPAQ correlated moderately with step counts. Finally, step counts correlated moderately with the total PA index ($r_s = 0{\cdot}44$), LT index ($r_s = 0{\cdot}44$) and sport index ($r_s = 0{\cdot}31$) of the Baecke questionnaire, except for the work index ($r_s = 0{\cdot}19$). Correlations between PA reported in the different questionnaires are also presented in Table 2.

Table 3 shows the mean (SD) amounts of questionnaire-based PA (min/week) for the different step count groups divided according to the pedometer indices of Tudor-Locke and Bassett[5]. Significant differences between the

Table 2 Correlation matrix: Spearman correlation coefficient (95 % CI)

		Step counts	Short-form IPAQ Total PA†	Short-form IPAQ Walking†	Short-form IPAQ MPA†	Short-form IPAQ VPA†	MLTPAQ Total PA†	MLTPAQ Walking†	MLTPAQ MPA†	MLTPAQ VPA†	Baecke Q Total PA index
Long-form IPAQ	Total PA†	0·37 (0·27–0·46)	0·73 (0·67–0·78)				0·36 (0·26–0·45)				0.30 (0.20–0.40)
	Walking†	0·19 (0·08–0·30)		0·68 (0·62–0·74)				0·24 (0·13–0·34)			
	MPA†	0·31 (0·21–0·41)			0·56 (0·78–0·63)				0·40 (0·30–0·49)		
	VPA†	0·25 (0·14–0·35)				0·78 (0·73–0·82)				0·41 (0·31–0·50)	
Short-form IPAQ	Total PA†	0·28 (0·17–0·38)					0·31 (0·21–0·41)				0·31 (0·21–0·41)
	Walking†	0·15 (0·04–0·26)						0·20 (0·10–0·31)			
	MPA†	0·33 (0·23–0·43)							0·41 (0·31–0·50)		
	VPA†	0·20 (0·09–0·31)								0·40 (0·30–0·50)	
MLTPAQ	Total PA†	0·32 (0·22–0·42)									0·40 (0·30–0·49)
	Walking†	0·10 (−0·01–0·21)									
	MPA†	0·32 (0·22–0·42)									
	VPA†	0·16 (0·05–0·27)									
Baecke Q	Total PA index	0·44 (0·35–0·53)									
	Work index	0·19 (0·08–0·30)									
	LT index	0·44 (0·35–0·53)									
	Sport index	0·31 (0·20–0·41)									

IPAQ, International Physical Activity Questionnaire (short-form, short version of the questionnaire; long-form, long version of the questionnaire); MLTPAQ, Minnesota Leisure Time Physical Activity Questionnaire; PA, physical activity; MPA, moderate physical activity; VPA, vigorous physical activity LT, leisure time.
†In min.

five step count groups were found for total PA, MPA and VPA reported in the long-form IPAQ, short-form IPAQ and MLTPAQ. For walking, only data based on the short-form IPAQ differed significantly between the step count groups. The work, leisure-time, sport and total PA indices of the Baecke questionnaire differed significantly between the five step count groups.

In total, 80·6 % of participants reached 7500 steps/d, 45·0 % reached 10 000 steps/d and 39·4 % reached 12 500 steps/d, whereas 30 min MVPA/d was reached by 85·4 % according to the long-form IPAQ, 84·8 % according to the short-form IPAQ and 68·1 % according to the MLTPAQ (Fig. 1).

Using the long-form IPAQ, the step count thresholds of 7500, 10 000 and 12 500 steps/d and the 30 min MVPA/d recommendation were in agreement in respectively 77·7 %, 54·4% and 48·7% of the participants (see Table 4). Based on the short-form IPAQ, respectively 76·5%, 51·8 % and 48·1 % of participants were well placed. Using the MLTPAQ, the recommendations were in agreement in respectively 71·9%, 53·1 % and 51·9 % of the participants. Some 89·2 % of the participants reaching 7500 steps/d, 94·2 % of those reaching 10 000 steps/d and 93·4 % of those reaching 12 500 steps/d reached 30 min MVPA/d, according to the long-form IPAQ. With the short-form IPAQ these figures were respectively 88·0 %, 90·6 % and 91·8 %. Of the participants, 74·8 % reaching 7500 steps/d, 73·4 % reaching 10 000 steps/d and 75·4 % reaching 12 500 steps/d reached 30 min MVPA/d based on the MLTPAQ.

Discussion

The first aim of the present study was to evaluate the associations between step counts and questionnaire-based PA. Objectively measured step counts correlated positively with the subjectively reported PA levels. Significant, positive associations between step counts and questionnaire-based PA were also found in previous studies[9,31] conducted in the USA, where walking is one of the most commonly reported forms of PA[32]. A median correlation of $r = 0·33$ (range: 0·02–0·94) was found between step counts and self-reported PA in a review of mostly non-European studies[33]. Surprisingly, in the present study, a low correlation was found between step counts and walking reported in the long-form IPAQ, short-form IPAQ and MLTPAQ. An explanation for this remarkable finding could be the lack of sensitivity of questionnaires[34] to detect walking, resulting in under-reporting of walking behaviour. Bassett *et al.*[35] also found that subjects underestimated their daily walking distance in the College Alumnus Questionnaire, compared with pedometer-based values. Furthermore, different types of walking were assessed through the various questionnaires. The long-form IPAQ asked about the combination of walking in various domains (i.e. work, transport,

Table 3 Differences in questionnaire-based physical activity (PA) across step count groups: healthy adult volunteers, Flanders, Belgium

	Pedometer index												
	Sedentary		Low active		Somewhat active		Active		Highly active				
Step count range	<5000		5000–7499		7500–9999		10 000–12 499		≥12 500				
Participants	*n* 12		*n* 55		*n* 84		*n* 61		*n* 64				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*F* (*P*)	*Post hoc* analyses†	η^2
Total PA (min/week)													
Long-form IPAQ	462	405	722	676	1069	820	1329	804	1542	904	12·4***	a, h	0·14
Short-form IPAQ	243	268	838	927	772	733	1286	1080	1458	1113	7·4***	c, h	0·09
MLTPAQ	199	194	347	309	416	279	524	430	485	326	8·2***	c, e, f, g, h	0·10
Walking (min/week)													
Long-form IPAQ	81	52	247	361	317	392	450	459	432	485	1·8^{NS}		0·02
Short-form IPAQ	58	63	558	702	424	538	754	753	634	702	5·4***	c, e, g, h	0·07
MLTPAQ	103	116	76	73	106	116	110	131	108	121	1·2^{NS}		0·02
MPA (min/week)													
Long-form IPAQ	303	331	334	371	525	441	611	434	733	476	7·8***	a, b, c, h	0·10
Short-form IPAQ	82	116	147	294	210	290	349	539	545	620	6·8***	a, b, c, d, h	0·08
MLTPAQ	104	107	255	298	292	238	373	371	336	253	7·4***	c, f, g, h	0·05
VPA (min/week)													
Long-form IPAQ	55	178	129	194	155	258	215	302	263	352	4·6***	c, d, f, h	0·06
Short-form IPAQ	47	144	113	188	135	243	172	272	206	257	2·7*	a, c, d, f, h	0·04
MLTPAQ	3	10	17	31	27	67	37	65	46	80	4·2**	a, c, d, h	0·05
Baecke questionnaire													
Work index	1·8	0·5	1·8	0·6	2·0	0·6	2·2	0·7	2·3	0·6	6·9***	a, b, f, h	0·09
LT index	1·9	0·6	2·3	0·5	2·5	0·6	2·6	0·6	2·6	0·7	6·3***	f, g, h	0·09
Sport index	1·4	1·2	1·9	1·3	1·9	1·2	2·2	1·2	2·5	2·1	3·2*	a, b, c, d, f, h	0·05
Total PA index	5·1	1·9	6·0	1·5	6·4	1·4	7·0	1·5	7·4	1·5	10·4***	a, c, h	0·13

IPAQ, International Physical Activity Questionnaire (long-form, long version of the questionnaire; short-form, short version of the questionnaire); MLTPAQ, Minnesota Leisure Time Physical Activity Questionnaire; MPA, moderate physical activity; VPA, vigorous physical activity.
Significance of differences between the five groups: **P*≤0·05, ***P*≤0·01, ****P*≤0·001 (NS, *P*>0·05).
†Some *post hoc* pairwise comparisons were not significantly different: a, sedentary–low active NS; b, sedentary–somewhat active NS; c, low active–somewhat active NS; d, low active–active NS; e, low active–highly active NS; f, somewhat active–active NS; g, somewhat active–highly active NS; h, active–highly active NS.

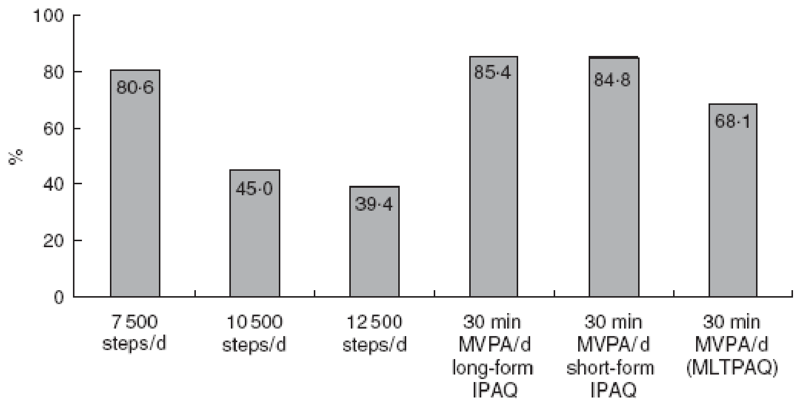

Fig. 1 Percentage of participants reaching the step count of 7500 steps/d, 10 000 steps/d and 12 500 steps/d, and the standard of 30 min of moderate to vigorous physical activity (MVPA) per day, as assessed by three different questionnaires: the long version and short version of the International Physical Activity Questionnaire (long-form IPAQ, short-form IPAQ) and the Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ)

home, leisure time) while the MLTPAQ assessed leisure/pleasure walking and walking to work only. The pedometer measured all ambulatory activity throughout the day.

Furthermore, differences in questionnaire-based PA between groups based on the pedometer indices of Tudor-Locke and Bassett[5] were evaluated. Results showed that the classification of activity levels based on step counts also highlighted differences in self-reported levels of PA (low to medium effect sizes). The more active participants were, based on step counts, the higher the levels of total, MPA and VPA reported in the long-form IPAQ, short-form IPAQ and MLTPAQ. The application of

Table 4 Number of participants reaching both, one or neither of two types of physical activity recommendations: 7500 steps/d, 10 000 steps/d, 12 500 steps/d and the 30 min of moderate to vigorous physical activity (MVPA) per day standard, as assessed by three different questionnaires

	7500 steps	
30 min MVPA/d based on…	Not reached	Reached
Long-form IPAQ		
Not reached	18	27
Reached	42	223
Short-form IPAQ		
Not reached	17	30
Reached	43	220
MLTPAQ		
Not reached	36	63
Reached	24	187
	10 000 steps	
	Not reached	Reached
Long-form IPAQ		
Not reached	37	8
Reached	133	131
Short-form IPAQ		
Not reached	34	13
Reached	136	126
MLTPAQ		
Not reached	62	37
Reached	108	102
	12 500 steps	
	Not reached	Reached
Long-form IPAQ		
Not reached	37	8
Reached	151	114
Short-form IPAQ		
Not reached	37	10
Reached	151	112
MLTPAQ		
Not reached	69	30
Reached	119	92

IPAQ, International Physical Activity Questionnaire (long-form, long version of the questionnaire; short-form, short version of the questionnaire); MLTPAQ, Minnesota Leisure Time Physical Activity Questionnaire.

these findings is that individuals who engaged more in MPA and VPA accumulated more steps per day. Again, unexpectedly, this was not the case for walking reported in the long-form IPAQ and MLTPAQ. Only walking in the short-form IPAQ differed significantly between step count groups. All indices (work, leisure-time, sport and total PA) based on the Baecke questionnaire also increased gradually when step counts augmented. Concluding, step counts are capable of discriminating between total, MPA and VPA reported in the different questionnaires.

A third objective of the present study was to compare currently used PA guidelines, to show differences in the percentages of participants reaching the step count thresholds. Of the participants, 80·6 % reached 7500 steps/d, 45·0 % reached 10000 steps/d and 39·4 % reached 12 500 steps/d. The guideline of 30 min MVPA/d, on the other hand, was reached by 85·4 % according to the long-form IPAQ, followed by 84·8 % according to the short-form IPAQ and by 68·1 % according to the MLTPAQ. There are various possible explanations for this discrepancy. It is known that over-reporting of PA may occur when using self-reported questionnaires, including the IPAQ[7]. The lower percentage according to the MLTPAQ could be explained by the 1-year time frame of the questionnaire, which could cause recall biases. Also the fact that the MLTPAQ was interviewer-administered may have had an influence: research assistants were trained to detect over-reporting of PA[6].

The current study also explored whether reaching different step count thresholds was sufficient to reach 30 min MVPA/d. When participants reached 7500 steps/d, the MVPA recommendation was reached in 89·2 % (by long-form IPAQ; 88·0 % by short-form IPAQ). Of participants, 94·2 % (by long-form IPAQ; 90·6 % by short-form IPAQ) of those reaching 10 000 steps/d reached 30 min MVPA/d. Participants reaching 12 500 steps/d reached 30 min MVPA/d in 93·4 % (by long-form IPAQ; 91·8 % by short-form IPAQ) of cases. All figures based on the MLTPAQ were lower (respectively 74·8 %, 73·4 % and 75·4 %). However, these results indicated that step count thresholds are stringent enough. Le Masurier *et al.*[19] found that 91 % of women reaching the 10 000 steps/d standard accumulated more than 30 min MVPA/d based on accelerometer data. In the present study, it was easier for participants reaching the step count thresholds to reach 30 min MVPA/d, rather than the other way around. No more than half of the participants (respectively 49·6 %, 48·1 % and 48·6 % based on the long-form IPAQ, short-form IPAQ and MLTPAQ) reaching 30 min MVPA/d reached 10 000 steps/d, for example. Welk *et al.*[9] reported that participants who performed more than 30 min of PA daily reached at least 10 000 steps/d some 73 % of the time. Tudor-Locke *et al.*[36] found that approximately 3000 steps are expected in 30 min of moderate-intensity ambulatory activity.

The present average step count level (12 100 steps/d) is clearly higher than that of a representative sample of Belgian adults (9700 steps/d)[23]. A possible explanation could be the fact that the present study population is a convenience sample of mostly working volunteers, implying cautious interpretations and limited generalizability of the results.

The present results reflect that caution is needed when assessing PA standards, especially when using different methods. It is remarkable that despite moderate correlations between step counts and questionnaire-based PA, the percentages reaching the standards differ notably. The subjective nature of questionnaires, possibly causing over-reporting, can be an explanation of the discrepancy. To avoid this problem, a gold standard, such as doubly labelled water or accelerometers, could be used to determine if the 30 min MVPA/d guideline is effectively reached.

In summary, there is a modest relationship between step counts and questionnaire-based PA in the present European sample. Objective pedometers not only provide a measurement of walking but also give an indication of total, MPA and VPA. Even though pedometers alone cannot discriminate between the intensity of activities nor reflect the amount of time spent in specific intensity PA categories, they provide sufficient information to be valuable in PA assessment in large, free-living populations. Less agreement was found between the currently used PA guidelines (30 min MVPA/d and step count thresholds), suggesting that caution is needed when comparing active quantities in different samples based on different methods.

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CHAPTER 2.1.3

PEDOMETER-DETERMINED PHYSICAL ACTIVITY AND ITS COMPARISON WITH THE INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE IN A SAMPLE OF BELGIAN ADULTS

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Pedometer-Determined Physical Activity and Its Comparison With the International Physical Activity Questionnaire in a Sample of Belgian Adults

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Pedometer-determined physical activity (PA) levels in Belgian adults were provided and compared to PA scores reported in the International Physical Activity Questionnaire (IPAQ). The representative sample (N = 1,239) of the Belgian population took on average 9,655 (4,526) steps/day. According to pedometer indices 58.4% were insufficiently active. Steps/day differed significantly between gender ($F = 5.0$, $p = .026$), age groups ($F = 3.3$, $p = .01$), employment status ($F = 6.2$, $p = .013$), and days of monitoring ($F = 7.4$, $p = .007$). Steps/day were negatively correlated to the time spent sitting and positively to PA at work, in transport, and in leisure time ($p < .001$). Steps data can discriminate between PA levels reported in the IPAQ. Belgian population pedometer-determined PA levels are higher than those reported in samples of the United States; however, there is a wide distribution of ambulatory behavior.

Key words: physical activity level, step counter, steps/day, survey

Physical inactivity is a major public health concern in modern society. Regular physical activity (PA) is needed to gain physiological and psychological health benefits and to reduce the risk for a number of adverse health outcomes including cardiovascular diseases, obesity, hypertension, diabetes mellitus, and all-cause mortality. International guidelines recommend that adults accumulate 30 min or more of moderate to vigorous PA on most, preferably all, days of the week (American College of Sports Medicine [ACSM], 2000; U.S. Department of Health and Human Services [USDHHS], 1996). To evaluate whether this recommendation is being reached, constant timing and summing of scattered bouts of activity during the day may be needed. This requires constant attention, which is impractical, to assess PA on the individual and population levels. Recently, an alternative guideline has been introduced, which is more practical than the 30 minutes/day recommendation and does not require constant tracking of at least moderate-intensity activity time during the day. This guideline recommends that accomplishing 10,000 steps/day improves health (Hatano, 1993, 1997; Wilde, Sidman, & Corbin, 2001). Consequently, with the continued promotion of the 10,000 steps/day recommendation, pedometers have become popular as a monitoring and motivational tool. Pedometers objectively assess ambulatory activities throughout the day in the form of step counts; several studies have shown that they provide a valid and accurate measure of activities in free-living conditions (Bassett et al., 1996; Welk et al., 2000). Moreover, pedometers are simple to use and, in comparison to accelerometers, are relatively inexpensive both in terms of cost per unit (pedometers: approximately US $20–50; accelerometers: approximately US $150–500) and data processing.

Even though pedometers have limitations such as variability between different brands and are insensitive to nonambulatory activities (i.e. cycling, swimming), pedometer-determined PA data are useful in PA studies in free-living populations (Bassett et al. 1996). The international comparison of population levels of PA can

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be less complex and the problem of incomparable data, due to different questionnaires in different languages and with different interpretations, is also resolved. Additionally, the recently introduced pedometer indices for public health by Tudor-Locke and Bassett (2004) offer a greater value to pedometer use and pedometer-based data. In the past, several studies have been conducted using a pedometer to collect PA data in specific groups of the population in free-living conditions (Bassett, Schneider, & Huntington, 2004; Chan, Spangler, Valcour, & Tudor-Locke, 2003;). However, information on population-based step counts is still sparse and has been collected only in a limited number of countries.

In 1989, Sequeira, Rickenbach, Wietlisbach, Tullen and Schutz (1995) showed that the pedometer was useful in a large, free-living population survey. In this Swiss population, the average number of steps/day differed between age groups: 11,900 for the 25–34-year-old men and 6,700 for the 65–74-year-old men, and 9,300 for the youngest women and 7,300 for the oldest women.

In the United States, Wyatt, Peters, Reed, Barry and Hill (2005) also used pedometers to collect information in a first ever statewide survey of walking. The data collected in 2002 revealed that the average adult in Colorado took about 6,800 steps/day. In 2001, Tudor-Locke, Ham et al. (2004) collected descriptive epidemiology data of pedometer-determined PA in adults in South Carolina. Participants wore a pedometer for seven consecutive days during winter and took on average about 6,000 steps/day. The latter two studies showed different step counts, which varied according to demographic characteristics. Men accumulated more steps/day than women, and white participants took more steps than non whites (Tudor-Locke, Ham et al., 2004). In both studies, steps/day declined with increasing age, and participants with a college degree, high income, and normal weight took more steps/day than participants with respectively a high school degree or less, low income, and obesity (Tudor-Locke, Ham et al., 2004; Wyatt et al., 2005).

According to Miller and Brown (2004), the average number of steps taken each day in a sample of working Australian adults was about 8,900. Workers in managerial and professional occupations reported lower weekday step counts (7,883) than technical (10,731) and blue collar (11,784) workers. Earlier, Brown, Ringuet, and Trost (2002) found that young mothers accumulated around 9,800 steps/day. The step level of the Western Australian adult population was 9,695 steps/day (McCormack, Milligan, Giles-Corti, & Clarkson, 2002).

In the literature, no recent pedometer-based data are available for European countries. Since Europe has different environmental characteristics (e.g. greater availability of bike lanes) and socioeconomic characteristics (e.g. governmental regulation of health care) than other parts of the world, pedometer-determined PA in Europe may also differ from pedometer-determined PA levels reported in other continents. Therefore, the first purpose of the present pilot study was to provide and evaluate pedometer-determined PA levels in a sample of Belgian adults. Comparisons in pedometer-determined PA were made between sexes, age groups, employment status, and days of monitoring.

Because pedometers are easy to use, more objective than surveys, and reasonably priced compared to accelerometers, they appear to be appropriate tools to assess worldwide PA levels. Sequeira et al. (1995) already proposed the use of pedometers as an objective index of PA. However, it remains unclear whether pedometer-determined PA data provide sufficient information to adequately describe differences in diverse domains of PA. For that reason, the second purpose was to compare pedometer-determined PA with reported work-, transport-, home-, and leisure time-related PA levels from the International Physical Activity Questionnaire (IPAQ).

Method

Procedures

A random sample of 5,000 names and addresses (1,000 names for each age group: 25–35 years old, 36–45 years old, 46–55 years old, 56–65 years old, and 66–75 years old) were obtained from the public record office. Of this sample, 3,340 telephone numbers were found and 2,751 persons were able to be reached by telephone within a maximum of four attempts. They were asked to complete the IPAQ long telephone version and to self-monitor pedometer-determined PA for 7 consecutive days. About 48% ($N = 1,322$) of them agreed to take part. One hundred four 66–75-year-old participants, who were not prepared to complete the pedometer protocol, completed only the IPAQ. To reach the participants without a telephone number and to increase the study sample, a written explanation of the study with the self-administered IPAQ long form was randomly sent to another 1,316 participants (386 letters went out to the 25–35-year-old age group; 263 letters were sent to the 36–45-year-olds; 232 to 46–55-year-olds; 248 to 56–65-year-olds; and 187 to 66–75-year-olds). The response rate to this written recruitment was 19.6% ($n = 258$). As a result a total of 1,684 participants completed the IPAQ form with 1,580 of this number consenting to wear the pedometer. Of this sample 1,239 participants completed the pedometer protocol.

Based on the methods of Tudor-Locke, Ham et al. (2004), a package was mailed to all participants who agreed to self-monitor pedometer-determined PA. The package included a pedometer, a written informed consent form, a protocol describing how and when to use the pedometer, an activity log to keep daily activity records, and a preaddressed and stamped envelope for return mailing. All participants were instructed to attach the pedometer to their waistband or belt during waking hours. They were asked to reset their pedometer to zero at the beginning of each day. Participants were asked to carry on their usual activities and to remove the pedometer only while bathing, showering, or swimming and to complete the activity log at the end of each day.

All participants gave their informed consent, and the study was approved by the Ethical Committee of Ghent University. Data collection took place between March and May 2005. Up to three attempts were made to contact participants who did not return the pedometer and/or the activity log after one month. Eventually 445 participants who did not complete the pedometer protocol were excluded from the present dataset.

Participants

In total, 1,239 25–75-year-old adults in Flanders, Belgium, completed the present pedometer study. Participants completed the IPAQ and self-monitored pedometer-determined PA for 7 consecutive days. The sample consisted of 604 men (age M = 49.2 years, SD = 13.7) and 635 women (age M = 48.1 years, SD = 13.5). The mean age of the total sample was 48.6 (SD = 13.6) years: 252 participants were 25–35 years old (SD = 20.3%), 269 were 36–45 years old (SD = 21.7%), 287 were 46–55 years old (SD = 23.1%), 248 were 56–65 years old (SD = 20%), and 183 were 66–75 years old (SD = 14.8%). This group finished school at the mean age of 19.5 (SD = 3.4) years (highest level of education: high school degree), and 19.4% had a low level of education (finished school at the maximum age of 16, having no high school degree). About 68% of all participants had a job, and 87% reported having a good-to-excellent state of health. All participants reported pedometer data on at least 3 days. Following recommendations by Tudor-Locke, Burkett et al. (2005), no participants were excluded from the dataset. Demographic variables such as gender, age, and level of education of the present sample were comparable to those of the overall Belgian adult population (respectively 51.2% women: χ^2 = 0.001, p = .973; 21.2% 25–35-year-olds, 24.5% 36–45-year-olds, 22.3% 46–55-year-olds, 17.3% 56–65-year-olds, and 14.8% 66–75-year-olds: χ^2 = 1.69, p = .997; 21.5% low level of education: χ^2 = 0.96, p = .327; see Scientific Institute of Public Health).

Comparisons were made between participants who provided step count information (N = 1,239) and those who did not complete the pedometer protocol (n = 445). Participants who had a job (odds ratio: 1.59, p = .002) were more likely to complete the pedometer protocol than unemployed participants. Analyses on gender, age, years of education, state of health, time spent sitting, and total amount of PA showed no significant differences.

Instruments

Pedometers. The pedometer used in the present study was the Yamax Digiwalker SW-200 (Yamax, Tokyo, Japan). According to the literature, the Yamax pedometer is accurate and reliable for counting steps (Crouter, Schneider, Karabulut & Bassett, 2003; Schneider, Crouter, Lukajic & Bassett, 2003).

Activity Log. Participants were requested to keep daily activity records for the seven consecutive days they wore the pedometer. They were asked to record the date, the day-end steps taken, and activities such as walking, soccer, fitness activities. The structure of the activity log was based on the activity log used by Tudor-Locke, Lind, Reis, Ainsworth, & Macera (2003). Next to the date and day-end steps taken, participants were asked to complete some closed-ended questions (yes or no), namely "Did you remove your pedometer during the day?" "Were you sick or injured?" "Did you participate in any sports or PA?" If the pedometer was removed, the reason and the amount of time of the removal were asked. Participants who engaged in any sports or physical activities were asked to record the type and duration of the exercise (e.g., 20 min spent walking). For each day, a maximum of three types of activities could be recorded. To impute the steps for biking and swimming, the number of minutes spent biking and swimming was asked. In line with the guidelines of *New Lifestyles*, after data collection, for every minute of biking and/or swimming, 150 steps counts were added to the day-end amount of the steps taken.

