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PROMOTING PHYSICAL ACTIVITY USING AN ACTIVITY MONITOR AND A TAILORED WEB-BASED ADVICE

Sander Slootmaker
PROMOTING PHYSICAL ACTIVITY USING AN ACTIVITY MONITOR AND A TAILORED WEB-BASED ADVICE

Sander Slootmaker
The study presented in this thesis was performed at the Institute for Research in Extramural Medicine (EMGO Institute), Department of Public and Occupational Health of the VU University Medical Center Amsterdam, The Netherlands. The EMGO-Institute participates in The Netherlands School of Primary Care Research (CaRe), which was re-acknowledged in 2000 by the Royal Netherlands Academy of Arts and Sciences (KNAW).

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VRIJE UNIVERSITEIT

Promoting physical activity using an activity monitor and a tailored web-based advice

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CHAPTER 1

GENERAL INTRODUCTION
**General Introduction**

The benefits of physical activity are well-documented, with regular physical activity (PA) being associated with a wide range of health benefits for individuals and populations. It has been linked to reduced risk of various chronic diseases, including cardiovascular disease, diabetes, and some types of cancer. Furthermore, PA improves functional capacity, fitness, and quality of life.

**How much physical activity is needed to stay healthy?**

To promote and maintain health, adults should accumulate a daily amount of at least 30 minutes of moderate intensity PA on at least five days of the week, according to the current Public Health PA recommendation. Children and adolescents are recommended to engage in PA of moderate or vigorous intensity for at least 60 minutes on each day of the week. Combinations of moderate and vigorous intensity PA can be accumulated to meet these recommendations. Moderate intensity PAs are activities such as brisk walking, bicycling, and active outdoor playing. Vigorous intensity PAs are activities such as aerobic dancing and sports involving a lot of running.

**Physical (in)activity in the Netherlands**

Levels of PA have decreased in the second half of the previous century. Surveillance data (2000-2007) from the Netherlands show consistent but low adherence to the Public Health PA recommendation. Children and adolescents are recommended to engage in PA of moderate or vigorous intensity for at least 60 minutes on each day of the week. Combinations of moderate and vigorous intensity PA can be accumulated to meet these recommendations. Moderate intensity PAs are activities such as brisk walking, bicycling, and active outdoor playing. Vigorous intensity PAs are activities such as aerobic dancing and sports involving a lot of running.

**In search of a promising physical activity intervention**

To achieve public health benefits, we are faced with the challenge to encourage more people to be more physically active more often. Over the years, different interventions to promote PA have been developed, however with mixed effects. Based on national and international literature, a number of promising factors can be mentioned that support health promotion programs in their implementation and subsequent impact.
multiple axis accelerometers provide comparable PA information. This type of information on PA may improve our understanding of the dose-response relationship between PA and health and identifying the determinants of PA.

DETERMINANTS OF PHYSICAL ACTIVITY

Developing effective interventions to promote a physically active lifestyle requires insight into important and modifiable determinants of PA. A theoretical basis is an important prerequisite for the development of interventions to successfully promote PA. A theoretical model that is frequently used to explain various health behaviors is the Theory of Planned Behavior. A Dutch version of this model is called the ASE-model (Attitude; Social influence and self-Efficacy). This model assumes that PA behavior is the result of the intention to engage in PA and intention itself is determined by attitudes, social influences and self-efficacy. ‘Attitude’ can be described as the general feeling of a person (good or bad, favorable or unfavorable) towards a certain behavior (e.g. PA). This feeling is determined by perceived positive or negative consequences of being physically active. Social influence can be described as the influence and expectations of significant others (e.g. friends, family, colleagues), but also by, for example, their level of PA (i.e. imitation, modeling). Self-efficacy is the perception of an individual about his or her capability to perform a certain activity. Another determinant of PA that is mentioned in the I-change and precaution adoption model is awareness.

Awareness of one’s physical activity

Physical activity is a complex behavior. The large possible number of different activities in combination with their distribution over the day and their time-span make evaluating the adequacy of one’s actual level of PA difficult. Various studies in Dutch adult populations have shown that inactive subjects, especially women and people with low educational level, are often not aware of the fact that they are insufficiently active, even when they are familiar with the Public Health PA recommendation and convinced of the importance of regular PA. Furthermore, respondents who are not aware of their inadequate PA level have a less positive intention to increase their level of PA than those who rate their own PA level as low. Thus, before people intend to become more physically active, they must first become aware of their inactivity and their need for change. The research in this thesis is based on the hypothetical model depicted in figure 1. Increasing awareness among people with insufficient PA levels through self-monitoring could improve the effectiveness of a PA intervention.

WEB-BASED COMPUTER-TAILORED PA INTERVENTIONS

The higher the level of personalization of an intervention, the more likely an intervention is effective in producing behavioral changes. Computer-tailored interventions are a relatively new way of delivering tailored PA information. Computer-tailored interventions provide respondents with personally adapted feedback about their present health behavior and/or the behavioral determinants. They also provide personally adapted suggestions to change behaviors that are potentially health threatening and to maintain behaviors that are beneficial for health. With the rapid development of the Internet, it is now possible to widely distribute computer-tailored interventions with relatively low costs and use them at any time of the day. Worldwide there are currently more than one billion Internet users and this number is still rising. The biggest penetration rate (i.e. the percentage of the total population that uses the Internet) is found in North America (73.6%), followed by Oceania (59.5%) and Europe (48.1%). In 2007, 84% of Dutch adolescents and 71% of young adults used the Internet on a personal computer at home. Furthermore, 75% of the Dutch adult Internet-users use the Internet to look for health-related or medical information. Therefore, Internet-based computer-tailored interventions are considered as a feasible strategy to promote PA.

Recently a few reviews became available on the effectiveness of web-based computer-tailored interventions to promote PA. These reviews show that most Internet-based computer-tailored interventions report positive behavioral outcomes and could be effective in increasing PA. However, intervention effects were short term, and there was limited evidence of maintenance of PA changes. Two web-based PA interventions found significant increases in moderate intensity PA among sedentary adults with type 2 diabetes and healthy adults. These studies included goal setting and automatically generated tailored feedback based on activity monitor outcomes. Providing a personal activity monitor in combination with a personalized PA advice via the Internet looks promising for PA promotion.

THE PAM-CONCEPT

In 2002, PAM B.V. (Doorwerth, the Netherlands) introduced a commercially available innovative product and concept to promote PA. This concept consists of a physical activity monitor (PAM) as well as a specially designed website (PAM COACH system) providing personalized PA advice, based on the amount of PA measured by the PAM. The use of an activity monitor in combination with a personal PA advice through the Internet was at that time a relatively innovative intervention. The intervention described included feedback on actual behavior and was individualized (for more details about the concept see Chapter 4). The PAM accelerometer with its direct PAM feedback (i.e. activity score) provides the user with an easy to use self-monitoring tool. The computer-tailored PA advice was generated interactively and took the individual preferences and possibilities of the user into account. This was meant to improve the uptake of the intervention and inclusion of PA in daily life. The PA advice gave the user individually tailored information on how to adopt a physically active lifestyle, which activities qualified as moderate or vigorous intensity PAs and how to overcome perceived barriers to PA. Messages on the Internet website were short and easily applicable in daily life, with the focus on stimulating moderate and vigorous intensity PA in short bouts during the day, avoiding patronizing messages. Advantages for the user of this individualized intervention were the flexibility of the PAM COACH system (the participants could decide where and when to login) and the advocated
stepwise progress in PA, tailored to actual PA levels. The use of the Internet looked specifically interesting for young people, because they generally have the skills to use the computer and are generally interested in new technology.\textsuperscript{66,67}

REALIZATION OF THE RESEARCH PROJECT
On behalf of PAM B.V., Dr. E.P.N. Damen approached the VU University Medical Center (VUmc) and the National Institute for Public Health and the Environment (RIVM) to evaluate the feasibility and effectiveness of the PAM-concept in intervention studies. After consultation with PAM B.V., the VUmc along with the RIVM decided to evaluate this concept. An application for funding was granted in 2002 by the Netherlands Organization for Health Research and Development (ZonMw), a non-profit organization. In order to conduct the PAM project, PAM B.V. sold the required PAMs to VUmc against market price, facilitated access to the PAM COACH website, and provided technical PAM support. PAM B.V. was not a partner in the research proposal and in the further execution and processing of the study.

AIM AND OUTLINE OF THE THESIS
The purpose of the research described in this thesis was three-fold:
1. to evaluate the use of the PAM for monitoring purposes in adolescents and young adults;
2. to evaluate the effectiveness of providing relative inactive adolescents and young adults with a PAM in combination with a personalized PA advice and
3. to evaluate the feasibility of this intervention.
We hypothesized that the use of a PAM combined with the PAM COACH system would increase awareness, the behavioral determinants of PA and subsequently PA among relatively inactive people.

The chapters 2 and 3 describe validation studies of the PAM accelerometer and the Activity Questionnaire for Adults and Adolescents (AQuAA), respectively. These PA measures were new or specifically modified to fit the studies described in this thesis.
Chapter 4 presents the design of the PAM study-protocol in detail. It provides an extensive description of the study background, objectives and execution of the project.
Chapter 5 gains more insight in the use of the PAM accelerometer for monitoring purposes. This chapter describes the comparability of self-reported PA (i.e. AQuAA) versus objectively measured PA (i.e. PAM) in subgroups of adolescents and young adults.

Randomized controlled trials were conducted to evaluate the feasibility and effectiveness of providing relative inactive people with the PAM in combination with an individualized PA advice given at the PAM COACH website. Chapters 6 and 7 present the short (3 month) and long-term (8 month) effectiveness of these trials on PA and its behavioral determinants among adolescents and young adults, respectively. The final chapter summarizes the main findings of this thesis and discusses the methodological issues derived from this thesis. After the conclusions, directions for future research and implications for public health are formulated.
CHAPTER 2

CONCURRENT VALIDITY OF THE PAM ACCELEROMETER RELATIVE TO THE MTI ACTIGRAPH USING OXYGEN CONSUMPTION AS A REFERENCE

ABSTRACT

BACKGROUND
Accurate assessment of activity is necessary to more objectively evaluate the health benefits of physical activity and the effectiveness of behavioural interventions designed to promote physical activity. Accelerometry-based activity monitors offer promise for the assessment of physical activity. The purpose of this study was to examine the concurrent validity of the Pam accelerometer relative to the Actigraph accelerometer using oxygen consumption as a reference, and to assess the test-retest reliability of the Pam.

METHODS
Thirty-two fit, normal weight adults (aged 21-54) performed two activities, treadmill walking and stair walking, while wearing the Pam, the Actigraph and the Cosmed K4b². Correlation coefficients and agreement in absolute energy expenditure (EE) levels between Pam, Actigraph and Cosmed were calculated. The test-retest reliability was examined among 296 Pams using a laboratory shaker. Intra-class correlation coefficients (ICC) and coefficients of variation (CV) were determined.