Questionnaire. The different domains of PA in a usual week (namely PA at work, transport-related PA, domestic and gardening activities, PA during leisure time, and the time spent sitting on a typical weekday and weekend day) were assessed with the IPAQ. The long-form telephone version and the self-administered version were both used. Both versions gave similar results, and the IPAQ was found to be a valid and reliable instrument to measure PA at population level in Europe (Craig et al., 2003) and in Flanders, Belgium (Vandelanotte, De Bourdeaudhuij, Sallis, Philippaerts, & Sjostrom, 2005). Based on the guidelines for data processing and analysis of the IPAQ (*Guidelines*, 2005), total scores for all walking, moderate and vigorous physical activities, and total scores for PA in the four domains, all expressed in minutes per week, were computed. The first question of the IPAQ asked about the employment status of participants (employed/unemployed). Two additional questions were added to the IPAQ to inquire about the number of years of education and the self-reported state of health (excellent/very good/good/moderate/poor).

Data Analysis

All analyses were conducted using SPSS 12.0 for Windows. Mean steps/day were evaluated for the whole sample and for groups defined by gender, age (25–35-year-olds, 36–45-year-olds, 46–55-year-olds, 56–65-year-olds, and 66–75-year-olds), employment status (employed vs. unemployed), and days of monitoring (weekday vs. weekend day) in a repeated measures ANOVA. The days of monitoring (weekdays vs. weekend days) were used as the within-subjects factor; gender, employment status, and age group as the between-subjects factors, and years of education as a covariate. The relation between groups based on the pedometer indices of Tudor-Locke and Bassett (2004) and the qualitative variable self-reported state of health were analysed with a chi-square test.

Similar to other studies, the skewed IPAQ data were first log-transformed to approximate normal distributions (Napolitano et al., 2003; Rzewnicki, Auweele, & De Bourdeaudhuij, 2002). Differences between the groups based on the pedometer indices of Tudor-Locke and Bassett (2004) in IPAQ results were tracked with MANOVAs. Results were adjusted for demographic variables, namely age, gender, and employment status. Parametric analyses were performed on the log-transformed IPAQ data: *F* values, *p* values and partial η^2, as a measure of effect size, are reported. The figures shown in Table 2 and in the results section are the means (*M*) and standard deviations (*SD*) of the nontransformed data. In addition, Pearson correlation coefficients were generated to compare between measured steps/day and the amount of PA reported in the IPAQ. Throughout, an alpha level of $p < .05$ was used to decide upon statistical significance.

Results

Adults in the present sample reported taking on average 9,655 (*SD* = 4,526) steps/day. In Table 1, steps/day are presented by gender, age, employment status, and days of the week. The results showed that men (*M* = 9,906, *SD* = 5,046) accumulated more steps/day than women (*M* = 9,428, *SD* = 3,984) ($F = 5.0$, $p = .026$). Steps also differed significantly across age groups ($F = 3.3$, $p = .01$). The most active group was the 36–45-year-olds (*M* = 10,589, *SD* = 3,620) who reported significantly more steps/day than all other age groups (36–45-year-olds vs. 25–35-year-olds [*M* = 10,238, *SD* = 4,188]: $p = .046$; 36–45-year-olds vs. 46–55-year-olds [*M* = 10,105, *SD* = 4,813]: $p = .046$; 36-45 year vs. 56–65-year-olds [*M* = 9,052, *SD* = 5,110]: $p = .004$; 36–45-year-olds vs. 66–75-year-olds [*M* = 7,693, *SD* = 4,255]: $p < .001$). The 46–year-olds were also significantly more active than the 66–75-year-olds ($p = .022$). Employed participants (*M* = 10,323, *SD* = 4,234) reported more steps/day than unemployed participants (*M* = 8,282, *SD* = 4,841) ($F = 6.2$, $p = .013$). And the whole sample took more steps on weekdays (*M* = 9,755, *SD* = 4,727) than on weekend days (*M* = 9,433, *SD* = 5,954) ($F = 7.4$, $p = .007$). No significant interaction effects could be found between these variables. The analysis did show a significant interaction effect between days of monitoring and the level of education ($F = 5.4$, $p = .02$). Further exploration showed that participants whose highest diploma was a high school qualification, took fewer steps on the weekend (*M* = 8,896, *SD* = 6,522) than on weekdays (*M* = 9,544, *SD* = 4,936), while there was no difference between days of monitoring (weekend: *M* = 9,802, *SD* = 5,432 vs. weekdays: *M* = 9,912, *SD* = 4,544) for participants who held at least a college certificate.

According to the pedometer indices of Tudor-Locke and Bassett (2004), 12.9% of the present population can be classified as sedentary (< 5,000 steps/day, *M* = 3,504, *SD* = 1,215), 19.4% were low active (5,000–7,499 steps/day, *M* = 6,353, *SD* = 714), 26.2% were somewhat active (7,500–9,999 steps/day, *M* = 8,788, *SD* = 711), 21.1% reached the recommended minimum 10,000 steps/day and can be classified as active (*M* = 11,123, *SD* = 716), and 20.5% were highly active with more than 12,500 steps/day (*M* = 16,232, *SD* = 4,105). Figure 1 shows the classification based on the pedometer indices according to age group. The relation between self-reported state of health and pedometer indexes was significant ($\chi^2 = 79.5$, $p < .001$). In the group that described their state of health as "poor," 95.9% were sedentary, low active and somewhat active, while 55.8% of those who reported having an excellent state of health were active and highly active. No significant relation could be found between

Table 1. Pedometer-determined physical activity (steps/day)

	n	Steps/day *M*	*SD*	*F (p)*
Gender				5.0 (*)
Men	598	9,906	5,046	
Women	624	9,428	3,984	
Age (years)				3.3 (**)
25–35	237	10,238	4,188	
36–45	267	10,589	3,620	
46–55	287	10,105	4,813	
56–55	248	9,052	5,110	
66–75	183	7,693	4,255	
Employment status				6.2 (*)
Unemployed	396	8,282	4,841	
Employed	826	10,323	4,234	
Day of monitoring				7.4 (**)
Weekday	1,217	9,755	4,727	
Weekend day	1,217	9,433	5,954	

Note. M = mean; *SD* = standard deviation.
*$p \leq .05$.
**$p \leq .01$.

gender and groups based on the pedometer indices of Tudor-Locke and Bassett (2004).

Table 2 shows the IPAQ results for the different groups, based on the pedometer indices of Tudor-Locke and Bassett (2004). Significant differences between the five pedometer groups were found for time spent walking (F= 17.5, p< .001, η_p^2 = .06), moderate PA (F= 14.7, p < .001, η_p^2 = .05), and vigorous PA (F= 8.1, p < .001, η_p^2 = .03). The time spent walking differed significantly between most groups (p< .05), except between the somewhat active and active group, and between the active and highly active group. Significant differences in moderate PA were found between most groups (p < .05), except between the somewhat active and active group. Also, the differences in vigorous PA were significant for most pairs (p < .05), except between the sedentary and low active group, and between the active and highly active group. Taking into consideration the different domains of PA, our analysis showed significant differences between the five groups for PA at work (F= 10.5, p< .001, η_p^2 = .03), transport-related PA (F= 15.5, p < .001, η_p^2 = .05) and leisure time PA (F= 12.1, p< .001, η_p^2 = .04). Some differences between pairs for PA at work (sedentary and low active group, low active and somewhat active group, sedentary and somewhat active group, and active and highly active group), for transport-related PA (sedentary and low active group, somewhat active and active group, and active and highly active group), and for leisure time PA (low active and somewhat active group, and somewhat active and active group) were not significant. Also, time spent sitting differed significantly between most groups (F= 10.1, p< .001, η_p^2 = .03), except between the sedentary and low active group, the low active and somewhat active group, the sedentary and somewhat active group, and the active and highly active group.

Steps/day were negatively correlated to the time spent sitting per week (r= -.15, p< .001) and positively related to PA at work (r= .24, p< .001), transport-related PA (r= .18, p< .001), and PA in leisure time (r= .20, p< .001). The domestic and gardening PA was not significantly correlated to the number of steps/day (r= -.001, p= .96). The three categories of PA were also positively correlated to the number of steps/day (walking: r= .20, p< .001, moderate PA: r= .15, p< .001 and vigorous PA: r= .22, p< .001).

Analysis of the activity log showed that 58.5% of the sample reported some sports or physical activities during the week of pedometer registration. The remaining 514 (41.5%) reported no sports or physical activities over the entire week. One hundred fifteen participants (9.3%) reported some PA on 5 days or more during the week of self-registration. The three most frequently reported sports or PA categories were walking, fitness activities, and jogging. Six participants reported three activities on at least 1 day. About 41% of all participants engaged in bicycling during the week of pedometer registration. For these, a mean of 7.6 (SD= 17.6) min/day of biking (1,140 [SD= 2,640] steps/day) was imputed to the day-end steps

Table 2. Differences in International Physical Activity Questionnaire results across groups based on pedometer indexes

Activity min/week	Sedentary		Low active		Somewhat active		Active		Highly active		F (p)	Diff.	η_p^2
	M	SD	M	SD	M	SD	M	SD	M	SD			
Walking	155	238	209	287	324	400	392	422	452	448	17.5*	c, d	06
Moderate PA	443	413	455	395	524	435	561	433	579	398	4.7*	c	05
Vigorous PA	42	153	68	229	119	287	164	318	152	297	8.1*	a, d	03
Work-related PA	75	269	198	479	357	635	503	715	517	703	10.5*	a, b, d, e	03
Transport-related PA	97	176	96	162	131	178	150	212	174	217	15.5*	a, c, d	05
Domestic-garden PA	422	472	379	416	400	442	379	401	344	372	2.3 ns		01
Leisure-time PA	96	153	111	167	151	230	162	221	236	274	2.1*	b, c	04
Sitting	2,903	1,222	2,937	1,253	2,916	1,260	2,538	1,134	2,390	982	10.1*	a, b, d, e	03

Note. M = mean; SD = standard deviation; PA = physical activity; a = no significant difference between sedentary and low active group; b = no significant difference between low active and somewhat active group; c = no significant difference between somewhat active and active group; d = no significant difference between active and highly active group; e = no significant difference between sedentary and somewhat active group; ns = not significant (p > .05)

*p ≤ .001

taken. About 4% engaged in swimming over the 7days of registration (M = 0.3 min/day, SD = 1.8).

Discussion

The first aim of the present study was to provide pedometer-based PA levels in a sample of Belgian adults and to compare step counts between gender, age groups, employment status, and days of monitoring. The entire sample of 25–75-year-old Belgian adults took on average 9,650 (SD = 4,520) steps/day. When comparing this mean step count to other pedometer-based study findings, the present sample is more physically active than other populations (Tudor-Locke, Ham et al., 2004; Wyatt et al., 2005). However, the large standard deviation reveals a wide distribution of ambulatory behavior in the present sample. In the United States, mean population levels of pedometer-determined PA were about 6,000 (SD = 3,700) steps/day for South Carolina citizens ages 18–65+ years (Tudor-Locke, Ham et al., 2004) and 6,800 steps/day for Colorado residents ages 18–60+ years (Wyatt et al., 2005). In Australia, PA levels were higher than in the United States. Consequently, the present PA level is more comparable to the levels of Australian workers (8,900 steps/day; Miller & Brown, 2004), Australian young women (9,000 steps/day; Brown et al., 2002), and the Western Australian population (9,695 steps/day; Mc Cormack et al., 2005). The only European pedometer-based study was performed in 1989 (Sequeira et al., 1995). The average number of step counts for Swiss men dropped from 11,900 steps/day in the 25–34-year-olds to 6,700 in the 65–74-year-olds and from 9,300 to 7,300 for Swiss women. In the present study the average amount of steps/day for men decreased from 10,600 in the youngest age group to 8,300 in the oldest age group and from 9,800 to 6,900 for women. No other recent data of European levels of pedometer-determined PA are available, so the present study is the single largest survey of adult pedometer-assessed PA in Europe in the 21st century.

When preparing the dataset, no cut-offs were used to limit high step counts. To encounter the problem of

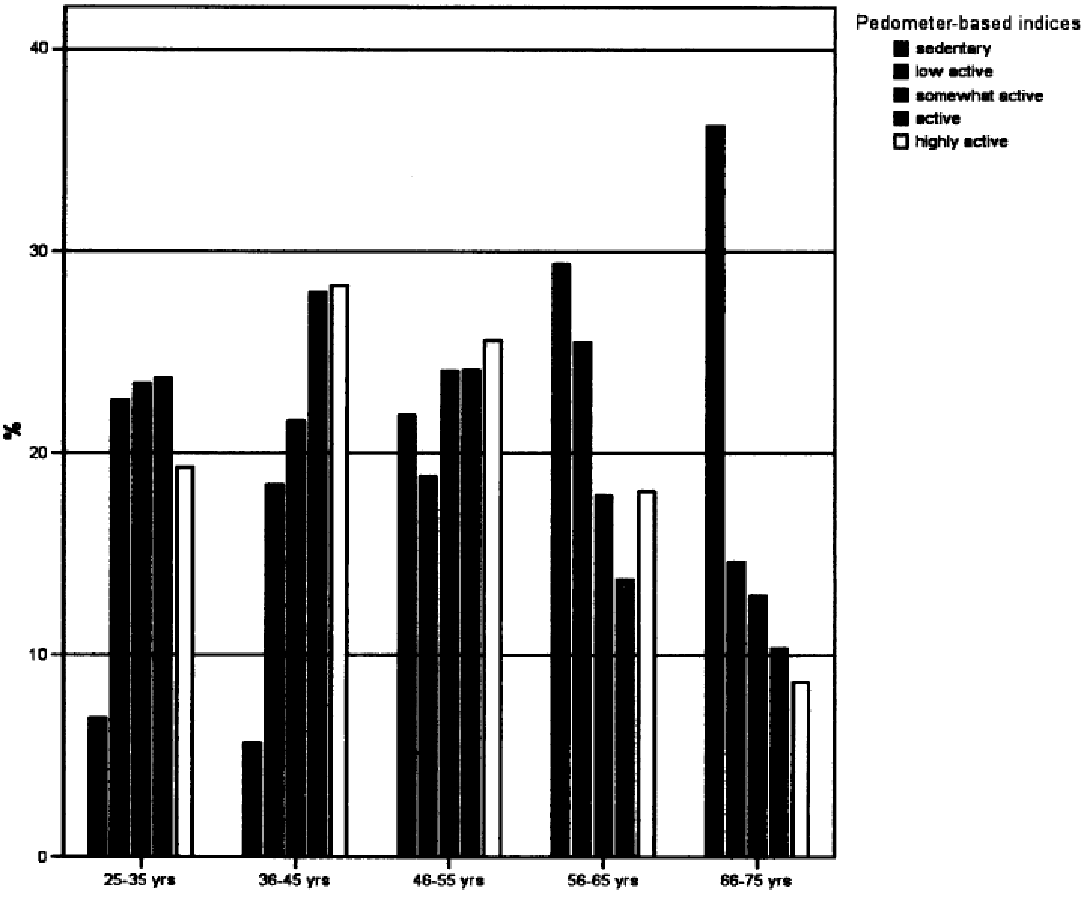

Figure 1. Percentage of participants in each age group meeting different activity levels based on pedometer indexes.

using mean steps/day, which are sensitive to extreme values, the recently introduced pedometer indices of Tudor-Locke and Bassett (2004) are helpful. Although the mean number of steps/day of the present population was high, classification based on pedometer indices showed that 58.4% of the entire sample was sedentary, low active, or somewhat active and did not reach the 10,000 steps/day standard. However, again, the percentage of the population reaching the recommended level is higher than it is in the United States. In South Carolina (Tudor-Locke, Ham et al., 2004), only 13.9% of the population took more than 10,000 steps/day, and in Colorado (Wyatt et al., 2005), no more than 16% could be classified as active or highly active. In the Australian study, 47% of the population reached the 10,000 steps standard (McCormack et al., 2005). The classification based on pedometer indices by Tudor-Locke and Bassett (2004) was not used in other Australian studies. Therefore, it was impossible for us to make any comparison. Similar to the findings made by Rutten et al. (2001), the present results on the relation between self-reported state of health and pedometer indices showed that people with poor health were predominately inactive. However, due to the cross-sectional study design, the direction of causality cannot be addressed. Further research is needed to examine the directionality on this interesting finding.

A variety of explanations exists for the differences in PA levels between Belgium and the United States. Environmental characteristics (e.g., bike lanes) and socioeconomic characteristics (e.g. health care) differ between Europe and the United States, and there is a relation between socioeconomic status (i.e., PA is more prevalent in higher socioeconomic classes); USDHHS, 1996), environmental variables (De Bourdeaudhuij, Sallis, & Saelens, 2003; USDHHS, 1996), and PA. Given this information, it is likely that PA levels in European countries differ from those in United States. An earlier survey (De Bourdeaudhuij & Sallis, 2002) revealed that the activity levels of Belgian adults were higher than those of the American sample. However, it is worth bearing in mind the following when comparing the Belgian and United States findings. First, data collection in the two studies in the United States (Tudor-Locke, Ham, et al., 2004; Wyatt et al., 2005) were completed in winter, while data in the present study were collected during spring. Tudor-Locke, Bassett et al. (2004) suggested considering the impact of seasons on pedometer-determined PA and suggested to plan for data collection in the fall or spring. Second, in the present study the day-end steps were increased with the equivalent in steps for the time spent biking and swimming. In the other studies (Brown et al., 2002; Miller & Brown, 2004; Sequeira et al., 1995; Tudor-Locke, Ham et al., 2004; Wyatt et al., 2005), no information was available on the processing of these nonambulatory activities. However, it should be mentioned that, in the present study, the equivalent in steps was based on data in the activity log, and the validity of this self-report instrument is unclear. Also note that, in the present study, employed participants were more likely to complete the pedometer protocol than participants who did not have a job. Furthermore, conclusions about differences between samples must be drawn with caution, as the recruitment approaches adopted in the various studies were different. Moreover, the validity, accuracy, and reliability may vary between different types and brands of pedometers (De Cocker, Cardon, & De Bourdeaudhuij, 2006; Schneider et al., 2003), and slow walking speeds (< 60 m/min), often occurring in elderly or sick individuals, may also be a source of error (Bassett et al., 1996). Finally, as yet no scientific agreement exists on the processing of nonambulatory activities.

Notwithstanding the variation in mean levels between different studies, similarities with other pedometer studies and earlier PA research (USDHHS, 1996) can be found. Similar to other pedometer studies (Bassett et al., 2004; Sequeira et al., 1995; Tudor-Locke, Ham et al., 2004), men accumulated more steps/day than women. However, these findings need to be interpreted with caution, as a variation of 500 steps/day may have limited biological value. Wyatt et al. (2005) found no significant gender differences in steps/day. Although the most active group were the 36-45 year-olds, the results showed a decline in mean steps/day with increasing age. The same was found in other countries (Sequeira et al., 1995; Tudor-Locke, Ham et al., 2004; Wyatt et al., 2005). Despite the increased leisure time on weekends (Brail & Chain, 1973), more steps/day were accumulated on weekdays than weekend days, a finding also shown in other studies (Bassett et al., 2004; Miller & Brown, 2004; Sequeira et al., 1995; Tudor-Locke, Bassett et al., 2004; Tudor-Locke, Ham et al., 2004). Again, despite the statistical significance, the practical significance is unclear. The present finding that employed participants accumulated significantly more steps/day than unemployed participants was inconsistent with the results of the Chan et al. (2003) study, in which full-time workers (7,100 steps/day) were less active than part-time workers (9,600 steps/day). It should be pointed out that in the latter study the place of recruitment was a predominately sedentary worksite.

A second objective of the present study was to evaluate differences between groups based on pedometer indices of Tudor-Locke and Bassett (2004) in work-, transport-, home-, and leisure time-related PA reported in the IPAQ. The results showed that the classification of activity level based on pedometer data corresponded to differences in self-reported levels of PA (low to medium effect sizes). The more active participants were, based on pedometer data, the higher their work-, leisure time-, and transport-related PA as reported on the IPAQ. Similar results were found for the amount of time spent sitting: low active groups (classified on pedometer data) reported more time spent sitting than active groups. Consequently, pedometer data are capable of discriminating between levels of PA reported on the IPAQ. Sequeira et al. (1995) found that pedometers were able to discriminate between sitting, standing, and moderate effort categories as well. Hence, the present study confirms the usefulness of the pedometer in objectively assessing PA in free-living conditions in large populations. In line with these findings, significant correlations were found between objectively measured step counts and subjectively reported levels of activity. Although the results showed statistically significant correlation coefficients between step counts and PA at work ($r = .24$, $p < .001$), leisure time PA ($r = .20$, $p < .001$), and transport-related PA ($r = .18$, $p < .001$), the coefficients are relatively small. By contrast, Bassett et al. (2004) found moderately significant associations ($r = .47$) between pedometer values and IPAQ scores in adults from an Amish community.

The most frequently reported sports or physical activities in the present study (walking, fitness activities, and jogging) were also the most popular sports or exercise forms reported in earlier American (Tudor-Locke, Bassett et al., 2004; Tudor-Locke, Ham et al., 2004) and European studies (Uitenbroek & McQueen, 1991). Although similarity was found in terms of activity popularity, the percentage of participants that reported engaging in some form of sports or exercise was different. Tudor-Locke, Ham et al. (2004) found that 89% of participants reported some activity on at least 1 day of the monitoring period, whereas the present results showed that 58.5% of the participants were active on at least one day. Analysis of the activity log showed that only 9.3% reported engaging in sports or exercise on at least 5 days of the week, whereas the recommendation is to accumulate a minimum 30 min of moderate to vigorous PA on most, preferably all, days of the week (ASCM, 2000; USDHHS, 1996). Taking this recommendation into consideration, the present sample could be classified as sedentary. On the other hand, when pedometer-based PA levels are analysed, this sample is relatively active compared to American samples. As such, it is possible that the majority of the Belgian sample accumulated more steps during working hours or other activities (e.g. transport activities) that were not classified as sports or exercise and are therefore not represented in the activity log. This is reflected in the comparison of IPAQ scores between the five pedometer groups. Significant differences between the five pedometer groups (Tudor-Locke & Bassett, 2004) were found for nonsport or nonexercise activities, namely PA at work and transport-related PA. Other studies also found that occupational activity (Chan et al., 2003; Sequeira et al., 1995; Tudor-Locke, Ham et al., 2004) and walking for transport (Tudor-Locke, Bittman, Merom, & Bauman, 2005) have an important role in total daily PA. For domestic and gardening PA, which also include nonsport or nonexercise activities, no significant differences were found between the five pedometer groups. It is possible that these activities do not have a significant impact in total daily PA.

The reliance on self-reported PA data drawn from the activity log, which remains to be validated, is a limitation of the present study. A second weakness is the lack of information on BMI or other physiological parameters, marital status, job classification, and income. Future studies could focus on the relation between pedometer-determined PA and other descriptive variables. Furthermore, similar studies to be conducted in Europe, the United States, and other continents could enable further international comparisons. Moreover, this dataset can be used as a baseline to evaluate the effects of programs designed to increase population PA levels in Flanders. Based on the present mean values of daily steps, 10,000 steps/day could be an achievable goal for this population, although managing 10,000 steps/day will be harder for older participants than for their younger counterparts. As mentioned earlier (Wyatt et al., 2005), gradually building up to an activity level by making small, incremental increases in PA could be a successful strategy for the most inactive of groups.

In summary, the present findings provide information about pedometer-assessed PA in a sample of Belgian adults. The Belgian sample accumulated higher pedometer-determined PA levels than those reported in samples of the United States. Additionally, pedometer-determined data provide adequate information to discriminate between levels of PA reported on the IPAQ, which confirms the value that pedometers can have in PA assessment in large, free-living populations.

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PART 2 ORIGINAL RESEARCH

2.2 PEDOMETER-BASED INTERVENTION STUDIES

CHAPTER 2.2.1

THE EFFECT OF PEDOMETER USE IN COMBINATION WITH COGNITIVE AND BEHAVIOURAL SUPPORT MATERIALS TO PROMOTE PHYSICAL ACTIVITY

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The effect of pedometer use in combination with cognitive and behavioral support materials to promote physical activity☆

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Abstract

Objective: 1. To demonstrate that combining pedometer use with cognitive and behavioral support materials has a positive effect on physical activity (PA) and attitudes towards pedometer use. 2. To investigate how familiar the study sample is with pedometers and the '10,000 steps/day' recommendation.

Methods: From a random sample, drawn from the phone book, 304 volunteered (18–75 year) to complete a questionnaire about familiarity with pedometers and the '10,000 steps/day' recommendation. A sample of 103 participants agreed to wear a pedometer for 3 weeks, and was randomly assigned to a condition with cognitive and behavioral support materials ($n = 51$) or without these materials ($n = 52$). Participants completed the International Physical Activity Questionnaire before and after 21 days of pedometer use and an additional questionnaire on the attitudes towards pedometer use.

Results: More than 58% had never heard of a pedometer. In both conditions, walking ($F = 10$, $p = 0.002$), moderate PA ($F = 11$, $p = 0.001$), and vigorous PA ($F = 14$, $p < 0.001$) increased over time, however no interaction effects could be found. Significantly more participants in the condition with support materials had a positive attitude towards pedometer use.

Conclusion: Wearing a pedometer, with or without support materials, may increase PA. In our study, cognitive and behavioral support materials only affected attitudes towards pedometer use.

Practice implications: More research is needed to investigate the effect of combining pedometer use with support materials on a longer time base and in less motivated people.

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Keywords: Step counter; Self-monitoring; '10,000 steps/day'

1. Introduction

International health guidelines recommend the accumulation of minimum 30 min of at least moderate-intensity PA on most, preferably all, days of the week [1–3]. With the increased use of pedometers as objective PA measurement, step count goals have been used [4,5], and '10,000 steps/day' has become a popular PA target [6,7].