RESULTS
Correlations for treadmill walking and stair walking respectively were $R^2=0.95$ and $R^2=0.65$ for Pam with Actigraph, $R^2=0.82$ and $R^2=0.93$ for Pam with VO₂, and $R^2=0.64$ and 0.74 for Actigraph with VO₂. Both the Pam and Actigraph underestimated EE during treadmill and stair walking by a substantial amount. The test-retest reliability of the Pam was high (ICC=0.80; 95% confidence interval 0.28 to 0.92) and intra-CV=1.5%.

CONCLUSION
The Pam and Actigraph accelerometers are comparable in assessing bodily movement during treadmill and stair walking. The Pam is a valid device to rank subjects in EE and can be useful in collecting objective data to monitor habitual physical activity.

BACKGROUND
In order to monitor trends in physical activity levels on a population level, there is a need for valid and reliable methods to quantify physical activity (PA). Recently, accelerometry-based activity monitors are used with increasing regularity to assess PA objectively under free-living conditions. Accelerometry is based on the intensity, frequency and duration of bodily movement. Favorable aspects of this method are the real-time data acquisition, the convenience and the relatively low-cost compared to other objective methods (e.g. doubly labeled water). The MTI Actigraph (Manufacturing Technologies Inc., Fort Walton Beach, FL), formerly known as Computer Science and Applications (CSA) is one of the most widely used accelerometers in PA research. A number of studies have validated the Actigraph to indirect calorimetry or relative to other accelerometers under both laboratory and field conditions. The literature suggests that the uniaxial accelerometers like the MTI Actigraph provide similar information under both conditions and are best placed on the hip or the lower back. One of the key limitations of accelerometers is that not all activity is reflected in acceleration or deceleration e.g. non-ambulatory physical activities with arm and or limb movements, walking on a gradient or weight-bearing activities. Various studies have demonstrated a significant underestimation of daily energy expenditure (EE) compared with the doubly labeled water method. Therefore the use of accelerometers in free-living individuals seems more valuable for comparing activity levels between groups of individuals than to quantify EE.

The Pam accelerometer (PAM, PAM B.V. Doorwerth, The Netherlands, figure 1) is a recently developed uniaxial accelerometer for general use.

Figure 1. Pam accelerometer with reader interface unit.
The PAM is based on similar technology as the Actigraph, and provides the user with a proxy measure for 24 hour PA (i.e. the PAM score) which is shown in its display. The PAM is easy to use by consumers as well as scientists. Extra features of the PAM are its memory capacity to store data up to three months and the ability to upload the PAM scores to a personal website providing tailored PA feedback. If proven valid and reliable, the PAM could be used for monitoring PA and at the same time providing immediate feedback. To date, no papers have been published on the validation and reliability of the PAM accelerometer. Considering the PAM and the Actigraph use the same uni-axial technology, we expect similar performance and limitations in assessing PA.

The purpose of this study is threefold. The primary purpose of this study is to test the validity of the PAM accelerometer relative to the Actigraph accelerometer in assessing PA while using indirect calorimetry as a reference in adults, performing treadmill walking and stair walking. Second, we compared all three instruments on their calculated MET scores during the same activities and finally the test-retest reliability of the PAM was examined on a laboratory shaker.

METHODS

PARTICIPANTS

Subjects were recruited through leaflets, personal contact, phone and e-mail within the VU University Medical Center. Detailed information about the study objective and the protocol of the study was provided to the subjects. Inclusion criteria were ability to walk and to walk stairs, not being pregnant and non-usage of beta blockers. All participants read and signed an informed consent statement. The study protocol was approved by the Medical Ethics Committee of the VU University Medical Center. Participants were instructed not to eat or smoke during the three hours preceding the tests.

PROCEDURES

A structured protocol of anthropometrics and resting physiological assessments was applied, followed by PAM, Actigraph and oxygen uptake (VO\textsubscript{2}) monitoring during treadmill walking and stair walking, under controlled laboratory settings. Body height was measured to the nearest 0.1 cm using a stadiometer (Seca model 125, Seca GmbH & Co, Hamburg, Germany) and body weight was measured to the nearest 0.2 kg with the subjects dressed in light clothing without shoes, using a calibrated scale (Seca model 888, Seca GmbH & Co, Hamburg, Germany). Percentage body fat was estimated from the sum of four skin fold thickness measurements on the right side of the body (biceps, triceps, sub-scapula, supra-iliac), using a Harpenden skin fold caliper (model HSB-BI, British Indicators, West Sussex, UK).

New PAMs (N=296) were tested and retested on a laboratory shaker (Edmund Bühler, SM 25, 36 mm amplitude). The accelerometers were clipped on a specifically designed framework, with their axis of measurement along the radius of the shaker. Sixty PAMs at a time were put on the laboratory shaker simultaneously and were tested twice, at three Hertz for a period of 10 minutes. Because the default PAM score is based on a 24 hour period, the PAMs were set to be eight times more sensitive to enable higher PAM scores and improve discrimination in a short period of time. Before each testing session the laboratory shaker was warmed up for 15 minutes to reduce the possible variability in speed and amplitude of the shaker.

ACCELEROMETERS

The PAM (model AM101, 58x42x13 mm, 28 g, figure 1) measures accelerations in the vertical plane with a sensitivity of 2 mV/G by means of a piezoelectric sensor. The acceleration signal is filtered (0.1 - 5 Hz), rectified and integrated in a capacitor. The voltage of the capacitor is measured each second and digitized by an Analog-to-Digital Converter (ADC) which gives an ADC score per second. In a microprocessor the ADC score is averaged per 24 hours resulting in a PAM score. For this study, the manufacturer created an extra output possibility on the PAM. This enabled us to monitor the ADC scores per second via a wired connection to a PDA (model m515, Palm Europe Ltd., Wokingham, UK). This single modification did not affect the assessment. In this paper, the ADC scores will be referred to as PAM scores. The participants carried the PDA in a pouch on the lower back.

The MTI Actigraph (model AM-7164, 50x41x15 mm, 43 g) is, like the PAM accelerometer, an uni-axial accelerometer with a similar mechanism that converts accelerations in activity counts. It can detect acceleration ranging in magnitude from 0.05 to 2.00 G with a frequency response from 0.25 to 2.50 Hz. Activity counts of the Actigraph were stored in one second epochs. Both accelerometers were directly clipped to a waist belt and were oriented in the vertical direction. The PAM was positioned at the spina iliaca anterior superior and the Actigraph was placed right of the PAM.
INDIRECT CALORIMETRY

Oxygen uptake (VO\textsubscript{2}) was measured on a breath-by-breath basis using a portable metabolic unit, the Cosmed K4b\textsuperscript{2} (Cosmed s.r.l., Rome, Italy), in this article referred to as Cosmed. The Cosmed has been shown to be a valid device compared with the Douglas bag method during cycle ergometry.\textsuperscript{91} Before each test, the oxygen and carbon dioxide analyzers were calibrated according to the manufacturer’s instructions. These instructions consisted of a four-step calibration process, namely a room air calibration, a reference gas calibration using 15.93% oxygen and 4.92% carbon dioxide, a delay calibration and finally a turbine calibration performed with a 3.00 liter syringe (Hans-Rudolph, Kansas City, MO, USA). The participants wore a chest harness with the Cosmed and breathed through a flexible face mask (Hans-Rudolph, Kansas City, MO, USA) that covered the subject’s mouth and nose. The Cosmed measured resting VO\textsubscript{2} and VO\textsubscript{2}\textsubscript{CO} during the performance of two selected activities.

ACTIVITIES

Two light-to-moderate intensity daily activities\textsuperscript{92} were selected:

1. Walking on a non-graded treadmill at three speeds; slow pace walking at 3 km/h (1.9 mph), moderate to brisk walking at 5.1 km/h (3.2 mph) and brisk to fast walking, but not running, at 7 km/h (4.4 mph);
2. Walking up and down stairs with a speed of 80 and 100 steps per minute (spm) utilizing a metronome; the stairs consisted of 11 steps with a stepheight of 18 cm.

Each participant began the testing procedure with a ten minute rest period in a sitting position to get used to the equipment. The intensities of each of the two activities were performed consecutively for five minutes. The participants had a minimum of 5 minutes rest between walking and walking the stairs. The order in which the activities were performed was the same for all participants.

DATA ANALYSIS

Data of the last minute of each activity was averaged for the PAM, Actigraph and Cosmed. Standardized longitudinal regression coefficients were computed using generalized estimating equations (GEE) between all three measures, and for both activities. These regression coefficients can be interpreted as Pearson correlation coefficients, with the advantage that GEE takes into account that multiple observations per subject (e.g., walking at 3, 5 and 7 km/h) are not independent.\textsuperscript{93} Scatter plots were used to graphically show the variability in individual counts per minute of the PAM and Actigraph versus the measured VO\textsubscript{2} data. As VO\textsubscript{2} does not increase linear with body weight we considered the 0.67 power to be a more appropriate basis for analyses.\textsuperscript{94} VO\textsubscript{2}-data (mL·kg\textsuperscript{-0.67}·min\textsuperscript{-1}) were converted to metabolic equivalents (METS) by dividing the average VO\textsubscript{2}-values during activity by the resting metabolic rate, i.e. the individual VO\textsubscript{2} in rest.

Mean MET with 95% confidence intervals were computed for all intensities. Paired t-tests were used to test the differences between the criterion (Cosmed), and the EE estimated by the accelerometers, to indicate whether the accelerometers over- or underestimated EE. One-way analyses of variance (ANOVA) with Bonferroni adjustment was used to examine the sensitivity of the PAM, Actigraph and measured oxygen uptake to changes in speed of treadmill walking and stair walking.

The coefficient of variation (CV) was calculated as an estimate of the intra- and inter-PAM variability of the data obtained on the laboratory shaker. The intra-class correlation coefficient (ICC) was calculated to describe the between-test variation. The ICC (model 3.1) is determined by a two-way mixed effects model for absolute agreement. An ICC close to one represents good repeatability. Using both CV and ICC gives good insight into the magnitude of (dis)agreement between the PAMs.\textsuperscript{95} GEE were performed using SPIDA (version 6.05, Statistical Computing Laboratory, Macquarie University, NSW, Australia) whereas all other analyses were performed using SPSS (version 11.0; SPSS Inc. Chicago, IL, US).
RESULTS

Physical characteristics of the 32 participants are listed in Table 1. The study population consists of fit, normal weight young adults. Table 2 shows mean values of the Cosmed, PAM and Actigraph during treadmill walking and stair walking at different speeds. ANOVA showed that indirect calorimetry and both accelerometers could distinguish the different intensities of treadmill walking and stair walking (p<0.001).