Using a pedometer can provide a reminder to be more active, however the question is whether simply providing a pedometer is enough to increase PA. There is also a need to increase knowledge regarding health benefits of PA, to motivate individuals [8], and to reinforce commitment to PA routine. According to Robinson and Rogers, and Dunn et al., cognitive and behavioral strategies (self-monitoring, goal-setting techniques) are essential [8,9]. Furthermore, Tudor-Locke and Bassett believe that providing guidelines and programs are also valuable [10]. In previous interventions, pedometers were used in combination with these strategies [11–16]. A different approach is the simple distribution of pedometers with limited information. The main purpose was to evaluate if combining pedometer use with cognitive and behavioral support materials, such as information on health, PA, and the '10,000 steps/day' recommendation, goal-setting, and self-monitoring in log books, has a positive effect on PA levels and on the attitudes towards pedometer use.

The use of pedometers and step count goals is popular in America, Canada, and Australia [17–19], but still novel and only recently (2–3 years) gaining popularity in Belgium,

☆ I confirm all patient/personal identifiers have been removed or disguised so the patient/person(s) described are not identifiable and cannot be identified through the details of the story.

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Europe. Consequently, an additional purpose was to evaluate how familiar the study population is with pedometers and the '10,000 steps/day' recommendation.

2. Methods

2.1. Procedures and participants

From the phone book covering the west part of East-Flanders, 724 telephone numbers of citizens of Zottegem, Belgium were selected by simple randomization (selection of the first name and every tenth name below the previous one). Within two attempts, 447 individuals older than 18 could be reached. A sample of 304 volunteered to complete a telephone interview relating to familiarity with pedometers and the '10,000 steps/day' recommendation (see Table 1). Participants prepared to use a pedometer for three consecutive weeks ($n = 103$) were asked to complete the International Physical Activity Questionnaire (IPAQ) at the end of the interview and after 3 weeks of pedometer use. Two-hundred-and-one participants were not willing to use a pedometer (66% "no interest in pedometer use", 24% "no time to wear a pedometer" and 16% "another reason").

After the interview, participants who agreed to wear a pedometer were randomly assigned to a condition using a pedometer with cognitive and behavioral support materials ('condition +') ($n = 51$) or a condition without those materials ('condition −') ($n = 52$) (1st participant: 'condition −', 2nd: 'condition +', 3rd: 'condition −', . . .). All participants were sent a package including: a pedometer, an informed consent form, a protocol describing how and when to use the pedometer, a questionnaire about the attitudes towards pedometer use, the IPAQ (both to complete after 3 weeks of pedometer use), and a preaddressed and stamped envelope to return the pedometer and questionnaires.

The 'condition +' was sent a brochure (designed by the researchers, based on items from the social cognitive theory [20]) with information on the importance of PA for health (two pages), the '10,000 steps/day' recommendation (three pages), and 20 tips on how to increase PA (e.g. 'take the stairs'). On the last three pages, participants were asked to set goals and to complete a daily step log book (to be returned to the researchers). The first week served to determine the baseline step level and in the second and third week participants were asked to increase their baseline step level by 2000 steps/day if the level was below 10,000 steps/day. If it was above the recommended 10,000 steps/day, participants were encouraged to maintain their physically active lifestyle.

2.2. Instruments

2.2.1. Telephone interview

First, gender, age group, educational level (elementary or high school = 'low-educated'; college or university = 'high-educated'), and employment status were asked. Then, individuals were asked close-ended questions (yes/no) related to knowledge about, and familiarity with pedometers and the steps/day-guideline (see Table 2).

2.2.2. IPAQ

The IPAQ short-form telephone version (before pedometer use) and self-administered version (after pedometer use) [http://www.ipaq.ki.se] were used to assess PA in the last 7 days. Both versions give similar results [21] and the IPAQ has been shown to be a valid and reliable instrument for measuring PA [21,22].

2.2.3. Pedometers

The Yamax Digiwalker SW-200 (Yamax, Tokyo, Japan) was used in the present study as it is known to be one of the best

Table 1
Descriptive characteristics

Variables	Total n (%)	Not willing to wear pedometer n (%)	Agreed to wear pedometer n (%)	χ^2 (p)	Condition + n (%)	Condition − n (%)	χ^2 (p)
n	**304 (100)**	201/304 (66.1)	103/304 (33.9)		51/103 (49.5)	52/103 (50.5)	
Gender				4.9 (*)			0.5 (ns)
Male	**136/304 (44.7)**	99/136 (72.8)	37/136 (27.2)		20/51 (39.2)	17/52 (32.7)	
Female	**168/304 (55.3)**	102/168 (60.7)	66/168 (39.3)		31/51 (60.8)	35/52 (67.3)	
Age				3.5 (ns)			0.8 (ns)
18–25 years	**79/304 (26.2)**	54/79 (68.4)	25/79 (31.6)		12/51 (23.5)	13/52 (25)	
26–55 years	**164/304 (54.3)**	101/164 (61.6)	63/164 (38.4)		30/51 (58.8)	33/52 (63.5)	
56–75 years	**59/304 (19.5)**	44/59 (74.6)	15/59 (25.4)		9/51 (17.6)	6/52 (11.5)	
Level of education				0.3 (ns)			0.8 (ns)
Low	**192/304 (63.2)**	129/192 (67.2)	63/192 (32.8)		29/51 (56.9)	34/52 (65.4)	
High	**112/304 (36.8)**	72/112 (64.3)	40/112 (35.7)		22/51 (43.1)	18/52 (34.6)	
Occupation				3.6 (ns)			0.6 (ns)
Employed	**213/304 (79.4)**	135/213 (63.4)	78/213 (36.6)		40/51 (78.4)	38/52 (73.1)	
Unemployed	**51/304 (16.1)**	34/51 (66.7)	17/51 (33.3)		7/51 (13.7)	10/52 (19.2)	
Retired	**40/304 (12.5)**	32/40 (80)	8/40 (20)		4/51 (7.8)	4/52 (7.7)	

ns, not significant ($p > 0.05$); $^*p \leq 0.05$.

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Table 2
Familiarity with PM and '10,000 steps/day' recommendation

	Total *n* (% yes)	Not willing to wear PM *n* (% yes)	Agreed to wear PM *n* (% yes)	χ^2 (*p*)
Have you already heard of a step counter or PM?	**127/304 (41.8)**	72/201 (35.8)	55/103 (53.4)	8.7 (**)
Where?				
Television	**31/127 (24.4)**	20/72 (27.8)	11/55 (20)	
Radio	**4/127 (3.1)**	3/72 (4.2)	1/55 (1.8)	
Magazine	**25/127 (19.7)**	14/72 (19.4)	11/55 (20)	
Home	**15/127 (11.8)**	10/72 (13.9)	5/55 (9.1)	
Work	**11/127 (8.7)**	6/72 (8.3)	5/55 (9.1)	
Family	**31/127 (24.4)**	16/72 (22.2)	15/55 (27.3)	
Other	**10/127 (7.9)**	3/72 (4.2)	7/55 (12.7)	
Have you already seen a PM?	**66/304 (21.7)**	36/201 (17.9)	30/103 (29.1)	5.0 (*)
Where?				
Television	**16/66 (24.2)**	8/36 (22.2)	8/30 (26.7)	
Home	**13/66 (19.7)**	9/39 (25)	4/30 (13.3)	
Work	**8/66 (12.1)**	3/36 (8.3)	5/30 (16.7)	
Family	**20/66 (30.3)**	11/36 (30.6)	9/30 (30)	
Other	**9/66 (13.6)**	5/36 (13.8)	4/30 (13.3)	
Do you know the function of a PM?	**114/304 (37.5)**	63/201 (31.3)	51/103 (49.5)	9.6 (**)
Where from?				
Television	**24/114 (21.1)**	12/63 (19)	12/51 (23.5)	
Radio	**2/114 (1.8)**	2/63 (3.2)	0 (0)	
Magazine	**20/114 (17.5)**	11/63 (17.5)	9/51 (17.6)	
Home	**17/114 (14.9)**	12/63 (19)	5/51 (9.8)	
Work	**13/114 (11.4)**	7/63 (11.1)	6/51 (11.8)	
Family	**27/114 (23.7)**	14/63 (22.2)	13/51 (25.5)	
Other	**11/114 (9.6)**	5/63 (7.9)	6/51 (11.8)	
Do you know how to use a PM properly?	**42/304 (13.8)**	21/201 (10.4)	21/103 (20.4)	5.7 (*)
Where from?				
Television	**5/42 (11.9)**	2/21 (9.5)	3/21 (14.3)	
Magazine	**5/42 (11.9)**	3/21 (14.3)	2/21 (9.5)	
Home	**10/42 (23.8)**	7/21 (33.3)	3/21 (14.3)	
Work	**8/42 (19)**	3/21 (14.3)	5/21 (23.8)	
Family	**13/42 (31)**	5/21 (23.8)	8/21 (38.1)	
Other	**1/42 (2.4)**	1/21 (4.8)	0 (0)	
Do you know how many steps/day are health beneficial?	**53/304 (17.4)**	28/201 (13.9)	25/103 (24.3)	5.1 (*)
Idea of this number (mean ± S.D.)	**7707 ± 3591**	7221 ± 3545	8250 ± 3636	$t = 1.0$ (ns)

PM, pedometer; ns = not significant ($p > 0.05$); $^*p \leq 0.05$; $^{**}p \leq 0.01$.

pedometers in regard to its accuracy and reliability for counting steps [23,24].

2.2.4. Questionnaire on attitudes towards pedometer use

The questionnaire included close-ended questions relating to pedometer use. Participants in the 'condition +' were asked to complete four additional items (see Table 3).

2.3. Data analysis

All data were analyzed using SPSS 12.0 for Windows. Chi-square tests were used to analyze descriptive characteristics, familiarity with pedometers, and attitudes. A repeated measures MANOVA was used to evaluate the effect over time, the differences between the two conditions, and the interaction effect (time × condition) of the truncated (maximum 2 h/day) and log transformed IPAQ values. For reasons of clarity and comparability, the numbers in Section 3 and in Table 3 are the means and standard deviations (S.D.) of the non-transformed IPAQ data. Independent samples *t*-tests were used to compare the reported number of steps/day between different groups. The difference in step counts after 3 weeks of pedometer use in participants in the 'condition +' was evaluated with a paired-sample *t*-test. The alpha level was set at 0.05, except for multiple tests ($\alpha = 0.01$).

3. Results

3.1. Familiarity with pedometers and the '10,000 steps/day' recommendation (see Table 2)

Significantly more individuals who agreed to wear a pedometer, than those not willing to wear one, had already heard of a pedometer, had already seen a pedometer, knew the function of the device, knew how to use it properly, and reported knowing how many steps/day are health beneficial.

Table 3
Attitudes towards pedometer use

	Condition + $n = 51$ n (%)	Condition − $n = 52$ n (%)	χ^2 (p)
I wore the pedometer everyday during the 3 weeks			1.4 (ns)
"Totally not agree" and "not agree"	5/50 (10)	9/49 (18.4)	
"Agree" and "fully agree"	45/50 (90)	40/49 (81.6)	
I wore the pedometer only the first couple of days			4.1 (*)
"Totally not agree" and "not agree"	49/50 (98)	42/48 (87.5)	
"Agree" and "fully agree"	1/50 (2)	6/48 (12.5)	
I found it pleasant to wear the pedometer			7.5 (**)
"Totally not agree" and "not agree"	1/50 (2)	9/48 (18.8)	
"Agree" and "fully agree"	49/50 (98)	39/48 (81.3)	
The pedometer bothered me during the day			2.9 (ns)
"Totally not agree" and "not agree"	48/51 (94.1)	40/48 (83.3)	
"Agree" and "fully agree"	3/51 (5.9)	8/48 (16.7)	
During the day, I was influenced by the number of steps			3.4 (ns)
"Totally not agree" and "not agree"	33/51 (64.7)	39/48 (81.3)	
"Agree" and "fully agree"	18/51 (35,3)	9/48 (18.8)	
I walked more because of the pedometer			2.9 (ns)
"Totally not agree" and "not agree"	37/50 (74)	42/48 (87.5)	
"Agree" and "fully agree"	13/50 (26)	6/48 (12.5)	
I would be prepared to use the pedometer for a longer period			5.6 (*)
"Totally not agree" and "not agree"	9/50 (18)	19/48 (39.6)	
"Agree" and "fully agree"	41/50 (82)	29/48 (60.4)	
I would buy a pedometer			4.2 (*)
"Totally not agree" and "not agree"	22 (45.8)	32 (66.7)	
"Agree" and "fully agree"	26 (54.2)	16 (33.3)	
I found the information on pedometer use clear			1.2 (ns)
"Totally not agree" and "not agree"	5/48 (9.8)	2/48 (4.2)	
"Agree" and "fully agree"	46/48 (90.2)	46/48 (95.8)	
I still have questions about pedometer use			17.8 (***)
"Totally not agree" and "not agree"	46/51 (90.2)	22/43 (51.2)	
"Agree" and "fully agree"	5/51 (9.8)	21/43 (48.8)	
I believe to know how many steps/day are health beneficial	35/49 (71.4)	22/51 (43.1)	8.1 (**)
Idea of number of steps (mean ± S.D.)	9714 ± 1274	9091 ± 2667	$t = 1.0$ (ns)
I find it a good idea to increase my PA by means of a pedometer and the '10,000 steps/day' recommendation.			
"Totally not agree" and "not agree"	5/51 (9.8)		
"Agree" and "fully agree"	46/51 (90.2)		
I find the combination of information on PA and health, pedometer use, and self-monitoring methods motivating to increase my PA			
"Totally not agree" and "not agree"	8/51 (15.7)		
"Agree" and "fully agree"	43/51(84.4)		
I find the combination of information on PA and health, pedometer use, and self-monitoring methods not motivating because I could not reach the target of '10,000 steps/day'.			
"Totally not agree" and "not agree"	45/51 (78.4)		
"Agree" and "fully agree"	6/51(11.8)		
I find it annoying to register the steps at the end of the day.			
"Totally not agree" and "not agree"	49/51 (96.1)		
"Agree" and "fully agree"	2/51 (3.9)		

ns, not significant ($p > 0.05$); *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

3.2. Amount of PA

Multivariate analyses showed no significant interaction effect ($F = 0.8$, $p > 0.05$), nor an effect for the different conditions ($F = 0.4$, $p > 0.05$). However, a strong time effect ($F = 8.3$, $p < 0.001$) was found, showing increases in minutes/week walking, minutes/week moderate, and minutes/week vigorous PA in both conditions (Table 4).

3.3. Attitudes towards pedometer use (see Table 3)

More participants in the 'condition −' than in the 'condition +' reported that they wore the pedometer only the first couple of days, they found it not pleasant to wear the pedometer, and they still had questions about pedometer use. Significantly more participants in the 'condition +' reported to be prepared to wear the pedometer for a longer period, would buy a pedometer, and

Table 4
Amount of physical activity

Min/week	Before pedometer use					After pedometer use					F (p)[a]
	Total	Condition +	n	Condition −	n	**Total**	Condition +	n	Condition −	n	Time effect
Sitting (mean min/day ± S.D.)	**370 ± 186**	396 ± 218	(41)	371 ± 148	(39)	**377 ± 176**	363 ± 190	(41)	393 ± 161	(39)	0.2 (ns)
Walking (mean ± S.D.)	**212 ± 290**	211 ± 290	(40)	212 ± 294	(42)	**267 ± 305**	257 ± 287	(40)	276 ± 324	(42)	6.1 (*)
Moderate PA (mean ± S.D.)	**56 ± 137**	58 ± 151	(50)	54 ± 121	(45)	**129 ± 215**	105 ± 189	(50)	157 ± 240	(45)	12.9 (***)
Vigorous PA (mean ± S.D.)	**43 ± 95**	39 ± 87	(41)	46 ± 102	(39)	**73 ± 130**	52 ± 115	(41)	94 ± 143	(39)	6.5 (*)

ns, not significant ($p > 0.05$); *$p \leq 0.05$; ***$p \leq 0.001$.
[a] F and p values represent difference over time (before vs. after) for both conditions (total).

believed to know how many steps are health beneficial. There was a trend that more participants in the ‘condition +’ were not bothered by the pedometer ($p = 0.088$), were influenced by the number of steps ($p = 0.065$), and reported to have walked more because of wearing a pedometer ($p = 0.091$).

3.4. Perception of the cognitive and behavioral support materials in the ‘condition +’ (see Table 3)

Results showed that 90% found it a good idea to increase PA by means of a pedometer and the ‘10,000 steps/day’ recommendation. Forty-three found that the whole concept worked to motivate an increase in daily PA. About 12% found it not motivating because ‘10,000 steps/day’ could not be reached. Two participants (3.9%) found it annoying to register the steps taken at the end of the day. About 94% ($n = 48$) completed the daily step log. There was an increase in average step counts (first week: 9291 ± 3526; third week: 10,010 ± 3250) ($t = 1.7$, $p = 0.087$).

4. Discussion and conclusion

4.1. Discussion

Despite the growing popularity of pedometers and the ‘10,000 steps/day’ recommendation, participants were not entirely familiar with the concept. Furthermore, it was hypothesized that providing cognitive and behavioral support materials would have a positive effect on the amount of PA. However, the ‘condition +’ did not report more PA over time than the ‘condition −’. Although previous pedometer interventions [11–16] used pedometers in combination with cognitive and behavioral strategies, present results showed that simply providing a valid pedometer without support materials to persons willing to use it, can result in a PA increase. Note that besides walking, also moderate and vigorous PA increased, suggesting that pedometer use can generally sensitize PA engagement. In contrast to the present results, Glazener et al. [25] suggested that the use of a pedometer alone without specific guidelines or individual step goals, may not be as effective in increasing PA as when recommendations or targets are being used.

While providing support materials had no additional effect on PA, it had a positive influence on the attitudes towards pedometer use. More than 84% of the participants in the ‘condition +’, believed that the whole concept motivated them to increase their PA. There was a trend that more participants in the ‘condition +’ reported to be influenced by the number of steps, and to walk more because of the pedometer. However, the majority in both conditions reported not being influenced by their step counts and not walking more, yet their PA increased. Possibly pedometer use not only sensitized for steps or walking, but also for general PA engagement.

Overall, present results should be interpreted with caution. Findings are limited in generalizability. The impact of support materials can be different in less motivated people or in persons not contacted or invited in advance and for example just given a pedometer with no further information. Secondly, the duration of the present study was only three weeks. Extra research is necessary to examine the use of promotional materials on a longer time base. Furthermore, there is no information on the actual use of the support materials. Further studies can evaluate the adherence to support materials. Finally, social desirability may have influenced the findings of the present study.

4.2. Conclusion

Wearing a valid pedometer (with or without support materials) may increase PA on a short time base. Furthermore, it was found that in our study support materials only affected attitudes towards pedometer use.

4.3. Practical implications

The present findings can be relevant to the merchandising industry, other researchers and practitioners who develop lifestyle PA programs, interventions, and promotion targets.

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CHAPTER 2.2.2

THE EFFECT OF A PEDOMETER-BASED WORKPLACE PHYSICAL ACTIVITY INTERVENTION

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Health Education Research (in revision)

ABSTRACT

Pedometer use and step count goals have become popular in physical activity (PA) interventions in different settings. Previous pedometer-based workplace interventions were short term, uncontrolled, and executed in the United States, Canada, Australia or Japan. The present European quasi-experimental study evaluated the effects of a 20-week pedometer-based PA workplace intervention. Pedometer-based and self-reported PA from one intervention worksite (68 participants at follow-up) were compared to the data of a comparison workplace (79 participants at follow-up). A downward trend in overall step counts from baseline (end of summer) to follow-up (winter) was found (F=3.3, p=0.071). However, the intervention effect revealed a significant smaller decrease in the intervention workplace (-618 steps/day) than in the comparison workplace (-1389 steps/day) (F=8.8, p=0.004). This intervention effect was only present in already active participants, reaching 10,000 steps/day at baseline (intervention participants: -1706 steps/day; comparison participants: -4006 steps/day) (F=5.5, p=0.023). Overall project awareness was very high (97%) and the separate intervention strategies were judged 'good-to very good' by 57%-95% of the participants. However, the proportion of intervention participants, reporting that they had adjusted their PA behavior (31%), and that they had used the pedometer (48%), was limited. Future workplace projects should give extra attention to inactive employees.

Introduction

Regular physical activity (PA) is associated with a reduced risk of morbidity and overall mortality [1]. To maintain good physical and mental health, all 18-65 years old adults should accumulate 30 minutes or more of moderate-intensity aerobic PA on 5 days each week, or a minimum of 20 minutes of vigorous-intensity aerobic PA on 3 days each week [1]. Next to these traditional guidelines, expressed in activity duration and intensity, step count goals such as '10,000 steps/day' have also been used to promote PA [2]. Together with step count guidelines, the use of pedometers, as a measurement tool and/or a behavior modification tool, has become popular in PA interventions in various settings [3].

The European pedometer-based project "10,000 Steps Ghent" was implemented in a whole community setting. Results showed a step count increase and high project awareness after one year [4]. Self-reports revealed that the participants not reaching 10,000 steps/day at baseline, increased their PA mostly at work, which suggests that the workplace might be a suitable location to reach this non-active group [4]. A review of Dishman et al [5] indicated that the typical worksite PA intervention had a non-significant, small positive effect on PA or fitness. Similar conclusions were drawn in a review by Marshall [6]. In contrast, strong evidence for a positive effect of a worksite PA program on PA was found in a review by

Proper et al [7]. It should be noted that most of the literature comprise studies showing that employees assigned to exercise increased their fitness if they exercised, which confirms the efficacy of an intervention. However, they do not represent the true population effectiveness of the interventions in real life [5].

Although the workplace has been recommended as an appropriate setting for promoting lifestyle PA [1], and the pedometer is found to be an effective tool to promote PA [3], only a limited number of worksite programs (n=9), using pedometers as intervention tool, could be found in the literature [8-16]. To change employees PA behaviors, different strategies such as counseling [8], tailoring [8], goal setting [8-13,15,16], self-monitoring [8-16], feedback [8-11,13,15], education [8-10,13,14,16], motivation [8,10,13,15,16], incentives [11,12], team competitions [11,12,15], contact with a facilitator [9], or focusing on organizational and environmental changes [14], were used in these pedometer-based worksite interventions. The majority of these studies reported significant increases in step counts [8-11,13,15], self-reported PA [12,14-16] and/or health parameters [9,13-16], mostly after interventions of short duration (4-12 weeks) [8-13,15]. However, most of the studies had problematic designs and reported the lack of a control group [8-13,15]. Furthermore, these worksite programs promoting pedometer use and (step count) goals, took place in the United States [8,11-13,15,16], in Canada [9], in Australia [10], or in Japan [14]. No research could be found studying the effects of a pedometer-based worksite intervention in Europe, a continent with different socioeconomic (e.g. healthcare regulation) and environmental (e.g. mild climate, walking/bicycle tracks) characteristics compared to other parts of the world. Therefore, the aim of the present quasi-experimental controlled study was to evaluate the effect of a 20-week pedometer-based PA intervention, based on the principles of the multi-strategy intervention “10,000 Steps Ghent”, in a Belgian worksite with mainly sedentary jobs. Intervention and comparison participants’ pedometer-based and self-reported PA were evaluated in the total sample and in those not reaching 10,000 steps/day at baseline (at-risk group). An additional aim was to describe the awareness of and opinion about the project in the intervention worksite.

Methods

Procedure

A quasi-experimental controlled pretest-posttest design was used in the present study. A social services company met three main selection criteria (employment of predominantly white-collar workers with a sedentary job; employment of at least 500 eligible employees;

and no earlier participation in a pedometer-based program). The company has a department near the research department, which was selected to be the intervention worksite, and a comparable department (7km further away), which served as the comparison worksite. The intervention and comparison workplace, both located in Ghent, were already exposed to the earlier community project “10,000 Steps Ghent” [4], which had an intensive promotion period between 2005-2006. However in the scope of this project, no actions were taken at the worksites participating in the present study.

Before baseline measurements (September 2007), all employees in both worksites were informed through email about the study purposes (to assess PA through a questionnaire and a 7-day pedometer registration). One week later at the worksite, researchers personally asked employees to participate. Those willing to participate were given information about the procedures, a questionnaire, a pedometer, an activity log, and a guide on how to use the pedometer and the activity log. Three weeks later, researchers collected the questionnaires, activity logs, and pedometers (only in the comparison worksite). Intervention participants were told that they would be informed about a PA intervention and that they could hold on to the pedometer during the intervention. At follow-up (February 2008), the same procedures were used for data collection. An additional questionnaire on the awareness of and opinion about the intervention was given to the participants in the intervention worksite. Information on response rates is shown in figure 1. All participants signed informed consent forms and the study protocols were approved by the Ethical Committee of Ghent University.

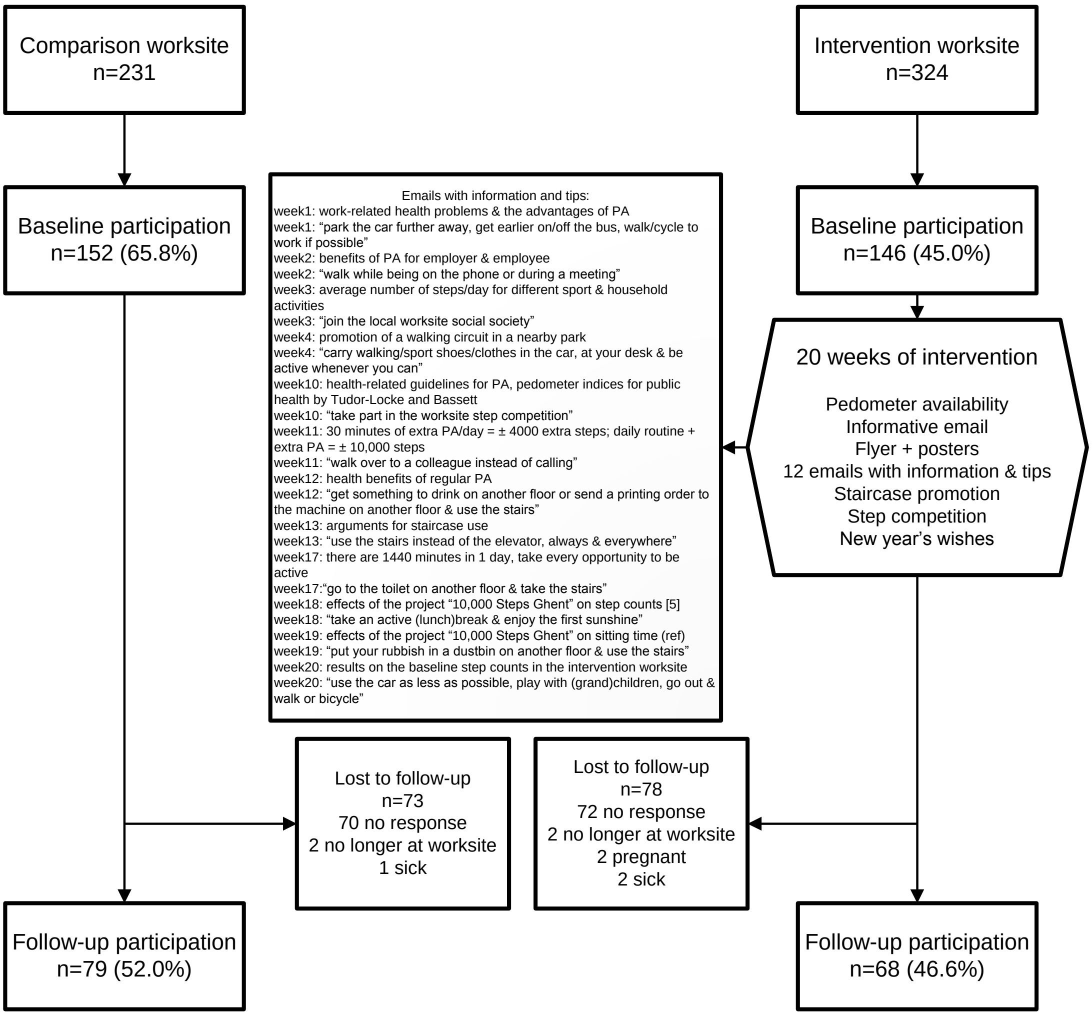

Figure 1: participants’ flow and intervention content.

Intervention

Participants in the intervention worksite were exposed to a 20-week PA intervention based on “10,000 Steps Ghent”, a whole-community intervention based on the social ecologic model [4]. The underlying idea is that interventions should include multi-level strategies focusing on behavioral and (social) environmental factors. Following aspects were emphasized during the present worksite intervention: education (emails), program feedback (pedometer use, email), motivation (email tips), environmental approaches (staircase use promotion, walking circuit), and components of the Social Cognitive Theory [17] such as self-monitoring (pedometer use), goal setting (10,000 steps/day), and social support (worksite step competition). Intrapersonal level strategies include pedometer use and educational and motivational emails and tips. A competition was implemented as an interpersonal level strategy, as competition was found to be a perceived benefit of PA for young Flemish men [18]. Furthermore, the stair case promotion approach was a strategy implemented at the physical environmental level. The researchers designed an intervention easy to implement. Little personal contact or arrangements were needed and only the assistance of the health and safety officer of the social services company was necessary. The present intervention elements were also implemented in previous successful pedometer-based worksite programs [8-16].

All intervention participants received an informative email in the first week of the intervention (October 2007). They were told that they could hold on to the pedometer of the pretesting during the intervention, and that different activities would be implemented in the coming weeks. In the first week, flyers were handed out through a local postal service, and posters were placed on each floor (n=6) on strategic places (copying machine, hall, water fountain). Every week, participants received an email with some information on health and/or PA with a tip on how to increase PA in the daily life (see figure 1). In November, staircase use was promoted by hanging posters at the staircase and elevators, and by placing footsteps on the ground leading to the stairs instead of the elevator (next to the staircase). In the last week of November, information was given on the activity planned in December, namely a worksite step competition. Through email, everyone was invited to form groups of 2-10 employees and to aim at as much steps as possible during the following 3 weeks. Activity logs, designed for the competition, were distributed through email and were sent back to the researchers at the end of the competition. Furthermore, weekly emails with information and PA tips were sent to all the participants (see figure 1). In January 2008, New Year's wishes and feedback on the worksite step competition were mailed to the intervention worksite. During the last 4 weeks of the intervention, participants received a weekly email with information and tips on how to increase PA (see figure 1). Furthermore, two new poster designs were used to promote staircase use. All flyers, posters, and emails referred to "www.10000stappen.be", an informative website.

Instruments

Questionnaire.

In the first part of the questionnaire, used at baseline and follow-up, participants were asked to complete demographic variables such as age, gender, highest degree of education (high school/ college/ university), height, weight, distance to work, transport to work (active/ motorized/ public transport), smoking behavior (smoker/ non-smoker), stage of change (precontemplation/ contemplation/ preparation/ action/ maintenance), and health (excellent/ very good/ good/ moderate/ poor).

In the second part of the questionnaire, the self-administered International Physical Activity Questionnaire (IPAQ) long form was used to assess PA at work, during transport, during domestic and gardening activities, and during leisure time. Based on the guidelines for data processing and analysis of the IPAQ (Guidelines, 2005), total scores for PA, expressed in minutes/week were computed. The IPAQ is known as a valid and reliable instrument to assess PA in Europe [19] and Belgium [20].

Pedometer. To measure PA objectively at baseline and follow-up, the Yamax Digi-Walker SW-200 (Yamax Cooperation, Tokyo, Japan) was used, which is known to be valid, accurate, and reliable for counting steps in adults [21].

Activity log. On a 7-day activity log, participants were asked to record the date, steps taken at the end of the day, the type of day (workday or not), and the type and duration of non-ambulatory activities (i.e. biking and swimming). An equivalent in step counts (150 steps for every minute of reported biking and/or swimming) was added to the daily total of step counts by the researchers [22].

Questionnaire at follow-up on the awareness of and opinion about the intervention. Participants in the intervention worksite were asked if they were aware of the intervention (yes/no). When they answered 'yes', they were asked to indicate of which parts of the intervention they were aware: flyers; posters at staircase; informative email; emails with information and tips; footsteps on the ground; worksite step competition; New Year's wishes; pedometer availability (one or more answers could be marked with a cross). They were also asked to judge those strategies on a 5-point scale (very bad/bad/neutral/good/very good). Furthermore, they were asked if they had adjust their PA and sport behaviors due to the intervention (yes/no) and how they did it (sport activities; parking the car further away; walk before work, at lunch or after work; walk during the weekend; walk the dog; use the stairs instead of the elevator; walk instead of using motorized transport) (one or more answers could be marked with a cross). In the next item, participants were asked which of the previous strategies was most easy to implement in their daily life (only one answer possible). Finally, intervention participants were asked if they used the pedometer, which they could keep after baseline measurement, during the 20 weeks of intervention (yes/no). When participants indicated 'no', the reason for not using the pedometer was asked (no interest; no time; wearing the pedometer is not useful; wearing the pedometer is bothersome; I am already active enough; I already did an earlier pedometer study) (one answer could be marked with a cross). Participants who used the pedometer during the intervention, were asked how often they were using it (daily/weekly/monthly/occasionally).

Data analysis

All data were analyzed using SPSS 15.0 for Windows (SPSS Inc., Chicago, USA) and the alpha level was set at 0.05. Body Mass Index (BMI) was calculated from the self-reported weight and height (weight/height^2) and recoded in 4 categories: underweight (BMI<20), normal weight (20≤ BMI<25), overweight (25≤BMI<30), and obese (30≤BMI). Independent samples t-tests (for quantitative variables) and chi-square tests (for qualitative variables) were used to compare characteristics between the intervention and comparison worksite at baseline and follow-up. Drop-out analyses were executed using independent samples t-tests and chi-square tests.

For every participant providing at least 3 days of pedometer registration (=total sample) [23], average daily step counts were calculated for the baseline and follow-up period. Values over 20,000 steps/day were recorded as 20,000 to limit unrealistically high averages and to ensure normal distributions [24]. This was done for 2 intervention participants and 2 comparison participants at baseline, and for 1 intervention participant at follow-up. To analyze the effect of the intervention on pedometer-based and self-reported PA, repeated measures analysis of covariance was conducted with time (baseline/follow-up) as the within-subjects factor, and worksite (intervention/comparison) and risk profile (<10,000 steps/day at baseline / ≥10,000 steps/day at baseline) as between-subjects factors. This analysis was executed using both a retained sample analysis (without drop-outs) and an intent-to-treat analysis (assuming a 15% decline in step counts at follow-up for drop-outs). As no differences were found between both analyses, only results on the retained sample analysis will be reported. The repeated measures analysis of covariance was also done to evaluate the effect of the intervention on workday and non-workday step counts. Descriptive statistics (n and %) were used to analyze the responses to questions about the awareness of and opinion about the intervention at follow-up.

Results

Participant characteristics

Participants' characteristics at baseline (all participants) and follow-up (all participants minus drop outs) are shown in table 1. Intervention participants were significantly older than comparison participants at both times (baseline: p=0.031; follow-up: p=0.026). There were significantly more participants with an unhealthy BMI (overweight and obese) in the comparison worksite than in the intervention worksite, this at baseline (p=0.006) and at follow-up (p=0.020). At baseline, the distance to work was significantly shorter for the intervention participants than for the comparison participants (p=0.004). No changes could be found between the two worksites in gender, education, smoking behavior, stages of change, and self-reported health at baseline and follow-up (see table 1). The total sample was mainly highly educated (college or university degree), had a low percentage of smokers, had a normal BMI, and reported to be in good health (see table 1). Drop-out analyses revealed that those who dropped out in the intervention worksite were significantly younger (37.2±9.1 year) (t=2.9, p=0.006) and took less steps at baseline (8073±3408) (t=2.3, p=0.026) than those who did not drop out (see table 1 and table 2). No significant differences could be found in those who dropped out and those who did not in the comparison worksite.

Table 1: Participants' characteristics at baseline (pre) and follow-up (post).

	Intervention group		Comparison group		Group contrast	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Variable	(n=146)	(n=68)	(n=152)	(n=79)	t/χ^2 (p)	t/χ^2 (p)
Age						
Years (mean ± SD)	**39.9 ± 9.8**	**41.4 ± 9.6**	**37.5 ± 8.7**	**37.8 ± 8.9**	**2.2 (*)**	**2.3 (*)**
20-29 years (%)	17.8	12.5	23.4	22.7	5.3 (ns)	4.9 (ns)
30-39 years (%)	30.4	31.3	35.9	37.3		
40-49 years (%)	34.1	34.4	31.0	28.0		
50-59 years (%)	15.6	20.3	8.3	10.7		
60-69 years (%)	2.2	1.6	1.4	1.3		
Gender						
Men (%)	42.2	50.0	52.1	43.4	2.7 (ns)	0.6 (ns)
Education						
College/university (%)	86.2	89.8	92.1	90.9	1.8 (ns)	0.0 (ns)
BMI						
Kg/m² (mean ± SD)	23.8 ± 3.5	23.7 ± 3.2	24.5 ± 3.8	24.3 ± 3.9	1.5 (ns)	1.1 (ns)
Underweight (%)	**6.9**	**6.5**	**9.9**	**11.0**	**12.6 (**)**	**9.8 (*)**
Normal weight (%)	**69.2**	**74.2**	**48.2**	**49.3**		
Overweight (%)	**18.5**	**12.9**	**34.0**	**32.9**		
Obese (%)	**5.4**	**6.5**	**7.8**	**6.8**		
Distance to work						
Km (mean ± SD)	**22.0 ± 17.7**	24.5 ± 19.2	**28.6 ± 19.9**	26.2 ± 17.5	**2.9 (**)**	0.5 (ns)
Transport to work						
Active	13.7	20.0	4.4	2.6	26.9 (***)	21.2 (***)
Motorized	70.5	64.6	93.1	94.9		
Public transport	15.8	15.6	2.5	2.6		
Smoking behavior						
Non smoker (%)	86.7	84.4	88.4	89.5	0.2 (ns)	0.8 (ns)
Stages of change						
Precontemplation (%)	16.8	18.3	20.0	17.3	0.9 (ns)	1.9 (ns)
Contemplation (%)	22.9	21.7	24.8	26.7		
Preparation (%)	19.1	16.7	17.2	21.3		
Action (%)	9.2	10.0	7.6	5.3		
Maintenance (%)	32.1	33.3	30.3	29.3		
Self-reported health						
Excellent (%)	5.9	4.7	7.5	6.6	4.6 (ns)	1.0 (ns)
Very good (%)	28.9	34.4	27.4	34.2		
Good (%)	63.0	59.4	57.5	55.3		
Poor (%)	2.2	1.6	7.5	3.9		
Weak (%)	0.0	0.0	0.0	0.0		

ns : non significant (p > 0.05) * 0.05 ≤ p < 0.01 ** 0.01 ≤ p < 0.001 *** p ≤ 0.001

Pedometer-based and self-reported PA

Analyses (adjusted for age, BMI and distance to work) revealed a downward trend in average steps/day from baseline to follow-up in the total sample (F_{time}=3.3, p=0.071) (see table 2). This decrease was however significantly different between the intervention and comparison worksite ($F_{time\ x\ worksite}$=8.8, p=0.004). The average number of step counts in the intervention worksite dropped by 618 steps from baseline to follow-up, while the step count decrease was larger (-1389 steps) in the comparison worksite (see table 2). Risk profile had a significant impact on this time x worksite interaction ($F_{time\ x\ worksite\ x\ risk\ profile}$=4.1, p=0.046). Post hoc analyses (adjusted for age, BMI and distance to work) showed that intervention participants reaching 10,000 steps at baseline had a smaller drop (-1706 steps/day) in average step counts than the comparison participants (-4006 steps/day) reaching 10,000 steps at baseline ($F_{time\ x\ worksite}$=5.5, p=0.023). There was no significant difference in step count change between intervention and comparison participants not reaching 10,000 steps at baseline ($F_{time\ x\ worksite}$=0.6, p=0.454) (see table 2).

Table 2: PA at baseline and follow-up for participants in the intervention and comparison worksite

	n	Baseline	Follow-up	Δ (95% CI)	F(p)[a]
Daily pedometer step counts (steps/day)					
Total sample	132	9290 ± 3732	8252 ± 3188	-1038 (-1512, -553)	3.3 (ns)
Intervention worksite	60	9484 ± 3684	8866 ± 3326	-618 (-1106, 35)	8.8 (**)
Comparison worksite	72	9129 ± 3789	7740 ± 2996	-1389 (-2201, -716)	
Risk profile at baseline					4.1 (*)
≥ 10,000 steps/day					
Intervention worksite	26	12,806 ± 2743	11,100 ± 3267	-1706 (-2665, -656)	5.5 (*)
Comparison worksite	25	13,345 ± 2665	9339 ± 3505	-4006 (-5234, -2459)	
< 10,000 steps/day					
Intervention worksite	34	6944 ± 1796	7158 ± 2181	+214 (-345, 832)	0.6 (ns)
Comparison worksite	47	6886 ± 1912	6889 ± 2306	+3 (-818, 481)	
Workday pedometer step counts (steps/workday)					
Total sample	128	7103 ± 2404	6821 ± 2158	-282 (-686, -18)	1.3 (ns)
Intervention worksite	57	7403 ± 2244	7317 ± 2087	-86 (-497, 238)	2.9 (ns)
Comparison worksite	71	6862 ± 2515	6423 ± 2145	-439 (-1087, -5)	
Non-workday pedometer step counts (steps/non-workday)					
Total sample	128	9251 ± 4534	8126 ± 4882	-1125 (-2065, -228)	4.2 (*)
Intervention worksite	57	9077 ± 4229	8366 ± 4896	-711 (-1857, 679)	1.7 (ns)
Comparison worksite	71	9389 ± 4789	7934 ± 4897	-1455 (-2899, -263)	
Self-reported total physical activity (minutes/day)					
Total sample	128	66.5 ± 53.4	70.5 ± 54.6	+4.0 (-8.0, 9.3)	1.3 (ns)
Intervention worksite	58	69.9 ± 58.0	72.1 ± 58.6	+2.2 (-148.8, 25.4)	0.02 (ns)
Comparison worksite	70	63.7 ±49.4	69.1 ±51.6	+5.4 (-356.8, 311.1)	

ns : non significant (p > 0.05) * 0.05 ≤ p < 0.01 ** 0.01 ≤ p < 0.001

[a]: when gender was entered as between subject factor in the analyses, effects did not change.

Average workday step counts did not change significantly over time in the total sample (F_{time}=1.3, p=0.262), however, there was a tendency for a slightly smaller decrease in workday step counts in the intervention worksite (-86 steps/day) than in the comparison worksite (-439 steps/day) ($F_{time\ x\ worksite}$=2.9, p=0.090) (see table 2). The risk profile had no influence on this interaction ($F_{time\ x\ worksite\ x\ risk\ profile}$=2.1, p=0.155). The average number of step counts on a non-working day decreased significantly from baseline to follow-up in the total sample (F_{time}=4.2, p=0.044). No significant difference in non-working step count change could be found between the intervention and comparison worksite ($F_{time\ x\ worksite}$=1.7, p=0.192). Again, the risk profile did not affect this ($F_{time\ x\ worksite\ x\ risk\ profile}$=0.001, p=0.975) (see table 2).

No significant changes in the total amount of self-reported PA could be found over time for the total sample (F_{time}=1.3, p=0.264). The changes in self-reported PA did not differ significantly between the intervention and comparison worksite ($F_{time\ x\ worksite}$=0.02, p=0.887), nor did the risk profile affect this ($F_{time\ x\ worksite\ x\ risk\ profile}$=0.07, p=0.788) (see table 2). Furthermore, the changes in self-reported PA in the different domains (at work, during transport, during domestic and gardening activities, or during leisure time) did not differ significantly over time, or between groups (data not shown).

Awareness of and opinion about the intervention

Almost 97% (n=63) was aware of the 20-week PA intervention. Nearly all participants were aware of the posters at the staircase (95%), footsteps towards the staircase (95%), informative email (92%), weekly email with information and tips (92%), and pedometer availability (92%). About 83% was aware of the worksite step competition and more than half (57%) were aware of the flyers and New Year's wishes (see table 3). A considerable amount of participants had a good to very good evaluation about posters at the staircase (89%), pedometer availability (88%), flyers (78%), informative email (77%), and weekly emails (68%). Less participants found the footsteps towards the staircase (56%), New Year's wishes (51%), and the worksite step competition (49%) good to very good (see table 3). Only 26 (8%) intervention participants took part in the worksite step competition, most of them women (81%,n=21) and half of them with baseline step counts below 10,000 steps/day (50%,n=13).

Table 3: Intervention participants' awareness and opinion about the project strategies.

	Awareness	Opinion of those who are aware of the strategy n (%)				
Strategy	**n (%)**	**very bad**	**bad**	**neutral**	**good**	**very good**
Posters at staircase	62/65 (95.4)	0 (0.0)	0 (0.0)	7 (11.2)	35 (56.5)	20 (32.3)
Footsteps towards staircase	62/65 (95.4)	1 (1.6)	4 (6.5)	22 (35.5)	25 (40.3)	10 (16.1)
Informative email	60/65 (92.3)	1 (1.7)	1 (1.7)	12 (20.0)	27 (45.0)	19 (31.7)
Weekly emails	60/65 (92.3)	1 (1.7)	2 (3.3)	16 (26.7)	25 (41.7)	16 (26.7)
Pedometer availability	59/64 (92.2)	0 (0.0)	1 (1.7)	6 (10.2)	36 (61.0)	16 (27.1)
Worksite step competition	54/65 (83.1)	1 (1.9)	6 (11.1)	20 (37.0)	21 (38.9)	6 (11.1)
Flyer	37/65 (56.9)	0 (0.0)	1 (2.7)	7 (18.9)	25 (67.6)	4 (10.8)
New year's wishes	37/65 (56.9)	0 (0.0)	4 (10.8)	14 (37.8)	18 (48.6)	1 (2.7)

Twenty (11 males) intervention participants (31%) reported to have changed their PA behavior because of the intervention. Most of them used the stairs instead of the elevator (90%,n=18). Less indicated 'sport activities' (35%,n=7), 'walking at work' (25%,n=5), 'walking during the weekend' (20%,n=4), 'walking for transport' (15%,n=3), 'parking the car further away' (10%,n=2), and 'walking the dog' (10%,n=2) as their strategy to increase PA. According to 45% (n=9), 'staircase use' was the most easy strategy to implement in daily life.
Almost half the intervention participants (48%,n=31) reported to have used the pedometer during the intervention. Most of them had baseline step counts below 10,000 steps/day (61%,n=19), and about half of them were men (45%,n=14). The majority used the pedometer occasionally (65%,n=20), 29% (n=9) daily, 3% (n=1) weekly and another 3% monthly. The other half did not use a pedometer and this for no particular reason (47%,n=16), because they believed to be already active enough (24%,n=8), because they found it bothersome (12%,n=4), because they had no interest in it (6%,n=2), because they had no time (6%,n=2), because they found it not useful (3%,n=1), or because they already completed an earlier pedometer study (3%,n=1). About 60% of those not using the pedometer during the intervention had baseline step counts below 10,000 steps/day.

Discussion

Summary of findings and reflections

Overall, a downward trend was found in average daily step counts from baseline (end of summer: September) to follow-up (winter: February) in 'somewhat active' employees [25] of a workplace with sedentary jobs. This decrease in daily step counts was significantly smaller in the intervention worksite than in the comparison worksite. Furthemore, a significant intervention effect was only found in already active participants reaching 10,000 steps/day at baseline. In addition, overall non-working day step counts decreased significantly and the

decrease in workday step counts in the intervention worksite was slightly smaller than that in the comparison worksite.
The overall decrease from baseline (summer) to follow-up (winter) may be explained by a seasonal effect: a previous pedometer-based study also revealed a decrease in the amount of PA during wintertime, compared with the rest of the year [26]. The findings suggest that this is mainly due to a decrease in non-working day step counts. Since the present worksite intervention was effective in reducing the step count decrease, which was probably caused by the time of year, it can be suggested that intervention participants partly compensated the decline of step counts due to wintertime by taking step counts indoors (for example taking the stairs, walking around at work). It has to be kept in mind that this strategy was overall only done by already active employees. Similar patterns (reaching already active people) were found in worksite fitness or exercise programs [6]. It was however thought that the present intervention would reach more inactive persons, since it was more accessible than e.g. fitness program. Here, the usefulness of the "10,000 steps/day-concept" for increasing PA [4,8-11,13,15] in inactive individuals could not be confirmed. Only the suitability of the concept for maintaining PA in already active people was proved.

Also, in contrast to the community project "10,000 Steps Ghent", the present worksite project did not result in increased step counts. However, it should be noted that the latter was evaluated after 12 months, consequently comparing data collected in springtime. In addition, "10,000 Steps Ghent" was designed to intervene at the individual, social, and environmental level of the whole community. The range of the present worksite intervention was less widespread, however the current workplace intervention was more explicitly present to the participants than in a community intervention, since individuals spend a considerable amount of their waking time in the workplace. Consequently, in the present study, almost everyone (97%) was aware of the intervention, while project awareness in "10,000 Steps Ghent" was somewhat less (63%) [4]. However, the higher project awareness here did not result in increased steps.

Despite the high overall intervention awareness and the good evaluation of the intervention strategies, only 20 participants (31%) reported to have changed their PA behavior because of the intervention. Intervention participants indicated 'the use of the stairs instead of the elevator' as most easy to implement in daily life (90%). A workplace study in the United States showed that this strategy was less popular (24%) [27]. However, the latter 8-week intervention did not promote stair use explicitly, while the present intervention did (posters in the hall and footsteps towards the stairs). Unfortunately, there is no objective information available on staircase use. Although staircase use can be a valuable aspect in a broad PA promotion approach, emphasizing the accumulation of lifestyle activities, it is important to recognize that simply taking the stairs instead of the elevator once or twice a day, is not enough to increase PA considerably. Boreham et al [28] showed that previously sedentary young women who progressed (over 7 weeks) from 1 ascent per day to 6 ascents per day, had considerable cardiovascular health benefits.

Although pedometers were made available to every employee in the intervention worksite, only 31 (48%) indicated to have used the pedometer during the intervention, mostly occasionally (65%), only 29% daily. It was however promising that most pedometer users (61%) had baseline step counts below 10,000 steps/day. However, the majority (59%) of those who did not use a pedometer was also inactive. The rather low proportion of pedometer users, could explain the low proportion of step count increase. Previous research showed that step count increase is associated with pedometer use, which partly mediated the effect of "10,000 Steps Ghent" on increasing step counts [29].

Practical implications

Although the differences between the worksites were significant, one could doubt the importance of the reduction in seasonal decline for health and wellbeing. It is indeed impossible to prove the biological relevance, since no objective health factors were measured here. Still, the step count decreases in the comparison worksite are considerable (-1389 steps or -15% from baseline overall, and -4006 steps or -30% from baseline in active comparison employees) and could stand for a decrease of about 13 minutes (overall) and 40 minutes (active employees) of walking. To prevent such decreases is meaningful, even in somewhat active employees.

Present findings suggest that this intervention was not effective for 'at-risk employees'. Consequently, more attention should be given to those most in need of (more) PA. The intervention was easy to implement and Marshall suggested programs with less 'organized' approaches [6], however, it is probably desirable to provide counseling sessions or extra support in order to increase PA in the workplace. Still, this approach may be unrealistic and unaffordable in a public health promotion perspective.

Furthermore, as only about half of the intervention participants used the free available pedometer during the program, future interventions could request (employees) explicitly to use the pedometer and to keep daily log books.

Although the intervention was implemented in the workplace, overall PA in different settings (e.g. during transport, leisure time) was promoted. Nevertheless, the intervention effect was only present on workday step counts. No significant intervention effect was found for non-workday step counts. Maybe more attempts should be made to affect leisure time and non-workday PA behaviors during workplace interventions.

Strengths and limitations

The main limitation of the present study is the substantial selection bias, caused by the relatively small sample size at baseline and the low response rate at follow-up. In addition, enrollment and attrition rates differed between the intervention and comparison worksite, as also did some participant characteristics. Furthermore, drop-out analysis revealed that the intervention drop-outs were younger and took less step counts than those who completed the study. Overall, these weaknesses limit the generalizability of the results. Moreover, the sample is limited to well educated, normal weight, non-smoking, and self-perceived healthy adults.

Other limitations are the lack of objective data on staircase use and the relatively short term follow-up period, giving data collection in different seasons. It is unknown whether step counts will indeed increase again in springtime and whether the intervention has any effect on that. In addition, the finding on the workday step count should be interpreted with caution. Since the pedometer used in the present study does not include a time indication, it is not known whether the workday step counts were actually taken at work or elsewhere. Furthermore, individual-level randomization was not possible. However, the present quasi-experimental study has also strengths. First of all, this pedometer-based workplace study is one of the few including a control group. Additionally, the intervention was done in a real life setting and evaluated with objective pedometer data. Pedometers are able to detect subtle change in PA behavior, which may not be found through questionnaire. That's maybe why the present effects on step counts were not confirmed by the self-reported PA data [30].