Table 1. Physical characteristics of the participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=32)</th>
<th>Men (n=14)</th>
<th>Women (n=18)</th>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>29.4 ± 7.3 (21-54)</td>
<td>29.7 ± 7.4 (21-50)</td>
<td>29.2 ± 7.4 (21-54)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.4 ± 8.7 (164.7-194.6)</td>
<td>184.3 ± 6.5 (171.5-194.6)</td>
<td>171.9 ± 5.9 (164.7-190.1)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.7 ± 13.7 (51.4-88.7)</td>
<td>82.9 ± 11.3 (63.8-98.7)</td>
<td>63.0 ± 7.7 (51.4-80.4)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.7 ± 3.2 (16.9-31.2)</td>
<td>24.4 ± 2.9 (20.7-31.2)</td>
<td>21.3 ± 2.8 (16.9-29.2)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>24.5 ± 6.3 (11.7-37.2)</td>
<td>20.0 ± 5.8 (11.7-30.4)</td>
<td>27.9 ± 4.2 (19.4-37.2)</td>
</tr>
<tr>
<td>Resting VO₂</td>
<td>2.6 ± 0.9 (1.2-5.2)</td>
<td>3.0 ± 1.0 (2.0-5.2)</td>
<td>2.3 ± 0.7 (1.2-3.4)</td>
</tr>
</tbody>
</table>

Values are means ± SD with range in parentheses; n, number of participants; BMI, body mass index; VO₂, oxygen uptake.

Table 2. Mean values of the Cosmed K4b², PAM and Actigraph accelerometer for treadmill walking and stair walking.

<table>
<thead>
<tr>
<th>Activity</th>
<th>VO₂ (mL/kg·min⁻¹/min)</th>
<th>PAM (score/min)</th>
<th>Actigraph (count/min)</th>
<th>CV for 10-sec Actigraph counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking at 3 km/h</td>
<td>40.0 (7.0)</td>
<td>766.7 (322.3)</td>
<td>1029.0 (258.2)</td>
<td>22.8 (4.4)</td>
</tr>
<tr>
<td>Walking at 5 km/h</td>
<td>56.1 (8.6)</td>
<td>2141.2 (312.3)</td>
<td>3512.7 (626.0)</td>
<td>7.4 (10.4)</td>
</tr>
<tr>
<td>Walking at 7 km/h</td>
<td>94.1 (10.3)</td>
<td>4267.4 (562.7)</td>
<td>5836.1 (1126.7)</td>
<td>7.4 (18.8)</td>
</tr>
<tr>
<td>Stair walking 80spm</td>
<td>84.4 (9.5)</td>
<td>1291.6 (253.3)</td>
<td>3206.6 (433.9)</td>
<td>30.6 (16.9)</td>
</tr>
<tr>
<td>Stair walking 100spm</td>
<td>100.7 (10.9)</td>
<td>1845.9 (405.9)</td>
<td>3888.7 (548.9)</td>
<td>30.7 (19.5)</td>
</tr>
</tbody>
</table>

Values are means with standard deviation in parentheses; CV, coefficient of variation.
Figure 3. The relation between the Cosmed (VO\(_2\)) and the PAM accelerometer (PAM score per minute) for treadmill walking and stair walking.

- Treadmill walking (3, 5 and 7 km/h), \(R^2 = 0.93; p<0.001\)
- Stair walking (80 and 100 spm), \(R^2 = 0.74; p<0.001\)

Figure 4. The relation between the Cosmed (VO\(_2\)) and the Actigraph accelerometer (Activity counts per minute) for treadmill walking and stair walking.

- Treadmill walking (3, 5 and 7 km/h), \(R^2 = 0.82; p<0.001\)
- Stair walking (80 and 100 spm), \(R^2 = 0.64; p<0.001\)
High correlations between both accelerometers were found for treadmill walking ($r^2=0.95$, figure 2) and stair walking ($r^2=0.65$). Both for treadmill walking and stair walking the correlation between the PAM and indirect calorimetry was slightly higher ($r^2=0.93$ and $r^2=0.74$ respectively) than the correlation between the Actigraph and indirect calorimetry ($r^2=0.82$ and $r^2=0.64$ respectively). All correlations had p-values below 0.001. The scatter plots in figure 3 and 4 show the relation between respectively, the PAM and Actigraph accelerometer with measured VO$_2$ ml/kg$^{1.07}$/min.

In table 2, mean activity counts per minute and CV of the counts per 10-sec for each activity from the Actigraph are shown. For an activity with a CV of ≤ 10, Crouter’s walking/running equation was used and for a CV above 10, Crouter’s lifestyle leisure time physical activity regression equation was used. Only the walking speeds five and seven km/h were processed with Crouter’s walking/running regression equation.

Table 3 and figure 5 show that the predicted EE of the PAM as well as the Actigraph, underestimated the measured EE by indirect calorimetry for both activities. The PAM underestimated measured EE for treadmill walking at three, five and seven km/h by respectively 48%, 30% and 30%. The predicted EE for stair walking at 80 and 100 steps was also underestimated by the PAM by 67% and 65%. The different regression equations to predict EE by Actigraph counts underestimated the EE for treadmill walking at three, five and seven km/h: Freedson by 44, 25, 37%; Hendelman by 17, 23, 45% and Crouter by 3, 32, 45% respectively. Only Crouter’s equation to predict EE for walking at a speed of three km/h was not significantly different from the measured MET (p=0.58). Crouter’s equation underestimated walking the stairs at 80 and 100 steps per minute by 25 and 31% while Freedson’s and Hendelman’s equation predicted EE less than half of the measured EE.

Table 3. Measured gross energy expenditure (METs) from indirect calorimetry and differences in energy expenditure of indirect calorimetry minus the energy expenditure estimates of the PAM and Actigraph for treadmill walking and stair walking.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Measured MET</th>
<th>Cosmed minus PAM</th>
<th>Cosmed minus Actigraph (Freedson equation)</th>
<th>Cosmed minus Actigraph (Hendelman equation)</th>
<th>Cosmed minus Actigraph (Crouter equation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean ∆</td>
<td>Mean ∆</td>
<td>Mean ∆</td>
<td>Mean ∆</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>Walking at 3 km/h</td>
<td>4.02 (1.31)</td>
<td>1.91</td>
<td>1.39; 2.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking at 5 km/h</td>
<td>5.66 (1.69)</td>
<td>1.74</td>
<td>1.11; 2.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking at 7 km/h</td>
<td>9.71 (3.79)</td>
<td>3.02</td>
<td>1.73; 4.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stair walking at 80 spm</td>
<td>8.56 (2.80)</td>
<td>5.76</td>
<td>4.74; 6.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stair walking at 100 spm</td>
<td>10.26 (3.53)</td>
<td>6.74</td>
<td>5.44; 8.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.13*</td>
<td>-0.35; 0.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All means and differences are expressed in MET; SD, standard deviation; 95% CI, 95% confidence interval; * p>0.05.
This study examined the validity of the Pam relative to the Actigraph, using indirect calorimetry as reference. High correlations ($R^2$) for the Pam accelerometer with indirect calorimetry for treadmill walking (0.93) and stair walking (0.74) were found. These correlations were slightly higher, compared to the correlations for the Actigraph with indirect calorimetry, 0.82 and 0.64 respectively. The observed correlations for the Pam and Actigraph during walking are high compared to previous reports of accelerometers, where correlations ($R^2$) were found ranging from 0.48 to 0.88.

Furthermore, the Pam showed a mean error score (measured EE by indirect calorimetry minus predicted EE by accelerometer) for treadmill walking of 2.2 MET. Although this indicates that the Pam does not give an accurate estimation of EE for both activities, the results for treadmill walking were comparable with the mean error scores of the Actigraph by Freedson (2.3 MET), Hendelman (2.2 MET) and Crouter (2.1 MET). The higher mean error score for stair walking (6.3 MET) displays the underestimation relative to the measured EE. Lower mean error scores for stair walking were found for the Actigraph regression equations of Freedson (5.2 MET), Hendelman (5.0 MET) and Crouter (2.6 MET). These results imply that the Pam and Actigraph should not be used to predict EE in free-living conditions, instead using these instruments only to assess patterns of PA.

The underestimation of predicted EE by both the accelerometers in this study was quite distinct and larger than in the leading EE validation studies of the Actigraph. In these studies, the VO$_2$-values of each activity were divided by the standard (70 kg, 40 yr old male) value for resting VO$_2$ of 3.5 ml·kg$^{-1}$·min$^{-1}$. In this study we chose for a more accurate approach to determine the MET per activity by dividing the VO$_2$-values of each activity by the individual resting metabolic rate (RMR) based on a recent study of Byrne et al which showed that the 1-MET value of 3.5 ml·kg$^{-1}$·min$^{-1}$ overestimates the actual resting VO$_2$ value on average by 35%. Even though we measured resting VO$_2$ during a ten minute rest period in sitting position instead of the supine position, it is reasonable to speculate that this resting VO$_2$ is more accurate than the standard 3.5 value. Furthermore, the average VO$_2$ in rest (2.6 ± 0.4 ml·kg$^{-1}$·min$^{-1}$) found in Byrne’s study, including 642 women and 127 men, was comparable with the average resting VO$_2$ observed in our study (2.6 ± 0.9 ml·kg$^{-1}$·min$^{-1}$).

The relatively high correlation between the output of the Pam and Actigraph accelerometer during treadmill walking ($R^2$=0.95) and stair walking ($R^2$=0.65) demonstrates a comparable way of assessing of bodily movements. However when the counts were converted to METs to compare EE, a difference in absolute MET scores was found for both activities. This underestimation of the Pam relative to the Actigraph accelerometer is largely caused by the different regression equations used but may also be explained by a difference in frequency optimum of the accelerometers. The Actigraph detects accelerations from 0.05-2.0 G and is band-limited with a frequency response from 0.25 to 2.5 Hz, whereas the Pam has its optimum of sensitivity from 2 to 7 Hz. The frequency of stair walking at 80 and 100 steps per minute corresponds to 1.3 and 1.6 Hz, which is outside the frequency optimum of the Pam. This could also explain the greater mean error of the Pam for walking at three km/h (1.2 Hz.), compared with walking at a speed of five (2 Hz) and seven km/h (2.8 Hz.). This hypothesis would imply that the Pam has difficulties assessing physical activities with lower frequency movements such as very slow walking and ambulant household activities and seems therefore more suitable to monitor moderate to vigorous PA behavior.
A high test-retest reliability of the PAM at three Hz was found \((ICC = 0.80)\), which is similar to the range of values reported previously for the CSA and Tritrac using motorized vibration tables.\(^{100,101}\) Additionally, compared to previous reliability studies\(^{100,101}\), low intra-instrument \((1.5\%)\) and inter-instrument \((4.4\%)\) CV’s were found. These intra- and inter instrument CV’s of the PAM can be considered as good.\(^{100}\)

Walking speed is enforced when walking on a treadmill. This enforcement may differ in its impact on accelerometer and oxygen uptake scores. Therefore, the participants were asked also to walk up and down a 25 meter hallway at their own pace. An average self-determined walking speed of five km/h was found \(\text{(data not shown)}\), which is comparable with findings of a recent study.\(^{96}\)

No significant differences were found, nor for the actual EE neither the estimated EE by the PAM and Actigraph, when walking at ones own pace and treadmill walking at five km/h. Hence, the results found for walking on a treadmill \(\text{(at five km/h)}\) seem applicable for walking in free-living conditions.