Conclusion

The present pedometer-based workplace intervention was successful in already active individuals, by showing a reduction in the decrease in step counts caused by the time of year. Project awareness was very high and the employees had a good to very good evaluation of the intervention strategies. Continued high-quality research investigating the effectiveness of easily implementable pedometer-based workplace interventions nested in a supportive environmental context is needed to contribute to the health promotion field.

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The following papers regarding the intervention at the macro-level, do not describe in detail the approaches used before and during the community intervention "*10,000 Steps Ghent*". The project was based on a social ecological model (McLeroy et al, 1988; Stokols, 1992; Gregson et al, 2001), meaning that strategies are being developed to intervene at different environmental levels (intrapersonal, interpersonal, organizational, community, societal). A strategy can have an effect on that specific level, but also on all the levels below it.

Throughout the intervention, the role of power in environmental change should be recognized. Consequently, *empowerment* (the process through which individuals, communities and organizations change their social and political environment), *community capacity*, and *social capital* are essential (Bartholomew et al, 2006; Harting et al, 2007). '*Community capacity'* is the interaction of human capital, organizational resources, and social capital available to increase community problem solving to improve or maintain well-being (Norton et al, 2002), while '*social capital'* is the total of norms and social networks available in a community (Morgan and Swann, 2004).

The community intervention was based on the five-stage process of community organization of Bracht and colleagues (1999). Stage one consists of the 'community analysis', or careful mapping of the community assets, capacity, and history, while involving local members of the community. In Ghent, the Department of Movement and Sports Sciences of the Ghent University, who had the approval of the researchers from Rockhampton, was the initiator of the intervention. At this stage, the local city (department sport and department mobility) and provincial (department sport) governments, three local health insurance companies, and the local health promotion service were involved to set up a broad framework for intersectoral collaboration. This core group, with citizens and professionals, prepared stage two, namely the 'design and initiation of a campaign', and made preliminary decisions regarding campaign objectives and interventions. It was decided that "*10,000 Steps Rockhampton*" (Brown et al, 2003) would form the basis of the intervention in Ghent. The initial aims of the Ghent project were to

- increase physical activity in sedentary citizens
- convince the population that regular physical activity
    - is beneficial for health
    - improves fitness and overall well-being

- is a way of easy exercising in daily life
- can enhance traffic and make it environmentally friendly

- integrate daily physical activity into the city scene
- convince intermediaries to carry out the message.

The central theme was *'10,000 steps'*, with the secondary tagline of '*every step counts' (elke stap telt, elke trap telt)*, used to stress that step counts can be accumulated during the whole day. Furthermore, the secondary tagline also encourages those who do not reach 10,000 steps/day to find ways to increase daily steps (Brown et al, 2003). Several strategies were adapted (e.g. media campaign, sale of pedometers) from the original campaign in Rockhampton. In the third stage, the 'campaign implementation', theory and ideas turned into action, translating the mission into an operating program. A sequential or simultaneous set of activities (see chapter 2.2.3) was implemented. During stage four ('program refinement and consolidation'), successes and problems in implementation were reviewed and new directions or modifications determined. For example, the sale of pedometers was disappointing, therefore, a loan system was developed by the local sports department. In the final stage, 'dissemination and durability', project results were spread and a durability plan included a vision for future improvements and strategies. In Ghent, it was decided that the local authorities could support the continuation of the campaign. Note that all stages were dynamic and may have overlapped each other.

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CHAPTER 2.2.3

EFFECTS OF "10,000 STEPS GHENT". A WHOLE-COMMUNITY INTERVENTION

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Effects of "10,000 Steps Ghent"

A Whole-Community Intervention

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Background: Currently there is a great deal of interest in multistrategy community-based approaches to changing physical activity or health behaviors. The aim of this article is to describe the effectiveness of the physical activity promotion project "10,000 Steps Ghent" after 1 year of intervention.

Methods: A multistrategy community-based intervention was implemented in 2005 with follow-up measurements in 2006 to promote physical activity to adults. A local media campaign, environmental approaches, the sale and loan of pedometers, and several local physical activity projects were concurrently implemented. In 2005, 872 randomly selected subjects (aged 25 to 75), from the intervention community Ghent and 810 from a comparison community, participated in the baseline measurements. Of these, 660 intervention subjects and 634 comparison subjects completed the follow-up measurements in 2006. Statistical analyses were performed in 2006.

Results: After one year there was an increase of 8% in the number of people reaching the "10,000 steps" standard in Ghent, compared with no increase in the comparison community. Average daily steps increased by 896 (95% CI=599–1192) in the intervention community, but there was no increase in the comparison community (mean change −135 [95% CI= −432 to 162]) (F time × community=22.8, $p<0.001$). Results are supported by self-reported International Physical Activity Questionnaire (IPAQ) data.

Conclusions: The "10,000 steps/day" message reached the Ghent population and the project succeeded in increasing pedometer-determined physical activity levels in Ghent, after 1 year of intervention.
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Introduction

Regular physical activity is essential for maintaining health and reducing the risk of many causes of morbidity and mortality.[1] However, most adults in Europe (43%–87%),[2] the United States (60%),[1] and Australia (43%)[3] lead a sedentary lifestyle. International guidelines recommend the accumulation of a minimum of 30 minutes of at least moderate intensity physical activity on most, if not all, days of the week.[1] An alternative guideline recommends the accumulation of 10,000 steps/day,[4] and both recommendations are being used in lifestyle physical activity interventions in different populations and in controlled settings.[5]

The "10,000 Steps Ghent" project was built on the approach used in the Australian "10,000 Steps Rockhampton" project[6] and served as a pilot intervention for Europe. In Rockhampton, which has high levels of overweight and obesity,[6] physical activity was promoted through a media campaign, health professionals, environmental support, and community initiatives. The present intervention also used multiple concurrent community-based strategies to promote physical activity to less at-risk adults. Guided by the social ecologic model,[7] this whole community intervention was designed to intervene at the individual (e.g., pedometer sale), social (e.g., workplace projects), and environmental (e.g., walking circuits) level.[8] Previous multistrategy community interventions (combining media advertising; community-based face-to-face instructions; walking groups; school, worksite, church and environmental initiatives), have reported no or only small physical activity changes,[9–13] and none have used objective pedometer assessment of physical activity as their main outcome measure.[10]

The primary aim of this paper was to report changes in both pedometer-determined and self-reported physical activity levels in Ghent after 1 year of intervention, compared with those in a comparison community. Since the project involved a pedometer step-count intervention, an influence on walking behavior was expected; this was assessed using pedometers and

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through the "walking" item of the International Physical Activity Questionnaire (IPAQ). A secondary aim was to evaluate whether the intervention was effective with insufficiently active people. Respondents who did not reach the 10,000 steps target at baseline were identified, and changes in their physical activity were compared in the intervention and comparison community. The final aim was to describe awareness of the project and the most common sources of project information in the intervention community.

Methods

Design

The study utilized a controlled pre–post design, with baseline data collected in March–May 2005 and follow-up data 12 months later. The intervention community was Ghent (capital of the East Flanders province of Belgium; population, 228,000), and the comparison community was the smaller city of Aalst (located 35 km to the southeast of Ghent; population, 77,000). Both communities were selected because of their demographic and geographic comparability.

Intervention Development and Implementation

The intervention was based on and performed in cooperation with researchers from the 10,000 Steps Rockhampton project.[6] The present project was developed by the Department of Movement and Sports Sciences of Ghent University, in collaboration with local city and provincial governments, three health insurance companies, and the local health promotion service. Physical activity was promoted to all adults in the defined Ghent community, using a central theme of 10,000 steps/day, with a secondary tagline of "Every step counts." The accumulation of at least 30 minutes of moderate-intensity physical activity on most, preferably all, days of the week,[14,15] and participation in more-vigorous activity or sport for a minimum of 20 minutes 3 days each week,[14] were also promoted. The implementation included several strategies at the different levels of the social ecologic model[16] (see Table 1).

Table 1. The social–ecologic approach of the 10,000 Steps Ghent intervention

Ecologic level	Intervention strategy
Intrapersonal	Local media campaign Website use Sale and loan of pedometers
Interpersonal	Dissemination of information through all associations
Organizational/ institutional	Workplace projects Projects for older people Dissemination of information through health professionals Dissemination of information through all schools
Community	Local media campaign Environmental approaches
Social structure, policy, and systems	Local media campaign Sale and loan of pedometers through the local town shop Sale and loan of pedometers through Ghent sport services department

Local media project. Press conferences were organized at the start of the intervention and again on six occasions during the year, with subsequent publicity about the project in local newspapers. A full-page advertisement was also published in the town magazine, a periodical delivered to every household. The project was mentioned about six times in local newscasts, and billboards were placed at 20 different locations.

Website. Information about the project, physical activity and health, tips on how to increase daily activity, frequently asked questions, contacts, and reports on planned or completed activities (e.g., a culinary walk in the city center) were placed on the project website (www.10000stappen.be).

Environmental approaches. Street signs were placed strategically throughout the city to raise awareness of walkable distances and to encourage walking. For example, from every public parking place, signs showed the number of steps to get to the city center. In addition, walking circuits were laid out in two local town parks, with signs along these to show distances traveled and the number of steps likely to be accumulated.

Sale and loan of pedometers. A booklet with "how-to" information and a step-count log were designed to be sold with pedometers that were used as both individual self-monitoring and motivational tools. The pedometer package (pedometer and booklet) was sold for €20 (about $26) by the local government information store, by the Ghent sport services department, by pharmacies, and by local divisions of the health insurance companies. The local sport services also coordinated a pedometer loan system of 15 kits through which schools, companies, and community groups could borrow a kit with flyers, posters, and 30 pedometers.

Workplace projects. A plan of action with specific information on how to promote physical activity in the workplace was given to the health/personnel departments of all companies with at least 100 employees (n=23). Kits were made available but no other (financial) support was given to the worksites.

Projects for groups of older people. In order to reach the large population of older, mostly inactive[1] people, all clubs (n=26) and services (n=8) for older people were given promotional materials and instructed on how to promote physical activity. All members of the clubs and services were also invited to a walk-event in the local town park.

Dissemination of information. Flyers, posters, and information about the pedometer loan system were sent to all schools (n=169), general practitioners (n=592), dieticians (n=26), and physical therapists (n=308), as well as to all associations and societies.

Evaluation

Recruitment and response rates. Twenty-five hundred citizens (25–75 years) were randomly selected from the population registers of each city (500 for each age group: 25–35, 36–45, 46–55, 56–65, 66–75). For those with a telephone number (1765 in Ghent, 1919 in Aalst), a minimum of four calls were made before recording the person as "not contactable" (419 in Ghent, 516 in Aalst). The response rate for this telephone recruitment was 54% (729 of 1346) in Ghent

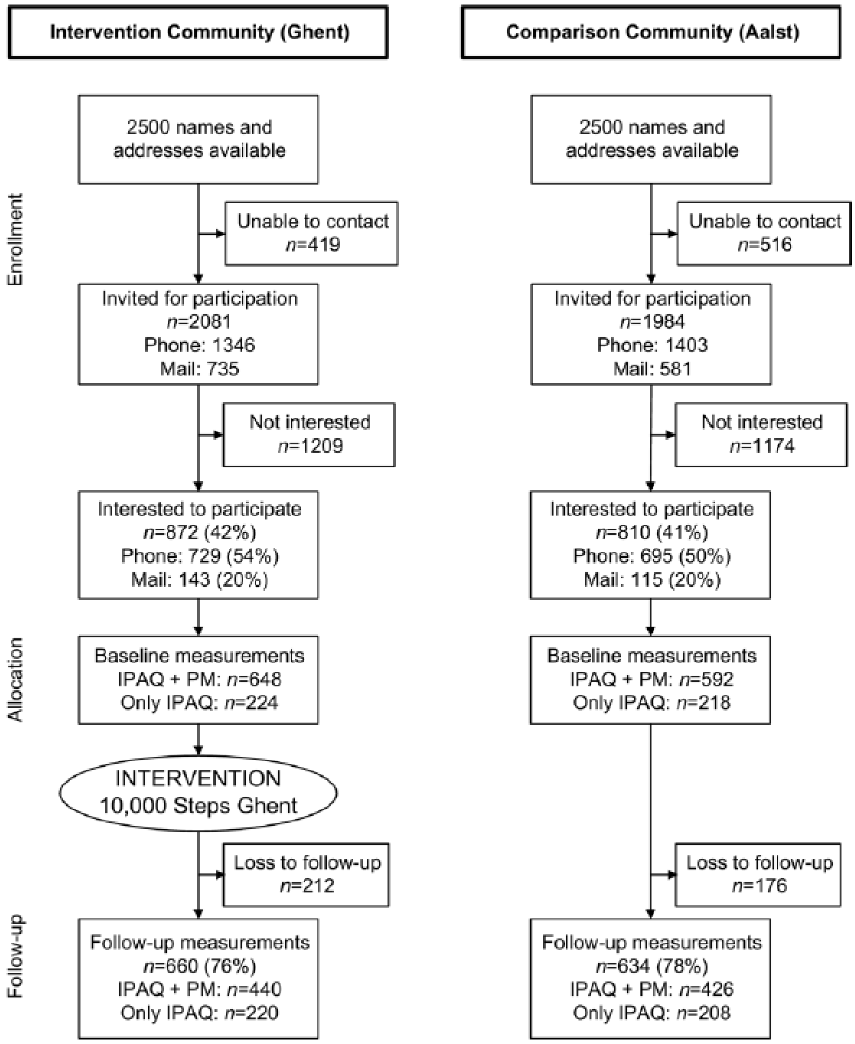

Figure 1. Participant flow. IPAQ, completion of the International Physical Activity Questionnaire; PM, completion of the pedometer records.

and 50% (695 of 1403) in Aalst. All those without a telephone number were sent a written invitation to participate in the study (735 in Ghent; 581 in Aalst). The response rate for this mailed recruitment was 20% in both communities, making the overall response rate 42% (n=872) in Ghent and 41% (n=810) in Aalst. More than three quarters of the initial respondents (Ghent: 76%, n=660; Aalst: 78%, n=634) completed the follow-up protocol. (see Figure 1).

Procedures for data collection. Participants were asked to complete the telephone-administered long version of the IPAQ and to monitor their pedometer steps daily for 7 consecutive days. Based on previous methods,[17] a package was mailed to all participants who completed the IPAQ and agreed to monitor their steps. The package included a pedometer, a protocol describing how and when to use it, an activity log for noting daily steps and keeping daily activity records, a written informed consent form, and a stamped addressed envelope for return mailing. All participants were instructed to wear the pedometer on their waistband or belt during waking hours. They were requested to reset their pedometer to zero at the beginning of each day, to continue with their usual activities, and to remove the pedometer only while showering, bathing, or swimming. They were asked to complete the activity log at the end of each day.

After 1 year of intervention, all participants who completed baseline measurements were contacted again by telephone or mail. They were asked to complete the IPAQ (baseline procedures) and a questionnaire relating to awareness of the 10,000 Steps Ghent project. After completion of the questionnaires, a package was mailed to them to monitor their steps for 7 consecutive days, if they had done this at baseline. All participants gave written informed consent and the study protocols were approved by the Ethical Committee of the Ghent University.

Seven interviewers (master degree, native speakers) were given 2 hours of interview training, focusing on the potential problem of overreporting, and were supervised throughout data collection.

Instruments

Physical activity questionnaire. The long form of the IPAQ was used to assess the different domains of physical activity in a usual week, namely physical activity at work, transport-related physical activity, domestic and gardening activities, and physical activity during leisure time. The IPAQ has been shown to be a valid and reliable instrument for assessing physical activity at the population level in Europe[18] and in Flanders, Belgium.[19] Total time for physical activity in the four domains and total time for walking, moderate, and vigorous physical activity, all expressed in minutes/week, were computed (www.ipaq.ki.se). Questions were also asked about participants' employment status (employed/unemployed), and about number of years of education and self-reported health (excellent/very good/good/moderate/poor).

Pedometers. The Yamax Digiwalker SW-200 (Yamax, Tokyo, Japan) was used in this study as it is known to be valid, accurate, and reliable for counting steps in adults.[20]

Activity log. Participants were requested to record the date, steps taken at the end of the day, and the type and duration of nonambulatory activities (i.e., biking and swimming) in an activity log.[21] Following established guidelines,[22] researchers added 150 steps to the daily total for every minute of reported biking and/or swimming.

Questionnaire relating to awareness of the project at follow-up. In 2006, additional items were used to assess awareness of the project. Participants were asked to complete the following questions: Have you heard or seen any messages about physical activity? (yes/no); If you have heard information about physical activity, where did you hear it? (open-ended); Have you heard of the 10,000 Steps Ghent project? (yes/no); Where did you hear about 10,000 Steps Ghent? (radio, TV, print media, Internet, street signs, workplace, health service, (para)medic, society, family, friends, or school); Are you aware of any of the following activities which are being supported by 10,000 Steps Ghent?: sale of pedometers, loan of pedometer boxes, walk circuits in local town parks? (yes/no); Have you used a pedometer in the last 10 months? (yes/no), and Where did you get your pedometer? (bought at 10,000 Steps point of sales/borrowed at 10,000 Steps/elsewhere). A timeframe of 10 months was used to avoid inclusion of baseline pedometer measurements.

Data Analysis

All data were analyzed in 2006 using SPSS 12.0 for Windows. Demographic characteristics of intervention and comparison respondents were compared, using independent-sample t-tests and chi-square tests. Average daily steps were calculated for the two periods of 7 days (baseline and follow-up). Values over 20,000 steps/day were recorded as 20,000 to limit unrealistically high average step counts and to ensure normal distribution.[17] Repeated measures of analysis of covariance (ANCOVAs) with time (baseline/follow-up) as the within-subjects factor and community (Ghent/Aalst) as the between-subjects factor, were conducted to evaluate the effects of the project on pedometer-determined and self-reported physical activity. These analyses were done for (1) the total sample and (2) those who did not reach the 10,000 steps/day target at baseline. Analyses were adjusted for age and number of years of education. Time × community interactions were used to test for intervention effects. Effect sizes (Cohen's d) were computed by subtracting the change in Aalst from the change in Ghent, and dividing this score by the pooled standard deviation of change.[23] Effect sizes were interpreted as negli-

Table 2. Characteristics of participants who completed pedometer and IPAQ registrations

Demographics	Ghent baseline (n=648)[a]	Follow-up (n=440)[a]	Aalst baseline (n=592)[a]	Follow-up (n=426)[a]	Baseline comparison t/χ^2 (p)	Follow-up comparison t/χ^2 (p)
Age (years)					0.2 (ns)	0.2 (ns)
Years (mean ± SD)	48.7 ± 14	49.8 ± 13.3	48.5 ± 13.3	50 ± 12.9		
25–35 (%)	21.6	16.1	18.9	14.8	2.2 (ns)	1 (ns)
36–45 (%)	20.5	22	23	21.1		
46–55 (%)	22.8	25.2	23.5	26.8		
56–65 (%)	19.8	22.5	20.3	21.6		
66–75 (%)	15.3	14.1	14.4	15.7		
Gender (%)					1.3 (ns)	2.2 (ns)
Men	47.2	47.5	50.5	52.6		
Level of education (%)					2.9 (ns)	2.3 (ns)
College or university degree	60	58.9	55.2	53.8		
Employment status (%)					0.1 (ns)	5.8 ($p \leq 0.05$)
Employed	68.1	62.4	67.3	54.4		
Self-related state of health (%)					2.4 (ns)	8.5 (ns)
Excellent	9.6	11.2	8.3	7.8		
Very good	2.9	30.5	29.3	29.6		
Good	51.2	49	48.7	49.4		
Poor	9.9	8.2	11.2	9.6		
Weak	1.9	1.1	2	3.5		

[a]Numbers vary slightly due to missing data for some items.
IPAQ, International Physical Activity Questionnaire; ns, not significant (p>0.05).

Table 3. Mean physical activity at baseline and follow-up for respondents in each community

	Respondents who completed IPAQ and pedometer records					Respondents who only completed IPAQ				
	Baseline (n=440)	Follow-up (n=426)	Δ (95% CI)	F(p)	d	Baseline (n=220)	Follow-up (n=208)	Δ (95% CI)	F(p)	d
Pedometer-determined PA (steps/day)				22.6 (***)	0.33					
Ghent	9596 ± 4256	10,491 ± 4306	+896 (599 to 1192)							
Aalst	9669 ± 4018	9534 ± 3978	−135 (−432 to 162)							
Walking (min/week)				4.7 (***)	0.15				5.7 (*)	0.23
Ghent	288 ± 357	305 ± 382	+17 (−47 to 14)			321 ± 391	323 ± 407	+2 (−53 to 49)		
Aalst	301 ± 387	271 ± 353	−30 (1 to 61)			308 ± 423	219 ± 335	−89 (31 to 145)		
Moderate PA (min/week)				7 (***)	0.17				1.1 (ns)	0.12
Ghent	480 ± 385	468 ± 372	−12 (−28 to 52)			448 ± 428	445 ± 390	−3 (−55 to 59)		
Aalst	554 ± 432	470 ± 401	−84 (43 to 125)			513 ± 427	461 ± 385	−52 (−7 to 111)		
Vigorous PA (min/week)				1.4 (ns)	0.05				0.1 (ns)	0.01
Ghent	112 ± 276	99 ± 255	−13 (−10 to 36)			120 ± 284	106 ± 271	−14 (−16 to 45)		
Aalst	106 ± 258	80 ± 200	−26 (1 to 50)			103 ± 258	93 ± 231	−10 (−25 to 46)		
Work-related PA (min/week)				15.9 (***)	0.27				5.3 (*)	0.23
Ghent	286 ± 561	355 ± 625	+68 (−111 to −26)			333 ± 619	355 ± 642	+22 (−98 to 54)		
Aalst	350 ± 642	300 ± 591	−50 (10 to 89)			410 ± 675	306 ± 576	−104 (33 to 175)		
Transport-related PA (min/week)				0.2 (ns)	0.03				0 (ns)	0.02
Ghent	140 ± 189	134 ± 168	−6 (−12 to 23)			144 ± 205	126 ± 193	−18 (−11 to 48)		
Aalst	110 ± 170	99 ± 131	−11 (−6 to 26)			101 ± 185	78 ± 118	−23 (1 to 45)		
Household PA (min/week)				1.5 (ns)	0.08				2.5 (ns)	0.17
Ghent	347 ± 375	308 ± 304	−39 (6 to 72)			299 ± 361	300 ± 318	+1 (−50 to 48)		
Aalst	423 ± 439	351 ± 369	−72 (31 to 113)			380 ± 415	317 ± 327	−63 (7 to 120)		
Leisure time PA (min/week)				4.4 (*)	0.15				0.1 (ns)	0.02
Ghent	140 ± 185	125 ± 178	−15 (−3 to 34)			140 ± 195	127 ± 206	−13 (13 to −12)		
Aalst	172 ± 264	125 ± 173	−47 (26 to 68)			118 ± 148	107 ± 143	−11 (−13 to 34)		

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
IPAQ, International Physical Activity Questionnaire; ns, not significant (p>0.05); PA, physical activity.

gible (<0.15), small (0.15–0.40), medium (0.40–0.75) or large (>0.75).[23] Descriptive statistics and chi-square tests were used to analyze the responses to questions about awareness of the project. A statistical significance level of 0.05 was used in all analyses.

Results

Participant characteristics

Demographic characteristics of the respondents who completed both the IPAQ survey and the pedometer/activity logs are shown in Table 2. Both samples were representative of the general population in each city, with the exception that respondents in Ghent were significantly older than the total community population (Ghent: 48.7 vs 46.5, t=4.0, $p<0.001$; Aalst: 48.5 vs 48.6, t=0.1, $p=0.910$). The proportion of men in both samples (Ghent: 48%; Aalst: 53%) were comparable to those in the total populations (Ghent: 50%, chi-square=22.1, $p=0.605$; Aalst: 50%, chi-square=0.3, $p=0.603$). There were no significant differences between Ghent and Aalst at baseline but at follow-up the proportion of employed participants was significantly higher in Ghent than in Aalst (see Table 2).

For the total sample, comparisons were made between subjects who provided step-count data at baseline and those who did not. Subjects who had a job were more likely to complete the pedometer protocol than unemployed subjects (odds ratio=1.58, $p=0.002$). Analyses of gender, age, level of education, state of health, and total amount of physical activity (based on IPAQ reports) showed no significant differences between the two groups.

Physical activity measures

Significant intervention effects were found for mean steps/day with an average increase of 896 steps/day in Ghent and a decrease of 135 in Aalst (see Table 3). In Ghent, 48% of the respondents had a minimum increase of 896 steps/day and average daily step counts increased significantly in both men (F=10.5, $p=0.001$) and women (F=12.8, $p<0.001$); and in young (25–45 years) (F=4.9, $p=0.029$), middle-aged (46–65 years) (F=6.8, $p=0.009$), and older (66–75 years) (F=9.3, $p=0.002$) adults.

Pedometer-based data revealed that the proportion of participants reaching the 10,000 steps/day target had increased from baseline (42%) to follow-up (50%) in Ghent (t=3.2, $p=0.001$). Extrapolation of this increase of 8% to the total population of Ghent indicates that 18,500 citizens became more active. Corresponding proportions in Aalst were 41% and 40% (t=1.3, $p=0.205$).

There were significant intervention effects for reported time spent in walking, moderate, work-related, and leisure-time physical activity for participants completing the IPAQ and pedometer protocol (see Table 3).