Several studies found that the Actigraph underestimates EE in free-living conditions.\(^{46,98,96}\) This is probably due to the large variability in acceleration counts and minute-to-minute variation for lifestyle activities other than walking. The results for the two-regression model of Crouter emphasize that the accuracy of the EE estimation from activity counts can be improved, using a walking or a lifestyle equation based on the variation in activity counts. However, in our study walking at 3 km/h showed the best results for EE estimation with the lifestyle equation. The MET values produced by the Actigraph equations differed per activity, because each equation is based on different activities. For that reason (overestimation), and considering the limitations of the accelerometer, the estimation of daily EE could be improved by using activity dependent regressions, instead of solely one for 24 hour EE.

Differences in activity counts between subjects can partially be attributed to placement of the accelerometers on the hip. A study of Metcalf et al. showed that the angle in which the Actigraph was worn, had a lowering effect of 6% on the Actigraph score when angled at 15° and even 29% when angled at 45°.\(^{100}\) In this study, the positioning of the accelerometers was checked, before and in-between the activities. However, individual differences in locomotion patterns may, during the activities, have resulted in differences in the angle in which the accelerometers were worn. Nevertheless, the output from both accelerometers was consistent during the activities, which suggest that the variation between subjects is more due to the positioning itself than the change of positioning. Most study participants were normal weight which reduces the risk of an effect due to the angle. Other sources of variation between subjects for treadmill walking could be ascribed to differences in step frequency\(^{100}\), however this was not assessed in this study.

Limitations of the study are that the results were found under laboratory conditions and may not be generalizable to field-based activities. Furthermore, the Actigraph used was purchased new a few months before the study and was calibrated by the manufacturer. However, not calibrating the Actigraph before the tests can be considered as a limitation of our study.

In conclusion, the correspondence between the PAM and the Actigraph results suggests that both devices produce similar estimates of bodily movement in fit, normal weight young adults. The PAM is a valid device to rank subjects in EE, but it underestimates EE by 36% during treadmill walking and 66% during stair walking. Both the PAM accelerometer as well as the Actigraph underestimate EE of treadmill walking and stair walking. The test-retest reliability of the PAM was high and comparable with the Actigraph. Therefore the PAM will most likely underestimate physical activity over a 24-hour period in field measurements by a substantial amount, like the Actigraph accelerometer. The PAM however can be useful in collecting objective data to monitor habitual PA and to discriminate between individuals who differ in PA levels. Further research is needed to assess the reliability and validity of the PAM accelerometer in field-based assessments of physical activity.

**PERSPECTIVES**

Substantial improvement in public health is possible through encouragement of PA in inactive groups. To achieve public health benefits, we are faced with the task to establish awareness of physical (in)activity and encourage, but also enable people to include more PA in their daily life. The PAM concept combines the objective measurement of physical activity by means of an accelerometer with a web-based tailored PA advice. By providing PA feedback on the PA level, this device may increase awareness and hence stimulate the recommended PA. In this study the PAM accelerometer shows a high test-retest reliability and the correlation between the PAM and indirect calorimetry was at least as good as the correlation between the MTI Actigraph and indirect calorimetry. Hence this study indicates that the PAM can be used for monitoring purposes as well as a tool to stimulate PA. A combined tool could benefit health promotion professionals in providing inactive subjects with immediate feedback about their PA level in their present situation.
Chapter 3

Test-retest reliability and concurrent validity of the Activity Questionnaire for Adults and Adolescents (AQuAA)

Submitted for publication: Chin A Paw MJM, Slootmaker SM, Schuit AJ, van Zuidam M, van Mechelen W. Test-retest reliability and concurrent validity of the Activity Questionnaire for Adults and Adolescents (AQuAA)
ABSTRACT

BACKGROUND
Accurate measures of physical activity are highly needed. We evaluated the test-retest reliability and concurrent validity of the self-report Activity Questionnaire for Adults and Adolescents (AQuAA).

METHODS
In the test-retest reliability study, 53 adolescents and 58 adults completed the AQuAA twice, with an interval of two weeks. In the validity study, 33 adolescents and 47 adults wore an accelerometer (Actigraph) during two weeks, and subsequently completed the AQuAA.

RESULTS
In adolescents the test-retest reliability was fair to moderate (intra-class correlations (ICCs) ranging from 0.30 to 0.59). In adults the test-retest reliability was fair to moderate for the time spent on sedentary, light and moderate intensity activities (ICCs ranging from 0.49 to 0.60), but poor for time spent on vigorous intensity activities (ICC=-0.005). The correlations between the AQuAA and Actigraph were low and non-significant. Compared with the Actigraph, time spent on all physical activities was significantly higher according to the questionnaire (except for light intensity activities in adolescents), while time spent on sedentary behaviors was significantly lower.

CONCLUSION
Reliability of the AQuAA is fair to moderate. The validity of the AQuAA compared to an accelerometer is poor. Both adolescents and adults underestimate the time spent on sedentary behaviors and overestimate the time spent on physical activities.