Table 4. Mean physical activity at baseline and follow-up for respondents in each community who did not reach the 10,000 steps target at baseline

	Baseline (n=250)	Follow-up (n=242)	Δ (95% CI)	F(p)	d
Pedometer-determined PA (steps/day)					
Ghent	6660 ± 2284	8247 ± 3137	+1586 (−1934 to −1239)	12.2 (***)	0.31
Aalst	6961 ± 2128	7710 ± 3051	+749 (−1070 to −428)		
Walking (minutes/week)				0.4 (ns)	0.03
Ghent	243 ± 333	242 ± 339	−1 (−32 to 35)		
Aalst	224 ± 329	210 ± 308	−14 (−16 to 43)		
Moderate PA (minutes/week)				1.8 (ns)	0.09
Ghent	444 ± 397	421 ± 370	−23 (−26 to 72)		
Aalst	488 ± 421	429 ± 389	−59 (10 to 108)		
Vigorous PA (minutes/week)				4.4 (*)	0.15
Ghent	81 ± 240	78 ± 235	−3 (−22 to 26)		
Aalst	81 ± 233	44 ± 131	−37 (9 to 63)		
Work-related PA (minutes/week)				9.6 (**)	0.26
Ghent	211 ± 496	280 ± 566	+68 (−121 to −16)		
Aalst	248 ± 556	206 ± 503	−42 (−4 to 87)		
Transport-related PA (minutes/week)				0.4 (ns)	0.03
Ghent	113 ± 179	100 ± 145	−13 (−7 to 31)		
Aalst	97 ± 153	80 ± 108	−17 (−1 to 34)		
Household PA (minutes/week)				0.6 (ns)	0.05
Ghent	356 ± 393	303 ± 307	−53 (9 to 97)		
Aalst	414 ± 454	341 ± 372	−73 (20 to 126)		
Leisure time PA (minutes/week)				0 (ns)	0.02
Ghent	116 ± 174	87 ± 145	−29 (8 to 49)		
Aalst	124 ± 208	100 ± 141	−24 (−1 to 49)		

*$p\leq0.05$; **$p\leq0.01$; ***$p\leq0.001$.
ns, not significant ($p>0.05$); PA, physical activity.

Table 5. Project awareness

	Ghent (n=660) (%)	Aalst (n=634) (%)	χ^2	Ghent gender comparison χ^2
Have you heard or seen any messages about PA?				
Yes (total group)	54	41.3	20.9 (***)	
Yes (men/women)	44.7/62.8	39.4/43.3		21.7 (***)
If you had information about PA, where did you get it from?			86.6 (***)	
10,000 Steps Ghent	12.1	0.2		
Men/women	11.9/12.3	0.3/0		4.4 (ns)
Media	30.3	32.8		
Men/women	25.4/34.9	32.7/32.9		5.1 (*)
Health services	11.2	8.4		
Men/women	6.9/15.2	6.0/10.7		10.2 (***)
Have you heard of the project "10,000 Steps Ghent"?				
Yes (total group)	63.2	10.4	384.9 (***)	
Yes (men/ women)	55.2/70.7	10.2/10.7		17 (***)
Are you aware of any of the following activities which are being supported by 10,000 Steps Ghent?				
Sale of pedometers (yes)	32.9	0.5	240.6 (***)	
Men/women	25.1/40.2	0/0.9		17 (***)
Loan of pedometer boxes (yes)	12.4	0.2	81.1 (***)	
Men/women	9.4/15.2	0.3/0		5.2 (*)
Walk circuits in local town-parks (yes)	6.5	0	42.7 (***)	
Men/women	4.1/8.8	0/0		6 (*)
Have you used a pedometer in the last 10 months?				
Yes (total group)	13.9	9.5	6.2 (*)	
Yes (men/women)	10/17.6	8.0/11.0		7.9 (**)
If you used a pedometer, where did you get it?			11.1 (ns)	
Bought at 10,000 Steps point of sales	2.0	0.3		
Borrowed at 10,000 Steps	1.2	0.3		
Elsewhere	10.7	8.9		

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
ns, not significant ($p > 0.05$); PA, physical activity.

Separate within-group changes were significant in Ghent for vigorous physical activity (F=1.6, p=0.029) and there was a trend of significance for moderate physical activity (F=1.4, p=0.058). In Aalst, transport-related physical activity decreased significantly (F=6.3, p=0.012). In the group that only completed the IPAQ, intervention effects were significant for walking and work-related physical activity (see Table 3). Within-group changes revealed that work-related physical activity increased significantly in Ghent (F=6.8, p=0.010) and decreased significantly in Aalst (F=11.5, p=0.001).

In participants, who did not reach the 10,000 steps/day target at baseline (at-risk group), there was an increase of 1586 steps/day in Ghent (+23%), compared with 749 steps/day (+11%) in Aalst (F time × community × group (at risk/not at risk)=1.1, p=0.285). Intervention effects were also significant for reported vigorous physical activity and work-related physical activity (see Table 4).

Awareness of the 10,000 Steps Project

In 2006, 54% of the Ghent sample and 41% of the Aalst sample reported hearing or seeing information about physical activity promotion (Table 5). In Ghent, about 12% voluntarily indicated 10,000 Steps Ghent as the source of their information, while in Aalst only one person answered 10,000 Steps Ghent. Almost two thirds (63%) of the Ghent respondents confirmed having heard of the project, compared with 10% in Aalst. The most commonly cited sources of information about the project were the print media, local TV, and street signs. In Ghent, more than 32% of respondents were aware of the sale of pedometers and about 12% of the loan system, but only 7% were aware of the walking circuits. About 14% of the Ghent sample reported using a pedometer in the last 10 months, compared with 10% in Aalst. In Ghent, 2% purchased a pedometer through one of the project's points of sale, and 1% borrowed one from the loan system. In the Ghent sample, significantly more women than men answered positively to most of the awareness questions (see Table 5).

Discussion

These findings demonstrate that the 10,000 Steps Ghent project was successful in increasing physical activity levels and reaching the population in the intervention community. Evidence of this positive impact was the significant increase in both pedometer-determined physical activity and self-reported physical activity from the IPAQ, as well as high project awareness in the intervention sample. The average increase of 896 steps/day was commensurate with a 9% increase from baseline steps/day in Ghent. This finding, together with the increase of 8% in the number of individuals who reached the 10,000 steps standard, is noteworthy on a population level. Even though effect sizes were relatively small (0.15–0.33), they are considerable for a whole-community intervention. Importantly, effect sizes for the pedometer data did not differ between the total study sample and the at-risk group, indicating that the intervention reached many who were deemed at risk at baseline. Surprisingly, the intervention was effective for total physical activity and not only for walking, as hypothesized.

Few other studies have examined the effect of multistrategy population-level interventions on physical activity behaviors.[11–13,24,25] In general, increases in physical activity have been reported among motivated subgroups of volunteers who register for intervention studies, but few of these have reported increases in physical activity on a community level. In contrast, in this study, there were significant increases in physical activity in randomly recruited community residents, as well as in those who were not initially meeting guidelines for physical activity. Self-reports revealed that the at-risk group increased their physical activity mostly at work, which suggests that the workplace might be an appropriate setting to reach this group.

The Australian 10,000 Steps Rockhampton project was the first whole-community multistrategy intervention to promote the 10,000 steps/day concept. Based on self-reported physical activity data from interview surveys, the main outcome of the Rockhampton project was that the downward trend in the percentage of citizens categorized as active (−6%) in the comparison community for the current study was not evident in Rockhampton (+1%). In contrast, in Ghent, there was a much greater increase (8%) in physical activity, as measured by objective pedometer data, and a much smaller decline in the comparison community of Aalst (−2%).

However, in Rockhampton (population 60,000), which is considerately smaller than Ghent (population 228,000), almost 95% of all respondents had heard of the project, compared with 63% in Ghent. This probably reflects the greater emphasis on social marketing in the Rockhampton project.[6] Interestingly, in both countries, women showed a greater awareness of the project strategies than men, and in Rockhampton there were significant increases in physical activity in women but not in men. This gender difference was not apparent in Ghent.

In Australia, 34% of the comparison community had heard of the project, compared with only 10% in the present study. Once again, this may reflect the greater emphasis on social marketing in the Australian project, with TV reports being picked up in both the comparison and intervention Australian communities. Apparently, the Aalst residents were less likely to have been exposed to the social and environmental intervention strategies, despite the close distance between present communities.

Even though Aalst (population 77,000) is the second largest city in East Flanders after Ghent, there is a reasonable difference in the size of these two communities. In terms of demographic variables however, respondents from each community were comparable, except that the proportion of employed participants was higher in Ghent at follow-up. Although this may have influenced pedometer-determined physical activity, the evidence is somewhat ambiguous.[22,26] Baseline step-count levels in both communities were also comparable, and relatively high compared with American samples (6000–6800 steps/day),[22] but lower than those reported in the UK (11,300 steps/day).[27] The present sample included more highly educated people than the total Belgian population (43%) (www.iph.fgov.be); this can be a potential source of bias. Furthermore, the intervention sample was slightly but significantly older than the general Ghent population. This is important because pedometer-determined physical activity is negatively associated with increasing age.[17,28]

The strengths of this study include the random recruitment of participants, intervention in a real-life setting, use of objective step data, and relatively small loss to follow-up. The main limitation of the study is that only short-term effects are described. Additionally, it is important to note that awareness may have been influenced by study participation; this would however have been true for both the Ghent and Aalst samples. Moreover, the awareness questionnaire reported only on descriptive items, so that further theoretic implications of the effect of the specific ecologic components on behavior could not be made.

Conclusion

The preliminary results of this pilot study for Europe are promising. The 10,000 Steps Ghent project is the first pedometer-based intervention to show an increase in physical activity levels at the whole-community level, supporting, the implementation of multistrategy intervention programs in whole communities. Consequently, the intervention will be continued in Ghent and will now be implemented in other parts of Flanders, Belgium, and possibly in other European cities.

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CHAPTER 2.2.4

THE EFFECT OF A PEDOMETER-BASED PHYSICAL ACTIVITY INTERVENTION ON SITTING TIME

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The effect of a pedometer-based physical activity intervention on sitting time

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ABSTRACT

Objective. To assess whether the "10,000 Steps Ghent" intervention had any effect on self-reported sitting time.

Methods. A multi-strategy community-based intervention was implemented in 2005 to promote physical activity (PA) to adults living in Ghent, Belgium. In 2005, 648 randomly selected participants (aged 25 to 75) from the intervention community Ghent and 592 from a comparison community, completed the International Physical Activity Questionnaire (IPAQ) and a pedometer log. Of these, 440 intervention participants and 426 comparison participants completed the follow-up measurements in 2006.

Results. A decrease of 12 min in total daily sitting time was found in the intervention community, compared with an increase of 18 min/day in the comparison community ($F=9.5$, $p=0.002$). The effect was seen for both weekday ($p=0.044$) and weekend day ($p<0.001$) sitting times. In the intervention community, total daily sitting time decreased more in the participants who increased their step counts (−18 min/day; $t=2.5$; $p=0.012$), than in those who did not (no change; $t=0.8$, ns).

Conclusions. After 1 year of intervention, total, weekday, and weekend day sitting times were reduced in the intervention community, while sitting time increased in the comparison community.

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Introduction

International guidelines recommend healthy adults (18–65 years) accumulate 30 min or more of moderate-intensity aerobic physical activity (PA) on 5 days each week, or a minimum of 20 min of vigorous-intensity aerobic activity on 3 days each week (Haskell et al., 2007). However, with increasing use of pedometers to measure PA, step count goals have become popular, and a target of '10,000 steps/day' has been adopted in several intervention studies, including "10,000 Steps Ghent", a multi-strategy PA intervention in a large community (De Cocker et al., 2007a).

In addition to the well-known effects of PA on health and well-being, several studies have recently shown that sedentary behaviors may impact on health outcomes independent of PA. For example, self-reported sitting time is significantly associated with an elevated risk of obesity and diabetes (Hu et al., 2003), an increase in cancer risk (Zhang et al., 2004), and a higher metabolic syndrome risk (Wijndaele et al., 2007), all independently of PA.

Two previous observational studies have found inverse relationships between objectively measured pedometer step counts and sitting time ($r=-0.34$, Miller and Brown, 2004; $r=-0.15$, De Cocker et al., 2007b). However, it is not known whether PA promotion strategies also result in reduced sitting time. The pedometer-based intervention "10,000 Steps Ghent" which was found to be effective in increasing step counts (De Cocker et al., 2007a), offered an opportunity to evaluate the 'incidental' effects of a whole-community PA intervention on sitting time.

Methods

Participants and procedures

The intervention was evaluated using a controlled pre-post design, with data collection at baseline and 12 months. The intervention community was the city of Ghent, and the comparison community, where no intervention took place, was the city of Aalst. Both East-Flemish communities were selected because of their demographic and geographic comparability. In 2005, 648 randomly selected participants (aged 25 to 75) from Ghent and 592 from Aalst completed the telephone administered long-version of the International Physical Activity Questionnaire (IPAQ) and a 7-day pedometer log. The follow-up study sample included 440 adults in Ghent (mean age: 49.8±13.1; proportion men: 47.5%; proportion employed: 62.4%), and 426 in Aalst (mean age: 50.0±12.9; proportion men: 52.6%; proportion employed: 54.4%). The pedometer served as a measurement tool and was to be returned after baseline and follow-up data collection.

During the intervention, PA was promoted in the defined Ghent community, using the central theme of '10,000 steps/day', with a secondary tagline of 'Every step counts'. Other PA guidelines (30 min/day of moderate PA on 5 days/week or 20 min of vigorous activity 3 times/week) were also promoted. A local media campaign (street signs, press conferences, advertisements), the sale and loan of pedometers, website use, workplace projects, projects for older people and the dissemination of information through health professionals, schools and associations were concurrently implemented. These strategies, based on the social ecological model, were designed to intervene at the individual (e.g. pedometer sale), social (e.g. workplace projects), and environmental (e.g. walking circuits) level. More details on the participants and procedures have been published elsewhere (De Cocker et al., 2007a).

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Instruments

IPAQ

The IPAQ long-version was used to assess sitting time during transport, sitting time on a usual weekday, and sitting time on a usual weekend day, all expressed in minutes/day. Validity and reliability of the IPAQ items have been shown to be acceptable: a previous study has reported a moderate correlation between the IPAQ sitting data and an estimate of sitting accounted for by CSA's (Craig et al., 2003).

Pedometer

The Yamax Digiwalker SW-200 (Yamax, Tokyo, Japan) was used as it is known to be valid, accurate, and reliable for counting steps in adults (Crouter et al., 2003).

Activity log

An activity log was used to record the date, the day-end steps taken, and the type and duration of non-ambulatory activities (i.e. biking and swimming) (De Cocker et al., 2007a). Participants were asked to complete the activity log at the end of each day for 7 days. Researchers added 150 steps to the daily total for every minute of reported biking and/or swimming (Miller et al., 2006, De Cocker et al., 2007a). Of the total sample 40.7% reported biking and 4.4% reported swimming during the week of pedometer registration at baseline, and 45% and 3.8% respectively at follow-up. The average daily step count without adding the equivalent for biking/swimming was 8494±3480 at baseline and 8698±3418 at follow-up. The averages with the imputation were respectively 9535±4112 and 10,009±4170. All participants providing at least 3 days of pedometer registration, were included in the present study (n=863).

Statistical analyses

All analyses were conducted using SPSS 12.0 for windows (SPSS Inc., Chicago, IL, 2003). Average daily steps and sitting time were calculated for the baseline and follow-up period. Mean values over 20,000 steps/day were recoded as 20,000 (De Cocker et al., 2007a). This truncation was performed for data from 33 participants at baseline and 28 at follow-up. Repeated measures analysis of covariance (ANCOVA) was used to evaluate the effect of the campaign on step counts and sitting time, with time (baseline/follow-up) as the within participants factor, community (intervention/comparison) as the between participants factor, and age and number of years education as covariates. Time by community interactions were used to evaluate the intervention effects. Paired samples t-tests were used to assess change in total sitting time in those participants who increased their step counts (intervention community: n=254, comparison community: n=208) and those who did not (intervention community: n=182, comparison community: n=213). Independent samples t-tests were used to compare the differences in sitting time, for those that increased steps and those that did not, between the two communities. A statistical significance level of 0.05 was used.

Table 1
Mean (SD) and change scores for step counts and sitting time at baseline and follow-up

	N	Baseline	Follow-up	Change (95% CI)
Daily step counts				
Intervention	438	9569 (4256)	10,491 (4306)	+896 (599–1192)
Comparison	425	9669 (4018)	9534 (3978)	−135 (−432–161)
Daily sitting time (min)				
Intervention	436	396 (162)	384 (150)	−12 (−24–0)
Comparison	420	378 (162)	396 (162)	+18 (0–24)
Weekday step counts				
Intervention	434	9845 (5043)	10,762 (5068)	+917 (565–1270)
Comparison	421	9824 (4468)	9673 (4439)	−151 (−502–200)
Weekday sitting time (min)				
Intervention	434	378 (18)	366 (168)	−12 (−24–0)
Comparison	421	354 (180)	360 (174)	+6 (−6–18)
Weekend day step counts				
Intervention	430	9475 (6157)	10,276 (6128)	+801 (247–1355)
Comparison	417	9707 (6269)	9471 (5648)	−236 (−818–346)
Weekend day sitting time (min)				
Intervention	430	294 (138)	288 (126)	−6 (−18–6)
Comparison	417	276 (126)	312 (126)	+36 (18–48)
Transport-related sitting (min/day)				
Intervention	436	42 (42)	42 (42)	0 (−6–0)
Comparison	421	48 (48)	48 (54)	0 (−6–6)
Daily sitting time (min) in participants who increased their steps				
Intervention	254	396 (138)	378 (138)	−18 (−6–36)
Comparison	208	384 (168)	402 (162)	+18 (0–36)
Daily sitting time (min) in participants who did not increase their steps				
Intervention	182	390 (162)	390 (150)	0 (−12–24)
Comparison	213	372 (162)	384 (162)	+12 (6–30)

Location of the study: Ghent, Belgium.
Date of the study: intervention: 2005–2006.
Data analysis: 2007.
Study population:
440 interventions participants: 49.8±13.1 years, 47.5% men, 62.4% employed.
426 comparison participants: 50.0±12.9 years, 52.6% men, 54.4% employed.

Results

As a result of data truncation, mean daily step counts were reduced by 112 steps/day at baseline and 109 steps/day at follow-up. There were significant intervention effects for both mean daily step counts and sitting time, overall (step counts: F=22.6, p<0.001; sitting time: F=9.5, p=0.002), and for weekday (step counts: F=17.8, p<0.001, sitting time: F=4.1, p=0.044) and weekend days (step counts: F=5.6, p=0.019; sitting time: F=17.7, p<0.001) separately (see Table 1). There was no significant intervention effect for transport-related sitting time (F=1.2, p=0.265). In the 254 intervention participants who increased their daily steps (by an average (SD) of 2840 (2316) steps/day), total sitting time (including non-transport-related as well as transport-related sitting) decreased significantly from baseline to post-intervention, by an average of 18 min/day (t=2.5, p=0.012). In comparison, there was no change in sitting time in the 182 intervention participants whose steps did not increase (mean (SD) step change=−1814 (1955)) (t=0.8, p=0.427). There was a trend for sitting time to increase in the comparison participants whose steps increased (2187 (2027) steps/day) (t=1.9, p=0.070), while there was no change in those whose step counts decreased (−2403 (2177) steps/day) (t=1.3, p=0.208). The change in sitting time in the intervention participants who increased their steps was significantly different from the change in the comparison participants who increased their steps (t=3.1, p=0.002). There was no difference in the change in sitting time between intervention and comparison participants whose steps did not increase (t=1.4, p=0.148).

Discussion

These findings indicate that, in addition to increasing daily step counts, the pedometer-based PA intervention "10,000 Steps Ghent" resulted in a decrease in sitting time. While average total, weekday, and weekend day sitting time decreased in the intervention community (by about 12 min/day overall), sitting time increased in the comparison community (by about 18 min/day).

Analyses of data from the intervention participants who increased their step counts showed that their total sitting time decreased significantly. This suggests that their increased steps may have displaced sitting time. There was however a tendency for an increase in sitting time in those comparison participants who increased their steps. This means that an increase in steps not necessarily results in a decrease in sitting time, consequently the present intervention may have caused the decrease in sitting time. Furthermore, there was no change in sitting time in the intervention and comparison participants whose step counts decreased. This may suggest that time is being reallocated to activities other than sitting.

The overall daily sitting time reported here (around 6.5 hr/day) was similar to that reported for American workers (6.1 h/day) (Welk et al., 2000) but lower than reported in an Australian, largely full-time working sample (9.4 h/weekday) (Miller and Brown, 2004), and lower than reported for Chinese women (7.4–8.1 h) (Zhang et al., 2004). It is not known whether the small change in sitting time seen here (12 min/day), has any biological significance, although it has been suggested that 15 min of PA per day may be sufficient to prevent population weight gain (Hill et al., 2003; Brown et al., 2005).

Previous research has shown that each 2 h increase in daily time spent sitting at work or watching TV, is associated with a 5–23% increase in risk of obesity and a 7–14% increase in risk of type 2 diabetes (Hu et al., 2003). The risks of metabolic syndrome and ovarian cancer are also increased with prolonged sitting time (Wijndaele et al., 2007; Zhang et al., 2004).

Study limitations and strengths

The main limitation of the present study are the self report nature of the data and the lack of information on BMI and on the context of sitting time. Apart from transport-related sitting, it is not known where or how participants spent their time sitting (e.g. while watching TV, using the computer at home or during sedentary tasks at work). Similarly, the pedometer is not able to assess the context or intensity of activities. The strengths of this study include the random recruitment of participants, intervention in a real-life setting, and relatively small loss to follow-up (68% of the intervention participants and 72% of the comparison participants were retained at follow-up).

Conclusions

This is the first intervention study to describe the 'unintended' effects of a whole-community pedometer-based PA intervention on sitting time. The results suggest that "10,000 Steps Ghent" was successful in decreasing sitting time, as well as in increasing step counts. The results are however preliminary, and further research with more objective measures is needed to explore whether focusing exclusively on PA is sufficient to reduce sitting time, or whether specific attention should be given to reducing sedentary behaviors.

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CHAPTER 2.2.5

MODERATORS AND MEDIATORS OF PEDOMETER USE AND STEP COUNT INCREASE IN THE "10,000 STEPS GHENT" INTERVENTION

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Moderators and mediators of pedometer use and step count increase in the "10,000 Steps Ghent" intervention

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Abstract

Background: The European pedometer-based "10,000 Steps Ghent" whole community intervention for 228,000 residents was found to be effective in increasing step counts by an average of 896 steps/day in a sub-sample of adults. The present study aimed to examine the characteristics of intervention participants (n = 438) who (1) used a pedometer and (2) increased their step counts. Additionally, the third aim was to examine the mediational effect of pedometer use on step count change.

Methods: The study sample consisted of 438 adults (207 male, mean age 49.8 (13.1) years). Binary logistic regressions were used to examine whether individual characteristics (gender, age, educational level, employment status, self-reported health condition, baseline step counts, baseline sitting time, baseline transport-related PA) and intervention exposure variables (having heard/seen a PA promotion message, being aware of the PA guidelines, and knowing about "10,000 Steps Ghent") were associated with (1) pedometer use and (2) a step count increase of 896 steps/day or more. Using pooled data (n = 864) from the intervention and comparison participants, a mediation analysis was conducted to see if the change in step counts was mediated by pedometer use.

Results: Age (49 years or more: OR = 3.19, $p < 0.005$), awareness of a PA promotion message (OR = 2.62, $p < 0.01$) and awareness of "10,000 Steps Ghent" (OR = 2.11, $p < 0.05$) were significantly associated with pedometer use. Participants with a college or university degree (OR = 1.55, $p < 0.05$) and those who used a pedometer (OR = 2.06, $p < 0.05$) were more likely to increase their steps by 896 steps/day or more. This increase was less likely among those with baseline step counts above 10,000 steps/day (OR = 0.38, $p < 0.001$). The mediation analysis revealed that pedometer use partly mediated step count change.

Conclusion: Pedometer use was more likely in older participants and in those who were aware of the "10,000 Steps" campaign. Increasing step counts was more likely among those with higher education, baseline step counts below 10,000 steps/day and those who used a pedometer. Pedometer use only partly mediated the intervention effect on step counts.

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Background

Low levels of physical activity (PA) are associated with an increased risk for adverse physiological and mental health outcomes including cardiovascular diseases, obesity, hypertension, diabetes mellitus type 2, different types of cancer, osteoporosis, and depression and anxiety [1]. Therefore, international guidelines recommend that all healthy adults aged 18–65 should engage in moderate-intensity aerobic PA for a minimum of 30 minutes on five days each week, or in vigorous-intensity aerobic PA for a minimum of 20 minutes on three days a week [2]. Nevertheless, the majority of American (60%) [1], Australian (43%) [3], and European (43–87%) [4] adults do not meet this recommendation. Consequently, diverse interventions in various settings and specific populations have been developed and implemented to promote PA [5].

Pedometers, which objectively measure ambulatory activities throughout the day in the form of step counts, have become popular as monitoring and motivational tools in PA interventions. Pedometers are easy to use and relatively inexpensive compared with other motion sensors (pedometer: approximately US $ 20–50; accelerometer: approximately US $ 150–500). Evidence suggests that the use of pedometers is associated with significant increases in PA levels [6,7] and significant improvements in health outcomes among adults [6]. In addition, step count goals such as '10,000 steps/day' have been used in the promotion of PA [8].

Pedometer interventions appear to be effective both in smaller settings (e.g. workplaces [9,10], churches [11], primary care [12,13]), and in whole community-based trials (e.g. "The Step-by-Step Trial" [7], '10,000 Steps Rockhampton" [14], "10,000 Steps Ghent' [15], and "Canada on the Move" [16]). The Australian 'Step-by-Step Trial" showed that pedometer use can enhance the effects of a self-help walking program. The main outcome of the '10,000 Steps Rockhampton" intervention was that the downward trend in the percentage of citizens classified as active in the comparison community was not evident in the intervention community [14]. The '10,000 Steps Ghent' whole community intervention succeeded in increasing step counts (average step count increase of 896 steps/day, $p < 0.001$) after one year of intervention [15]. Despite the overall effectiveness of these community-based interventions, it is possible that they only reached people who were already active, or that the intervention was more efficient for isolated subgroups (e.g. 20–30 year olds). In the "10,000 Steps Rockhampton" project, women were the early adopters of pedometer use; people aged 45 or more, those with higher levels of education, employed people, and those with an 'obese' BMI were more likely to report using a pedometer [14,17]. The results of the "Canada on the Move" project also showed that pedometer use was more likely among women and older people (44–64 years) [16].

Data from the '10,000 Steps Ghent' intervention provide an opportunity to examine whether the characteristics of people who used a pedometer and increased their step counts in this European whole community intervention, were similar to those seen in Australia and Canada. During the multi-strategy intervention, pedometer use was promoted in Ghent at different locations: pedometers could be bought or borrowed at the participants' own discretion. The first aim of the present study was to examine whether self-selected pedometer use in the intervention sample was associated with individual characteristics (gender, age, education, employment status, self-reported health, baseline step counts, baseline sitting time, and baseline transport-related PA) and intervention exposure variables (hearing or seeing a PA promotion message, knowing the amount of PA required for health benefit, and knowing about '10,000 Steps Ghent"). The second aim was to compare the individual characteristics and intervention exposure variables in intervention participants who increased their step counts considerably and those who did not. Using pooled data from the intervention and comparison participants, the third aim was to examine the potential mediating effect of pedometer use on step count change.

Methods

Procedures

Prior to the '10,000 Steps Ghent' whole community intervention for 228,000 residents, 2081 randomly selected 25–75 year old adults, living in the city of Ghent (Belgium), were invited to participate. Of those, 872 were interested, 648 completed baseline measurements and 440 participated in the one year follow-up. Baseline and follow-up measures consisted of the completion of the telephone-administered long version of the International Physical Activity Questionnaire (IPAQ) and the self-monitoring of pedometer steps for 7 consecutive days, using a daily activity log. At follow-up, participants were asked to also complete a questionnaire relating to awareness of the '10,000 Steps Ghent" project. Participants had to return the pedometer after baseline and follow-up data collection. Details of the study procedures have been described previously [15].

Participants

For aims 1 and 2, the sample consisted of 438 intervention participants (207 male) with a mean age of 49.8 (13.1) years. About 52.9% (n = 232) had a college or university degree and 67.5% (n = 295) were employed. The majority (n = 344, 79.1%) reported good to excellent health (see Additional file 1). At baseline, the sample took an average of 9595 (4256) steps/day, spent 20 (27) minutes/day in transport-related PA and 396 (164) minutes/ day sitting. For aim 3, pooled data from these 438 intervention participants and from 426 participants from the comparison city of Aalst [15] were used. All participants provided written informed consent and the study was approved by the Ethical Committee of Ghent University.

"10,000 Steps Ghent" intervention

During the intervention, PA was promoted in the entire city of Ghent, using the central theme of '10,000 steps/ day', with secondary taglines of 'every step counts' (elke stap telt) and 'every revolution (of bicycle pedals) counts' (elke trap telt). The guidelines, recommending 30 minutes of moderate-intensity PA on five days a week, or 20 minutes vigorous-intensity PA on three days a week [2], were also promoted. Multiple strategies, based on the social ecological model, were designed to intervene at the individual, social and environmental level. A local media campaign (street signs, press conferences, advertisements), the sale and loan of pedometers, the use of a website, workplace projects, projects for older people and the dissemination of information through health professionals, schools and associations were concurrently implemented. More details on the intervention strategies can be found elsewhere [15].

Instruments

IPAQ

The long version of the IPAQ was used to assess sitting and PA in different domains (work, transport, household and leisure time) in a usual week. The IPAQ is known to be a valid and reliable instrument for assessing PA in Europe [18] and Belgium [19]. In the present study, only sitting time and transport-related PA items were used, since walking and biking for transport reflect the concept of lifestyle PA promoted through "10,000 Steps Ghent".

Pedometer

The valid, accurate, and reliable Yamax Digiwalker SW-200 (Yamax Cooperation, Tokyo, Japan) was used in the present study to measure free-living step counts [20].

Activity log

Participants were asked to record the date, steps taken at the end of each day, and the type and duration of non-ambulatory activities (i.e. biking and swimming). For every minute of reported biking and/or swimming, researchers added 150 steps to the daily total number of reported step counts [15,21]

Questionnaire relating to awareness of the project

The following questions, asked at one-year follow-up, were used in the present study: Have you heard or seen any messages about PA promotion? (yes/no); Do you have any idea about the amount of PA that is required for health benefit? (yes/no + open ended); Have you heard of the "10,000 Steps Ghent" project? (yes/no); Have you used a pedometer in the last 10 months? (yes/no). A timeframe of 10 months was used to avoid inclusion of baseline pedometer measurements.

Data Analysis

All individual characteristics (gender, age, education, employment status, self-reported health, baseline step counts, baseline sitting time, and baseline transport-related PA) and intervention exposure variables (hearing or seeing a PA promotion message, knowing the PA guidelines, knowing about "10,000 Steps Ghent", and self-selected pedometer use during the intervention) were interpreted as categorical variables and dichotomized using median scores as follows: age (M = 49 year), baseline sitting time (M = 6.2 hours/day) and baseline transport-related PA (M = 10.7 minutes/day). Descriptive statistics (numbers and percentages) were calculated using cross tabs. Binary logistic regression was used to examine whether individual characteristics and intervention exposure variables were associated with (1) pedometer use during the intervention and (2) greater than mean step count increase (> 896 steps/day). Results are expressed as odds ratios with 95% confidence intervals and p values. All data were analyzed using SPSS 15.0 for Windows (SPSS Inc., Chicago, USA) and statistical significance was set at 0.05.

As suggested by Cerin et al [22], the Freedman-Schatzkin difference-in-coefficients test was used to assess the mediational effect of pedometer use on step count change. A measure of step count change between baseline and one year follow-up, free of auto correlated error, was recreated by regressing the step counts at follow-up onto the step counts at baseline. The Freedman-Schatzkin test assesses a mediational effect by comparing the relationship between the independent variable (the intervention) and the dependent variable (step count change) before and after adjustment for the mediator (pedometer use) (see figure 1). It tests the null hypothesis that the difference between the unadjusted (without pedometer use as mediator: τ) and adjusted (with pedometer use as mediator: τ') regression coefficients of the independent variable is zero. The test consists of two regression analyses. The first examines the impact of the intervention condition (dummy variable) on the residualized change step count scores, providing an estimate for τ (relationship between intervention condition and step count change before adjusting for the mediator). The second looks at the effect of the intervention on residualized change step count scores after controlling for pedometer use (dummy variable), giving an estimate for τ' which represents the independent effect of the intervention condition on step count change after adjusting for the mediator. The significance test of the

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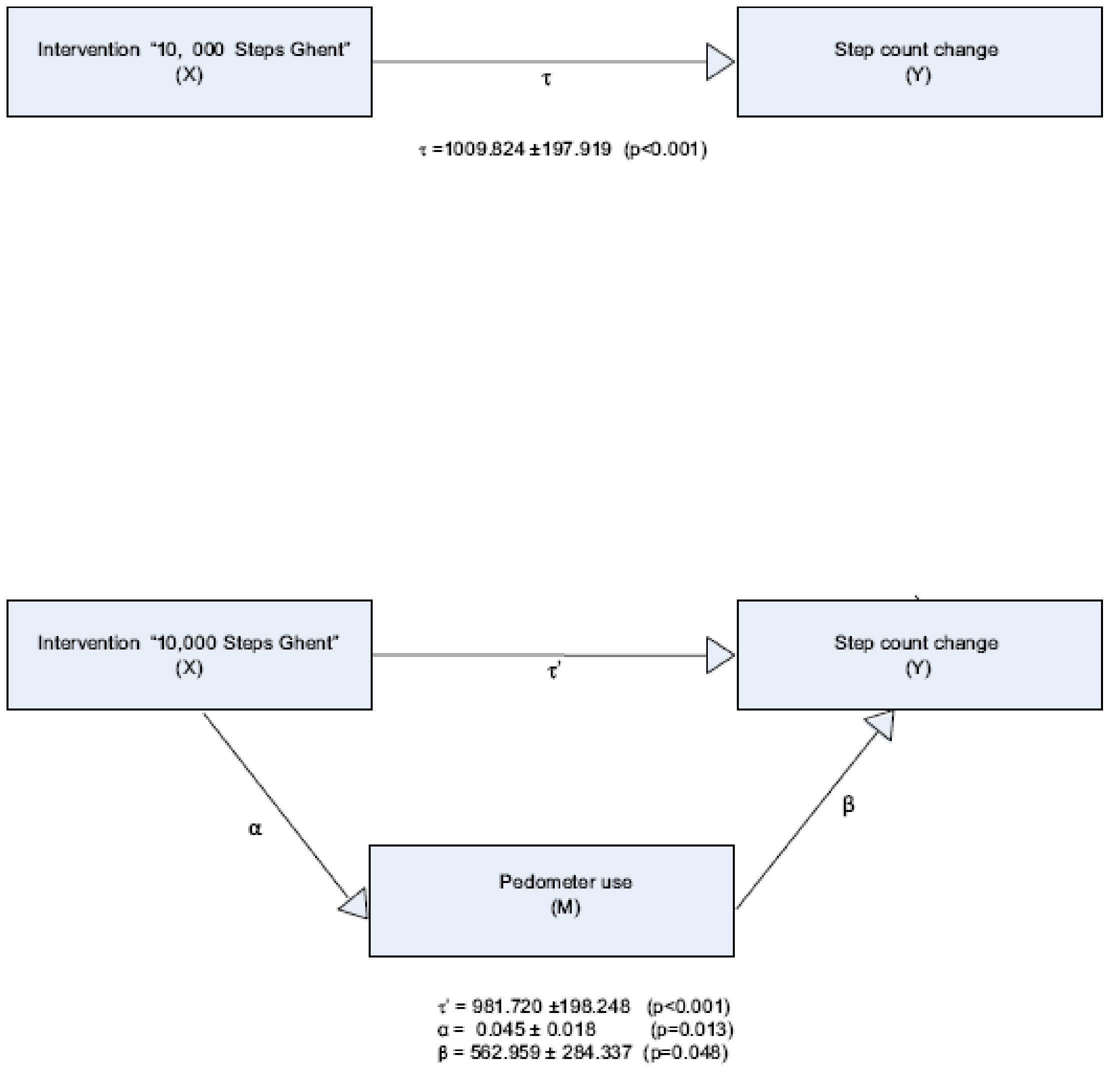

Figure 1
Path diagram for the analysis of the mediational effect of pedometer use on step count change.

mediational effect is computed by dividing (τ - τ') by its standard error and comparing the obtained value to a t-distribution with N – 2 degrees of freedom [22]. If the t-value is > 1.984 there is a significant mediation effect at the 5% level. The proportion of the intervention effect mediated by pedometer use was calculated by subtracting the adjusted relationship between the intervention exposure and step count change (τ) from the unadjusted relationship (τ'), and dividing the sum by the unadjusted value ((τ - τ')/τ) [23].

Results

Only 72 (16.4%) intervention participants used a pedometer during the one-year intervention period. Participants older than 49 years (p = 0.001), those who reported having heard or seen a message about PA promotion (p = 0.006), and those who knew about "10,000 Steps Ghent" (p = 0.047) were more likely to report pedometer use. None of the other potential explanatory variables was significantly associated with pedometer use during the intervention (see Additional file 1). Post hoc chi-square analyses examined the inter-relationship between these significant moderating variables. There was a strong positive relationship between PA promotion message recall and project awareness ($\chi^2 = 58.7$, $p < 0.001$). About 44.2% of those who reported having heard or seen a PA promotion message ($\chi^2 = 7.3$, $p = 0.007$), and 46.5% of those aware of the project ($\chi^2 = 3.2$, $p = 0.074$), were older than 49 years.

Overall, 209 (47.5%) participants showed an increase in average step counts of 896 steps/day or more at one-year follow-up. Participants with a college or university degree ($p = 0.046$), and those who used a pedometer during the intervention ($p = 0.014$) were more likely to have increased their step counts by 896 steps/day or more, while those with a baseline average step count level of more than 10,000 steps/day were less likely to have increased their step counts by 896 steps/day or more ($p < 0.001$). None of the remaining variables was significantly associated with the step count increase of 896 steps/day or more (see Additional file 1). Post hoc analyses revealed that more than half those with a college or university degree (54.8%), had fewer than 10,000 steps/day at baseline ($\chi^2 = 3.8$, $p = 0.051$).

Regression coefficients of the different paths are shown in Figure 1. Results revealed that the intervention "10,000 Steps Ghent" was a significant predictor of step count change ($p < 0.001$) before adjusting for the mediator, pedometer use. After adjusting for pedometer use, the intervention condition remains a significant predictor of step count change ($p < 0.001$), however the value of the adjusted regression coefficient (τ') is significantly lower than the regression coefficient before adjusting for pedometer use (τ) ($t = 2.1$), pointing to a significant mediation effect. This analysis revealed that pedometer use partly mediated ($(\tau - \tau')/\tau = 0.028$ or 2.8%) the effect of the intervention on step count change.

Discussion

The "10,000 Steps Ghent" whole community intervention was effective in increasing step counts: almost half the intervention participants increased their step counts on average by 896 steps/day or more at one-year follow-up. However, the proportion of intervention participants using a pedometer through loan or sale service during the intervention was modest (16%). The purpose of the present study was to investigate which individual characteristics and exposure variables were associated with pedometer use and step count increase.

Pedometer use in Ghent (16%) was remarkably similar to that in the Australian "10,000 Steps" intervention in Rockhampton (18%) [17]. The predictors of pedometer use were also very similar in these two studies and in the "Canada on the Move" intervention. For example, in all three studies older people (over 49 in Ghent, over 45 in Rockhampton [17], and in the 44–64 year age group in Canada [16]) were more likely to have used a pedometer. Other previous pedometer-based studies have shown that PA is inversely associated with age [24-26], so the finding that pedometer use is more prevalent among older people is encouraging. Furthermore, in all three studies, individuals being exposed to program variables (having heard or seen a message about PA promotion and knowing about the "10,000 Steps" project in Ghent; having seen the street signage/walking trials and visited the website in Rockhampton [17]; and campaign awareness in Canada [16]) were more likely to report using a pedometer. The latter seems a logical finding, however explaining why older participants were more likely to use a pedometer is difficult, as participants who were aware of PA promotion messages or the "10,000 Steps Ghent" project, were no more likely to be older than 49 years than those who were unaware. It is possible that older people had more time or more interest in trying out a pedometer. Mostly, they care for their health, and like to have defined guidelines and goals concerning their health behavior. Using a pedometer gives them the opportunity to set and reach goals regarding their PA.

Although pedometer use was more likely among women, and employed and higher educated individuals in Rockhampton [17], and more likely among women, college and university graduates, and high-income earners in Canada [16], gender, education and employment status were not significantly associated with pedometer use in the present Ghent study.

Participants with a college or university degree were however more likely to record a step count increase in this project, suggesting that more efforts are needed to reach those with lower levels of education. A previous cross-sectional pedometer study conducted in the United States, also revealed that higher educated individuals had significantly more daily step counts than lower educated persons [24]. Wyatt et al [25] on the other hand, found that steps did not differ significantly as a function of education level in Colorado. However, in the present study, there was a tendency for those with higher education to have a baseline step count below 10,000 steps/day. Furthermore, the present findings showed that less active individuals (i.e. those with a baseline step count level below 10,000 steps/day, and consequently those with a college or university degree) were more likely to increase their steps. This promising outcome suggests that the whole-community intervention, which was designed to reach sedentary people, was indeed effective for those most in need of (more) PA, and not for already active individuals.

As pedometer use was only one of the strategies promoted during this multi-component intervention, it was interesting to find that it was associated with the observed increase in step counts. Our analyses showed that the multi-strategy intervention was successful in promoting and stimulating pedometer use, which in turn resulted in positive step count changes. The intervention effect was however only partly mediated by pedometer use (2,8%), which is not surprising as only one in six people reported using a pedometer. The findings suggest that, although the pedometer was valuable in promoting increased step counts in a whole community, the other strategies (the media campaign, street signs, website, workplace projects, working with health professionals and targeting older people) could also be important. Post hoc mediation analyses showed that the intervention was significantly mediated by awareness through street signs (11.1% mediation) and workplace projects (7.3% mediation). This suggests that promotion, available for the whole community (i.e. street signs), or in smaller settings (i.e. workplaces) has an effect on step count change. The latter mediating effects were even greater than that of pedometer use, which was thought to be an important mediator of the intervention. Notwithstanding, this is the first time that the mediating effect of pedometer use on increasing activity has been demonstrated in a whole community intervention.

One limitation of this study is that the questions about pedometer use were not asked at baseline, so information on pre-intervention pedometer use was not available. However, a previous Belgian study [27] has shown that pedometer use was not common in East-Flanders at the time that this intervention was implemented. A second limitation is the lack of information on BMI or other health variables, and additional socio-demographic variables like marital status, income and job classification. The strengths of this study include the large sample size, the random sample of participants for the evaluation (i.e. they were not 'volunteers' in the intervention program), the age range (25–75 years), and the longitudinal step count data.

Conclusion

The findings suggest that age and intervention awareness were positively associated with pedometer use, which was in turn (along with education and low baseline step counts) a significant predictor of step count increase in this whole community intervention. Mediation analyses showed that the intervention effect on increasing step counts was only partly mediated by pedometer use, illustrating the importance of the other strategies used in this campaign.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KDC participated in the design of the study, collected and analyzed the data, and led the writing of the paper. KDC wrote the manuscript, while IDB, WB and CC participated in the design of the study, collaborated with partners on the development of the intervention, discussed the analysis plan, and provided substantive feedback on the manuscript. All authors have read and approved the final manuscript.

Additional material

Additional file 1
Table 1: Analysis of the moderator effects on pedometer use and step count increase.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1479-5868-6-3-S1.doc]

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Table 1: Adjusted odds ratios and 95% CIs for step count increase and pedometer use.

	Used PM voluntary					Increased step counts ≥ 896				
	N	**N increasing (%)**	**adj OR**	**95% CI**	**P**	**N**	**N using PM (%)**	**adj OR**	**95% CI**	**P**
Gender										
Male	209	25 (12.0)	1.00 [c]			207	91 (44.0)	1.00 [c]		
Female	231	47 (20.3)	1.48	0.82-2.65	0.191	231	118 (51.1)	1.23	0.81-1.85	0.336
Age										
< 49 years	219	26 (11.9)	1.00 [c]			218	109 (50.0)	1.00 [c]		
≥ 49 years	219	45 (20.5)	**3.19**	**1.65-6.19**	**0.001**	218	99 (45.4)	0.73	0.44-1.20	0.217
Educational level										
High school	207	35 (16.9)	1.00 [c]			206	87 (42.2)	1.00 [c]		
college/university	233	37 (15.9)	0.85	0.46-1.56	0.595	232	112 (52.6)	**1.55**	**1.01-2.40**	**0.046**
Employment status										
Unemployed	144	25 (17.4)	1.00 [c]			143	67 (46.9)	1.00 [c]		
Employed	296	47 (15.9)	1.10	0.54-2.22	0.802	295	142 (48.1)	1.03	0.60-1.76	0.924
Health condition										
Weak-moderate	91	15 (16.5)	1.00 [c]			91	40 (44.0)	1.00 [c]		
Good-excellent	346	56 (16.2)	1.12	0.56-2.22	0.749	344	167 (48.5)	1.16	0.71-1.88	0.560
Baseline average daily step counts										
< 10,000	251	34 (13.5)	1.00 [c]			251	140 (55.8)	1.00 [c]		
≥ 10,000	187	38 (20.3)	1.44	0.78-2.64	0.245	187	69 (36.9)	**0.38**	**0.24-0.60**	**<0.001**
Baseline daily sitting time										
< 6.2 hours	228	41 (18.0)	1.00 [c]			227	108 (47.6)	1.00 [c]		
≥ 6.2 hours	210	31 (14.8)	1.12	0.61-2.07	0.709	209	101 (48.3)	0.82	0.53-1.27	0.372
Baseline daily transport-related PA										
< 10.7 minutes	223	30 (13.5)	1.00 [c]			223	112 (50.2)	1.00 [c]		
≥ 10.7 minutes	214	41 (19.2)	1.25	0.71-2.20	0.446	212	96 (45.3)	0.92	0.61-1.38	0.676
Having heard/seen any message about PA promotion										
No	188	16 (8.5)	1.00 [c]			187	83 (44.4)	1.00 [c]		
Yes	251	56 (22.3)	**2.62**	**1.33-5.19**	**0.006**	250	126 (50.4)	1.17	0.75-1.82	0.489
Knowing the amount of PA required for health benefit										
No	231	25 (10.8)	1.00 [c]			231	111 (48.1)	1.00 [c]		
Yes	209	47 (22.5)	1.86	0.96-3.60	0.064	207	98 (47.3)	0.86	0.54-1.38	0.538
Knowing about '10.000 Steps Ghent'										
No	149	11 (7.4)	1.00 [c]			148	70 (47.3)	1.00 [c]		
Yes	291	61 (21.0)	**2.11**	**1.01-4.40**	**0.047**	290	139 (47.9)	1.02	0.65-1.61	0.934
Using a PM voluntarily										
No						366	166 (45.4)	1.00 [c]		
Yes						72	43 (59.7)	**2.06**	**1.15-3.67**	**0.014**

CI = confidence interval

PM = pedometer

Adj OR = adjusted odds radio

[c] reference group

PA = physical activity

PART 3: GENERAL DISCUSSION

The aim of the present thesis was to investigate the role of pedometers and the '10,000 steps/day'-concept in the promotion of physical activity. First, some pedometer-related methodological studies were conducted to investigate how valid an inexpensive pedometer is, what pedometer step counts represent, and what the comparison is between pedometer-based data and self-reported physical activity in Flemish adults. A next phase of the research project included physical activity promotion through pedometer use and step count goals in interventions at the micro-, meso-, and macro-level. Complete results and thorough discussions about each study separately were described in detail in the previous part (part 2: original research). In this final part of the thesis, main findings and reflections of the different studies, plus an overall discussion and conclusion of the thesis will be given, followed by strengths and limitations, practical implications, and some directions for future research.

1 Main findings and reflections of the studies

1.1 Pedometer-related methodological aspects

1.1.1 What about inexpensive pedometers?

The first study (chapter 2.1.1) evaluated the validity of the inexpensive 'Stepping Meter' (€ 1 or $ 1.2 each) against the valid Yamax Digi-Walker in adults in free-living conditions. Results showed that about 74 % of the inexpensive 'Stepping Meter' gave invalid results and made an overestimation (n = 467) or underestimation (n = 254) of step counts of more than 10 %, which was the criterion used to examine validity (Basset et al, 1996; Crouter et al, 2003; Schneider et al, 2004).

In this study, the inexpensive 'Stepping Meter' was found to be invalid for counting steps in adults in free-living conditions. Also other inexpensive pedometer models, often given as (free) marketing gadgets, for example 'McDonald's Stepometer' (Gao et al, 2005) and 'Kellogg's Special K step counters' (Tudor-Locke et al, 2006), showed to be unacceptably inaccurate. Overestimations are probably due to over-sensitivity of the internal mechanism, resulting in step counting during non-stepping movements, such as sitting, twisting the hip, bending over, and kneeling. An unprotected reset button, causing unintentional resetting, may clarify the underestimations. Considering the health-related purpose of pedometers, i.e. measuring needed physical activity and/or motivating (more) physical activity, invalid pedometers such as the 'Stepping Meter' cannot be used, as they will give incorrect information. For example, a 20 % error in a 10,000 step day, is 2000 steps, so either 8000 or

12,000 would be recorded, which results in a considerable difference in activity level. Individuals taking 8000 steps/day would be classified as 'somewhat active', while taking 12,000 steps/day corresponds to being 'active' (Tudor-Locke and Bassett, 2004; Tudor-Locke et al, 2008).

1.1.2 What do step counts and step count goals represent?

The second methodological study (chapter 2.1.2) compared pedometer-based physical activity with self-reported physical activity from one interview and three questionnaires. Step counts correlated well with self-reported total physical activity (r = 0.28 to 0.44), and with moderate physical activity (r = 0.31 to 0.33). Significant correlations between step counts and vigorous physical activity were somewhat lower (r = 0.16 to 0.25), and low between steps counts and self-reported walking (r = 0.10 to 0.19). Furthermore, the study compared step count thresholds (7500 steps/day, 10,000 steps/day, and 12,500 steps/day) with the guideline of 30 minutes of physical activity per day. Agreement (either reaching both targets or either not reaching both targets) between 30 minutes/day, which was measured with different self-reports, and the pedometer-based step count targets ranged between 72 % and 78 % for the 7500 steps/day target, between 52 % to 54 % for the 10,000 steps/day target, and between 48 % and 52 % for the 12,500 steps/day target. Of the total sample, 80.6 % accumulated 7500 steps/day, 45 % 10,000 steps/day, and 39.4 % 12,500 steps/day. The standard of 30 minutes of moderate to vigorous physical activity per day was reached by 68.1 % to 85.4 % according to the validated questionnaires. At least 75 % to 89 % of those reaching 7500 steps/day, also reached 30 minutes of physical activity; between 73 % and 94 % of those reaching 10,000 steps/day, also achieved 30 minutes of physical activity; and 75 % to 93 % of those accomplishing 12,500 steps/day, reached 30 minutes guideline.

This study showed that pedometer-based physical activity correlated positively with all self-reported physical activity. Consequently, pedometers provide not only a measurement of walking behaviour, they also give an indication of total, moderate and vigorous physical activity. Surprisingly, lowest correlations were found between step counts and walking, maybe due to the lack of sensitivity of the questionnaires to detect walking (Ainsworth et al, 1993). Despite significant correlations, it was shown that the percentages reaching the different guidelines (step count guidelines and minute guideline) differ remarkably, maybe due to the subjective nature of questionnaires, possibly causing over-reporting. However, as stated in the introduction of the thesis, also the use of pedometers and activity logs may cause problems of over-reporting (for example overestimating the time spent bicycling) or under-reporting (for example forgetting to register the time spent bicycling). The use of pedometers that include “time in activity” or “aerobic steps” could be helpful to further investigate the discrepancy between the different recommendations.

1.1.3 What about pedometer-based physical activity, and its relation with self-reported physical activity in Flanders?

The third methodological study compared self-reported physical activity, reported in the International Physical Activity Questionnaire (IPAQ), with pedometer-based physical activity data in a representative sample of Flemish adults. The more step counts participants accumulated, the higher their work-, leisure time-, and transport-related self-reported physical activity, and the lower the amount of sitting time. Consequently, pedometers are capable of discriminating between different physical activity levels reported in the IPAQ.

Another objective of this study was to provide and evaluate step counts of a Flemish sample and to make comparisons in step counts between demographic variables. The representative Belgian sample took on average 9655 steps/day, which is higher than step count levels in the United States (Tudor-Locke et al, 2004; Wyatt et al, 2005). This may be due to different environmental (for example, availability of bike lanes) characteristics in both countries. Though, the Flemish level was comparable with levels in Australia (Miller and Brown, 2004; McCormack et al, 2006; Schmidt et al, 2007) and Switzerland (Sequeira et al, 1995). However, like in most continents, present men took (slightly) more step/day than women, and although the most active group were the 36-45 year-olds, Flemish step counts declined with increasing age. Finally, employed individuals clearly accumulated more steps than unemployed people, and slightly more steps were accumulated on weekdays than on weekend days. The latter may be explained by the fact that about two thirds of the sample were employed and half reported activity at work. Despite the fact that the total sample was on average ‘somewhat’ active, this large survey of adult pedometer-based physical activity showed a wide distribution of step count levels, suggesting that the promotion of physical activity is still needed.

1.2 Physical activity promotion through pedometer-based interventions

1.2.1 Are support materials necessary in an individually-based pedometer intervention?

One of the aims of this study (chapter 2.2.1) was to investigate how familiar a sample of Flemish adults was with pedometers and the ’10,000 steps/day’-concept. In February 2005, when the study was executed, no more than 42 % of the study sample had already heard of a pedometer, only 17 % believed to know how many steps/day are health beneficial, and 34 % were willing to wear a pedometer.

To investigate if pedometer use is more effective when used in combination with cognitive and behavioural support materials, a 3-week intervention was implemented. One group only used a pedometer, while the other group used a pedometer plus support materials such as an information brochure, and a log to set goals and record steps. In both groups, walking, moderate and vigorous physical activity increased significantly. Consequently, pedometer use can encourage general physical activity engagement, and not only walking. No significant difference in effect on physical activity could be found between the two groups. However, the attitudes towards pedometer use were better in the group using a pedometer in combination with cognitive and behavioural support materials, than in the group simply using a pedometer. It should be noted that the present study sample consisted of volunteers willing to use a pedometer, and that the intervention duration was short.

1.2.2 Is a pedometer-based intervention at the workplace effective in Flanders?

The quasi-experimental controlled study in chapter 2.2.2 evaluated the effects of a 20-week pedometer-based physical activity intervention in a workplace in East-Flanders. Overall, a downward trend in step counts from baseline (end of summer) to follow-up (winter) was found, probably due to a seasonal effect. A previous pedometer-based study also revealed a decrease in the amount of physical activity during wintertime, compared with the rest of the year (Tudor-Locke et al, 2004). However, the decrease in the intervention workplace (-618 steps/day) was significantly smaller than the step count decline in the comparison workplace (-1389 steps/day), showing that the present pedometer-based worksite intervention was effective in reducing the step count decrease. This intervention effect was however only present in already active participants, reaching 10,000 steps/day at baseline, and not in the 'at-risk employees' with daily baseline step counts below 10,000. Other worksite fitness or exercise programs also showed to be more effective in already active people (Marshall, 2004), however, the present intervention was thought to be more accessible for inactive individuals. Furthermore, employees were highly aware of the campaign and the separate intervention strategies were found to be 'good - to very good'. Nevertheless, the proportion of intervention participants reporting that they had adjusted their physical activity behaviour (about one third) and that they had used the pedometer (almost half of the sample), was somewhat limited.

1.2.3 What are the effects of a European pedometer-based community intervention?

The aim of the study in chapter 2.2.3 was to describe the effectiveness of the multi-strategy community project "10,000 Steps Ghent" on physical activity levels after one year of intervention. Results showed an 8 % increase in the number of intervention participants reaching 10,000 steps/day, compared with no increase in the comparison community. Average daily steps increased by almost 900 steps/day in the intervention community, while there was a slight decrease in the comparison participants' step counts. Significant intervention effects were also found for walking, moderate, work-related, and leisure-time physical activity. In the at-risk group (baseline step count level below 10,000 steps/day), step counts increased by almost 1600 steps in the intervention community, and by almost 750 steps in the comparison community. In conclusion, results showed that the "10,000 Steps Ghent" campaign was successful in increasing total physical activity levels in both active and inactive participants. Furthermore, the European intervention was found to be effective in both men and women. In contrast, within the Australian 10,000 Steps intervention only women showed significant increases in physical activity. A possible explanation for this cross-cultural difference is the way in which physical activity was promoted. In Ghent, the focus was not exclusively on steps and walking but also on time-based physical activity recommendations (i.e. 30 minutes/day and 3x/week 20 minutes of sport) and other activities like cycling, gardening,... were promoted. In Australia, it was decided to only use a very specific physical activity message (namely 10,000 steps/day). Later research, however, found that reactions to the 10,000 steps/day message of Australian mid-aged men tended to be negative. The majority of them indicated that they found the idea of doing 30 minutes of physical activity each day more appealing. Focussing on pedometers and walking may not appeal to this group (Burton et al, 2008). Furthermore, it is possible that also social (e.g.

family responsibilities and employment involvement), personal (health consciousness) or climatic (e.g. active transport or outdoor activities may be more comfortable to accomplish in a mild European climate than in hot, humid Australian weather) factors had an influence on gender differences in intervention effects.

Another study (chapter 2.2.4) described the effects of the pedometer-based community intervention "10,000 Steps Ghent" on sitting time. A 12 minutes decrease in total sitting time was found in the intervention community, while the comparison community reported an 18 minutes increase in total sitting time. Intervention participants who increased their step counts during the intervention showed a decrease in their sitting time, suggesting that their increased steps may have displaced sitting. However, in the comparison participants who increased their step counts, a tendency towards increased sitting time was found. Consequently, an increase in step counts does not necessarily result in decreased sitting time, therefore, it can be concluded that the pedometer-based community intervention may have caused the decrease in sitting time.

The last study of this thesis (chapter 2.2.5) aimed to examine the characteristics of the intervention participants who (1) used a pedometer and (2) increased their step counts, during the campaign "10,000 Steps Ghent". Furthermore, the mediational effect of pedometer use on step count change was evaluated. Results showed that pedometer use was more likely among older individuals, an encouraging finding, as it has been shown that physical activity is inversely associated with age (Tudor-Locke et al, 2004; Wyatt et al, 2005). Furthermore, pedometer use was significantly associated with awareness of physical activity promotion messages, and awareness of "10,000 Steps Ghent". An above average steps count increase was more likely among those with higher education. On the other hand, it was promising that a step count increase was more likely in those with baseline step counts below 10,000 steps/day. Finally, those who used a pedometer were more likely to have increased their steps. However, pedometer use only partly mediated the intervention effect on step counts.

2 Overall discussion and conclusion

Several aspects can be concluded from the methodological studies. First of all, the use of untested inexpensive pedometers such as the 'Stepping Meter' is unacceptable for research and/or practice. Furthermore, as shown by the studies in chapter 2.1.2 and chapter 2.1.3, valid pedometers are capable of offering adequate information to discriminate between different types of physical activity. It was found that pedometers not only captured walking, but that they also gave an indication of moderate, vigorous and total levels of work-, transport-, leisure time-, household-, or gardening-related physical activity. Consequently, although a valid pedometer cannot assess physical activity intensity or duration, it is sufficiently valuable in the assessment of (total) physical activity in large, free-living adult samples.

The promotion of physical activity through pedometer use and the use of step count goals in a European country is promising if implemented at the micro-, meso-, and macro-level. On individual base, pedometer use can increase physical activity. The present workplace physical activity intervention was also found to be effective, however, only in already active employees. The pedometer-based community intervention showed to be effective in both active and inactive individuals. In all interventions, the pedometer was used as a motivational and behaviour modification tool which allowed self-monitoring, goal-setting and getting feedback. These strategies focussed on the individual factors associated with physical activity (e.g. self-efficacy).

The present studies did not measure theoretical concepts, nor did they examine the process through which pedometers operate, however, previous studies examined the effect of pedometer-based interventions on conceptual frameworks underlying the intervention (i.e. behaviour theories and models), giving mixed results for self-efficacy, outcome expectations, motivational readiness, decision balance, and self-regulation (Speck and Looney, 2001; Rooney et al, 2003; Rooney et al, 2005; Berry et al, 2007; Clarke et al, 2007; Dinger et al, 2007; Winett et al, 2007; Faghri et al, 2008) (see general introduction p 29-30).

An overall finding of the present intervention studies is that the pedometer interventions did not only affect walking behaviour, but also other (sport) activities. The intervention at the micro-level resulted in more walking, and in increased moderate and vigorous physical activity. The macro-level intervention showed significant intervention effects for walking, moderate physical activity, and for work-related physical activity and leisure time physical activity. Surprisingly, despite a significant intervention effect on step counts, the meso-level intervention did not result in increased step counts or augmented self-reported physical activity. However, it can be concluded that the pedometer-based interventions succeeded in promoting lifestyle physical activity. Previous studies also confirmed that pedometers motivated participants to increase activities other than walking (Mutrie et al, 2003; Mutrie et al, 2004; Merom et al, 2007).

As said above, it was unexpected that the worksite campaign did not result in increased step counts, whereas the community intervention did. The different timeframes of both studies can be an explanation: the workplace intervention was evaluated over a 5 month period, comparing physical activity in different seasons (as stated above physical activity can decrease during winter (Tudor-Locke et al, 2004)), while "10,000 Steps Ghent" was evaluated over a 12 month period. Furthermore, the community project was designed to intervene at the individual, social, and environmental level of the whole community. The scope of the worksite project was less widespread and limited to the workplace itself. However, the workplace intervention strategies were more explicitly present to the worksite participants than in the community intervention, since individuals spend a considerable amount of their waking time at the workplace. Consequently, the intervention awareness of the workplace intervention was higher than the project awareness of "10,000 Steps Ghent". Notwithstanding, the higher project awareness during the workplace intervention did not result in increased steps, nor did social support (considered to be a significant correlate of physical activity) from colleagues result in positive effects.

The results of the present community intervention confirm the usefulness of applying social ecological models to change physical activity. Previous studies also found that a community-based social ecological approach can positively influence physical activity behaviour and attitudes (Cochrane and Davey, 2008). The present study results indicate that the combination of intervention techniques at different levels is needed to achieve positive effects. Next to intervening at the individual level, other social and environmental strategies were also needed to change behaviour. The partly mediational intervention effect of pedometer use (individual level strategy) on step count increase confirms this statement.

Furthermore, the number of pedometer users was somewhat limited (14 %), while the overall intervention effect was considerable.
Still, social ecological analyses can sometimes lead to confusion and difficulty in testing explanations of effects. The complexity of social ecological perspectives may limit comprehensive testing and evaluating (Stokols, 1996).

To conclude, this thesis confirms the value of pedometers in measuring physical activity in free-living populations. Pedometer-determined physical activity data (step counts) correlated reasonable well with self-reported physical activity of different questionnaires. The pedometer has shown to be able to assess, not only walking, but also moderate, and vigorous physical activity in different contexts such as work, transport, leisure time, household and gardening. Consequently, valid pedometers can provide information about a person's total physical activity level. However, not all pedometers are valid, so caution is needed with inexpensive and not validated devices.

Furthermore, the present thesis supports the motivational dimension of pedometers in physical activity interventions at different levels. Wearing a pedometer, with or without support materials, may increase physical activity in a short term intervention at the micro-level. However, adding cognitive and behavioural support positively affected attitudes towards pedometer use.
At the workplace, a pedometer-based intervention showed to be successful in already active individuals: a reduction in the decrease in step counts, probably caused by the time of year, was found.
The pedometer-based project in the community was successful in reaching the population, and is one of the few interventions at the macro-level that showed an increase in physical activity levels in both active and inactive, randomly selected individuals. Furthermore, "10,000 Steps Ghent" was successful in decreasing sitting time, which was an unintended effect of the campaign. During the intervention, pedometer use was positively associated with age and intervention awareness; while pedometer use, a higher education, and a low baseline step count level were found to be significant predictors of step count increase. Finally, these findings encourage the implementation of multi-strategy community interventions. It was found that pedometer use partly mediated the intervention effect, suggesting that other strategies are also important.

3 Strengths and limitations of the studies

Some limitations and strengths of the original research of the thesis will be mentioned here. A weakness of the first two methodological studies is the use of convenience samples of volunteers. The convenience sample of mostly employed and already active adults in chapter 2.1.2 implicates cautious interpretations and limits the generalisability of the results. However, when testing the validity of an inexpensive pedometer (chapter 2.1.1), the influence of participant characteristics on the findings may be rather minimal.
Even though the original random sample in chapter 2.1.3 was obtained from the public record office and the demographic variables of the study participants were comparable to those of the overall Belgian adult population, certain threats to the generalisability of the results need to be mentioned. First of all, the random samples were obtained from only two cities in East-Flanders, a typical Flemish province in Belgium. Second, the sampling methods have limitations. Though the telephone survey provided the opportunity to interview participants, not everyone was registered in the phonebook or within reach, causing exclusion of possible participants. Furthermore, the alternative written recruitment method resulted in a rather low response rate (about 20 %). Third, no more than half of the contacted individuals agreed to participate in the study. Unfortunately, there is no information available about the characteristics of the non-participants.
Also in the study on the micro level, a considerable number of contacted participants (66 %) were not willing to wear a pedometer. Again, no information on their activity level is available. It should be taken into account that those not willing to wear a pedometer may be consistently less active or less motivated or interested in becoming (more) active. On the other hand, about one quarter of the employees (meso-level intervention) who did not use the pedometer while they were given the opportunity to wear it, reasoned that they were already active enough. However, about 60 % had baseline step counts below 10,000 steps/day.

Despite randomised recruitment before the intervention at the micro-level (chapter 2.2.4), results are also limited in generalisability, because participants were motivated to use a pedometer. Furthermore, the study sample was relatively small and consisted of mostly employed, healthy adults, recruited through telephone survey from only one city in East-Flanders, limiting the representativeness of the sample. Another weakness of this study is the lack of information on actual use of the cognitive and behavioural support materials during the individually-based intervention. The main limitations of the meso-level study were the substantial selection bias, limited generalizability and relatively short term follow-up period.

An overall weakness of the studies presented in this thesis it the fact that the study samples were limited to East-Flemish healthy adults. East-Flanders is situated in the Flemish Region of Belgium, which is only one part of the country. The three Belgian regions (Flemish Region, Walloon Region, Brussels-Capital Region) have different powers for example relating to the economy, employment, transport, environment, town and country planning, and supervision of the provinces, communes and intercommunal utility companies.

The pedometer-based interventions at the meso- and macro-levels were pilots for Europe, but the East-Flemish nature of the samples and interventions may limit the generalisability of the interventions. Furthermore, also within Europe, cultures, climates, and environments may differ, which may result in differences in physical activity level and the opportunities to promote it.

Another issue concerning the 'location' of the studies, is the fact that the workplace participating in the meso-level intervention (2007) was located in Ghent, the community where the macro-level intervention took place in 2005-2006. However, both intervention and comparison workplace were situated in Ghent and half of the employees lived at least 20 km from their work, suggesting that they are not inhabitants of Ghent and thus not exposed to the total community campaign. Still, the other half lives in Ghent and one could take offence at this aspect.

In the study at the macro-level, randomization was only possible within the already existing communities. However, it was a strength of the study that within the intervention and comparison community, participants were randomly selected. Another methodological strong point of the study was the large sample size at baseline and the relatively small loss to follow-up.

On the other hand, it should be noted that also in the studies in chapter 2.2.3, 2.2.4, and 2.2.5 recruitment was done via telephone and mail. The overall response rate was no more than 42 %. Again, no information is available about the individuals who were not interested to participate. Furthermore, the studies about the macro-level intervention only reported effects on physical activity and sitting time after one year. In addition, there is no information available about the context of sitting reported in the communities. It could have been useful to know where and how participants spent their sitting time, for example at work, at home, or during screen activities.

Due to social desirability, the use of self-reported physical activity data, could be a weakness, however, the combination of both self-reported and more objective pedometer data was a good solution for this thesis, as previously suggested by different authors (Sallis and Saelens, 2000; Tudor-Locke and Myers, 2001; Tudor-Locke et al, 2002). Still, it has to be considered that pedometers also have some limitations (no information about activity intensity, activity duration, and non-ambulatory activities). Another strength of the thesis as a whole, is the fact that all interventions were evaluated through 'control group' studies. In addition, all interventions were implemented in real-life settings.

4 Practical implications

Although many physical activity interventions have been implemented previously, physical inactivity remains a worldwide public health problem that still needs to be addressed in the future. When developing, designing, and implementing future physical activity promotion programs, research of the present thesis can be a source of ideas, information, advise, and recommendations. The different studies of the thesis provide some practical implications for physical activity research and/or promotion.

First of all, results from the methodological pedometer-related studies implicate the following: due to considerable validity problems of untested inexpensive pedometers, their use should not be recommended for research or practice purposes. As they give incorrect information, these inexpensive devices could damage any investment in good quality pedometers for physical activity assessment and physical activity health promotion. It would be beneficial to introduce a quality label or a consensus on industry standards for pedometer quality to optimize the usefulness of pedometers, as suggested by Tudor-Locke and colleagues (2006). Recommended criteria are: (1) sensitivity threshold of 0.35 g, (2) maximum ± 1 step error on the 20 Step Test, (3) maximum ± 1 % error during treadmill walking at 80 m/min, and (4) maximum 10 % error when compared with ActiGraph or Yamax Digi-Walker in free-living conditions (Tudor-Locke et al, 2006).

Since the pedometer is able to assess walking, moderate, and vigorous physical activity in different contexts, the use of pedometers as monitoring device is recommended when accelerometers are not available. This thesis supports the usefulness of pedometers in determining physical activity in large, free-living adult populations.
Furthermore, the methodological study in chapter 2.1.2, comparing pedometer data with data from different questionnaires, found discrepancies between the currently used health-related guidelines (step count goals and the goal expressed in minutes of physical activity) despite the fact that moderate correlations were found between step counts and questionnaire-based physical activity. Percentages of participants reaching the standards differed notably, maybe due to over-reporting in the questionnaires. Consequently, caution is needed when comparing proportions classified as 'active' based on different instruments.

Secondly, the pedometer-based intervention studies give insights which may be meaningful for research and practice. The study on the individual-based level showed that despite the growing popularity of pedometers and step count goals, ongoing promotion of the concept is still needed, since most participants were not familiar with it. It was assumed that the low familiarity with pedometers resulted in the low proportion of participants willing to wear a pedometer. Physical activity promoters have to consider that certain individuals may be "scared off" by pedometers and resist to wear the device. Consequently, wide accessibility of valid pedometers needs encouragement and it is recommended to provide sufficient information along with it, regarding the device and its use. Maybe role models can also help to convince people to wear a pedometer.
Furthermore, the results suggested that the support of cognitive and behavioural materials is recommended, as the combination of pedometer use with support materials gave better attitudes towards pedometer use (finding it more pleasant to wear a pedometer, willing to wear the pedometer for a longer period, having a better knowledge about pedometers). However, motivated individuals simply wearing a pedometer, with or without support materials, may increase their physical activity on a short time base.

As the workplace pedometer-based intervention was only effective for already active employees, more attention should be given to employees most in need of (more) physical activity. The present workplace intervention was easy to implement and although Marshall (2004) suggested programs with less 'organized' approaches, it is recommendable to provide

counselling sessions or extra support in order to increase physical activity in the total workplace.
Furthermore, it was found that the significant intervention effect on step counts was only present on workdays. Consequently, during future workplace interventions, more attempts should be made to affect leisure time and non-workday physical activity behaviours.
According to the participants, a popular intervention strategy was the use of the stairs instead of the elevator. By placing posters in the hall and by placing footsteps towards the stairs, the promotion of staircase use can indeed be a valuable strategy, however it should always be placed in a broad physical activity promotion approach, emphasizing the accumulation of different lifestyle activities. It is important to recognize that simply taking the stairs instead of the elevator once or twice a day, is not enough to increase physical activity considerably.
A final suggestion for other workplace interventions, is to request employees explicitly to use the pedometer and to keep daily log books. In the present intervention, pedometers were made available to every employee in the worksite, however, only half of the participants reported to have used the pedometer during the intervention (again pointing out the fact that some individuals resist to use a pedometer), which could have caused the low amount of step count increase. It was found that pedometer use was significantly associated with a step count increase in the community-based intervention.

The pedometer-based community intervention showed promising results regarding project awareness, physical activity levels, and sitting behaviours in both active and inactive participants. However, specific attention should also be given to individuals with lower levels of education, as it was found that participants with a college or university degree were more likely to report step count increases. However, due to its overall successfulness, the multi-strategy intervention, which served as a preliminary pilot for Europe, is ready for use in other cities, communities, or countries. Moreover, since limited evidence-based physical activity interventions were ready to use in health organizations, the Flemish minister of Wellbeing, Public Health and Family decided to use "10,000 Steps Ghent" as a base for a large physical activity promotion project through the local health services.
Pedometer use showed to be an important intervention strategy, however, results suggested that the entire multi-strategy campaign was important to affect physical activity. Pedometer use only partly mediated the intervention effect, consequently, also awareness through street

signs and workplace projects for example, are essential to obtain a significant intervention effect on the community's physical activity level.

5 Directions for future research

The present thesis already investigated many aspects about pedometers and pedometer-based interventions. However, many facets still need to be explored regarding physical activity promotion through pedometer use and step count goals.

Present studies did not include information about BMI or other physiological parameters, and socio-demographic variables such as marital status, job classification, and income. Future studies could focus on the relation between pedometer-determined physical activity and these descriptive variables.
Furthermore, no theoretical concepts or processes through which pedometers operate were measured and examined in the present intervention studies. However, future research could focus on these aspects. It would be interesting to know whether setting step count goals is "the drive" in continuing/successfully finishing a program, which cognitions are involved in reaching/not reaching a step count goal, and whether people feel more competent when they make relatively low or high goals.
In addition, it would be valuable to further investigate why people refuse to wear a pedometer. What are their cognitions? Are they avoiding the confrontation with the fact that they are inactive? Are they ignoring their "problems" and therefore showing resistance? Can this high percentage of people refusing to wear a pedometer decrease as now more promotion about pedometer use is made in whole Flanders?

The effects of cognitive and behavioural support materials was investigated through a short duration individual-based intervention, given to volunteers willing to use a pedometer. Future research should evaluate the effects on physical activity behaviour and attitudes in less motivated individuals, for example, in inactive patients given a pedometer by their physician.
Furthermore, long-term effects of additional support materials should be investigated, since the present interventions only lasted for 3 weeks. Baker et al (2008) found that in the short term (4 weeks), pedometer use and step count goal-setting may be effective in promoting

walking, but that in the long term (52 weeks), step count levels were no longer different from those at baseline. The authors suggested that additional support may be required to sustain increases in walking (Baker et al, 2008). Participants in the previous individual-based study were highly motivated to walk and already reasonably active. Consequently, in the future, it should be examined whether pedometer use with additional support materials (1) could increase physical activity and attitudes over a longer time, (2) whether the additional support materials would make a difference compared with purely pedometer use over a longer time, (3) and whether the effects would be the same in less motivated, inactive individuals.

The overall evaluation of the pedometer-based community intervention proved the effectiveness of the "10,000 Steps Ghent" in increasing physical activity after one year. Earlier research however revealed that individuals might fall back into their previous (inactive) routine, once the (intensive) intervention period is completed (Rhodes et al, 1999). In Ghent, the campaign is still ongoing in a less intensive manner, i.e. the website, walking circuits in the parks, and signs in public parking places are still available; however, other posters in the streets or some other marketing strategies (for example advertisements in town magazine, press conferences) are no longer explicitly present. Consequently, one could wonder whether the 'low(er) profile intervention', following the initial intervention, is enough to maintain positive effects on physical activity. A second follow-up study should be conducted to evaluate the long-term (for example 4-year follow-up) effects of the project on physical activity. However, isolating the effect of "10,000 Steps Ghent" will be difficult, since other physical activity interventions, implemented in the previous years, may cause contamination. Still, maintenance and long-term adherence to physical activity are necessary to accomplish sustainable public health effects. A recent systematic review (Müller-Riemeschneider et al, 2008) of physical activity, multi-component interventions in healthy adults showed evidence for long-term increases in physical activity behaviour and physical fitness over 12 to 24 months. The majority of these studies used strategies to maintain increased levels of physical activity over time, including repeat interventions or booster strategies such as mails, phones, internet, groups sessions or combinations. Most substantial long-term increases in physical activity were found in comprehensive and high quality interventions, using additional exercise prescriptions and booster strategies. These review findings could assume successfulness of "10,000 Steps Ghent" over a long time, however, the long-term effectiveness of the community project remains to be proven.

Physical inactivity is linked with inverse health effects (US Department *Surgeon General*, 1996), which in turn have negative economic consequences for healthcare costs (Wang et al, 2004). However, population-based interventions can positively affect the amount of physical activity (Kahn et al, 2002) and consequently improve public health (Haskell et al, 2007). Unfortunately, there is still a considerable amount of individuals not meeting the health-related physical activity guidelines (US Department *Surgeon General*, 1996; Varo et al, 2003; Bauman et al, 2003). Consequently, ongoing physical activity promotion is needed and the strategies used should be both effective and cost-effective (Roux et al, 2008). As suggested previously (Müller-Riemeschneider et al, 2008), additional cost-effectiveness analyses of physical activity interventions are warranted to assess the feasibility of their strategies on a broad population basis. It is important to know how money can be spent with maximum public health benefits (Roux et al, 2008). An evaluation of seven exemplar physical activity interventions (included strategies were community-wide campaigns, social support, individually adapted behaviour change, and enhanced access) showed that all interventions were cost-effective and offered good value for money, with increases in both survival and health-related quality of life (Roux et al, 2008). However, today, little is known about the cost-effectiveness of pedometer-based campaigns (delivered in the community). Therefore, future research could evaluate the cost-effectiveness of programs such as "10,000 Steps Ghent".

An additional unintended effect of "10,000 Steps Ghent" was the decrease in sitting time. Owen et al (2000) argued that sedentary behaviour should not be seen as the other side of the physical activity coin, but as a class of behaviours that can coexist and also compete with physical activity. They believed that it may be valuable to make a distinction between physical activity and sedentary behaviour, and to address each as a problem for research and for public health action in its own right. The findings of the present thesis regarding the effect of a pedometer-based community intervention on sitting time (while step counts increased, sitting time decreased in the intervention participants, suggesting that one displaced the other) are however preliminary. Further research, using more objective measures, should explore whether focusing exclusively on physical activity is sufficient to reduce sitting time, or whether specific attention should be given to sedentary behaviours. In addition, to have more information about the context of the sitting time would be interesting.

It would be helpful to know on what kind of sedentary behaviours interventions should focus.

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