BACKGROUND
Physical activity (PA) is an important behavior related to a number of health outcomes. Accurate assessment of PA levels is important to understand the association between PA and health, but also to monitor secular trends in behavior and to evaluate the effectiveness of interventions and programs. However, valid and appropriate assessment of physical activity PA is a challenging task. First, since PA behavior varies considerably within and among individuals and populations. Second, there are several health-related dimensions of PA, such as caloric expenditure, aerobic intensity, weight bearing, flexibility, and strength. Epidemiological studies have typically used subjective measures, such as the questionnaire, to assess PA in populations. PA questionnaires are easy to administer, non-reactive (does not alter the behavior of the individual being surveyed), relatively inexpensive and accepted by study participants.

Dependent on the research question a different type of information is needed, e.g. sports activities, leisure time activities, work-related activities and active transportation. In addition, interest can be on ‘habitual’ or usual PA or PA in the past day(s), week, month, year or even a lifetime. Hence, many questionnaires have been developed for different purposes and populations. Few of these questionnaires also focus on sedentary behavior. Independent of PA, sedentary behavior is associated with obesity, a risk factor for many chronic diseases. Therefore, it is important to assess the amount of time spent on specific sedentary behaviors such as watching TV and computer use as well.

PA questionnaires are usually developed for specific age groups. A disadvantage of age-group specific questionnaires is that levels of PA are difficult to compare. To be able to compare PA levels between different age groups, one questionnaire that can be used in different age groups and which estimates PA in a standardized way would be valuable.

The aim of the Activity Questionnaire for Adolescents and Adults (AQuAA) is to estimate light, moderate, vigorous, and total PA, but also sedentary behavior among both adolescents and adults.

This paper presents two studies: one study investigating the test-retest reliability, and another study investigating concurrent validity of the AQuAA compared to an accelerometer. Both studies were performed among adolescents and adults between 12 and 38 years of age.
METHODS

THE ACTIVITY QUESTIONNAIRE FOR ADOLESCENTS AND ADULTS

The structure of the AQuAA is based on a previously developed Dutch PA questionnaire for adults (SQUASH). The SQUASH was not designed to measure energy expenditure, but to give an indication of the habitual activity level. The SQUASH was based on their intensity (≥4 MET). Thus, the SQUASH does not include questions on light intensity PA or sedentary behaviors except for light household activities and light activities at work and school. The AQuAA was developed for evaluation of the effectiveness of a PA intervention for adolescents and young adults. We modified the SQUASH since we needed a questionnaire that

1. measures both physical activity as well as sedentary behavior;
2. can be used in adolescents as well as young adults;
3. is suitable for assessing changes over short periods of time.

For this specific purpose we made the following adaptations:

1. The AQuAA contains questions on light, moderate and vigorous intensity activities as well as sedentary behaviors;
2. To improve the validity of the answers we included age-specific examples of activities;
3. The questions in the AQuAA relate to activities performed in the previous seven days, instead of ‘an average week in the past months’.

Physical activities are divided in five categories: i.e. commuting activities; physical activities at work or school; household activities; leisure time activities; and active sports (Appendix 1). Each category includes questions on time spent on various activities with examples of activities to facilitate completion. The only difference between the questionnaire for adults and adolescents are the examples provided. For each activity the frequency (‘how many days in the past week’), duration (‘how long’) and perceived intensity (‘low’, ‘medium’ or ‘high’) are asked for. Completion of the questionnaires takes on average 15 to 20 minutes.

The five main outcomes are a total physical activity score (AQuAA score in MET*min/wk), and time spent on sedentary, light, moderate and vigorous intensity activities in minutes per week.

Table 1: Cut-off values for light, moderate and vigorous intensity physical activities for adolescents and adults in MET values.

<table>
<thead>
<tr>
<th>Activity intensity</th>
<th>Adolescents (≤18 years)</th>
<th>Adults (18-55 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>&lt;2</td>
<td>&lt;699</td>
</tr>
<tr>
<td>Light</td>
<td>2-5</td>
<td>700-4478</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-8</td>
<td>4479-8252</td>
</tr>
<tr>
<td>Vigorous</td>
<td>≥8</td>
<td>≥8253</td>
</tr>
</tbody>
</table>

For this specific purpose we made the following adaptations:

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The five main outcomes are a total physical activity score (AQuAA score in MET*min/wk), and time spent on sedentary, light, moderate and vigorous intensity activities in minutes per week.

Table 1 presents the cut-off values for sedentary, light, moderate and vigorous intensity activity. The AQuAA score is based on the sum of all activities ≥ 2 MET, expressed in minutes per week times the corresponding MET-value according to Ainsworth (i.e. MET*min/wk) . Thus if a person reports to have walked twice a week at light intensity (2.5 MET) for 1 hour and 30 minutes the calculation would be as follows:

→ 2x90 min = 180 min/week
→ 2.5 MET = labeled as light intensity for both adults/adolescents
→ 180*2.5=450 MET*min/week

PROCEDURES

The reliability and validity study were conducted and analyzed separately and involved different subjects.

TEST-RETEST RELIABILITY STUDY

A sample of adolescents (n=59) aged 12 to 16 years was recruited from a secondary school in a middle-sized city in the Netherlands (one first grade and one fourth grade class). A sample of young adults (n=63) aged 25 to 38 was recruited from a soccer team, a department of the KLM Royal Dutch Airlines and a department of the VU University Medical Center in Amsterdam. Both samples administered the questionnaire twice with an interval of two weeks. Adolescents filled in the questionnaire in the classroom with classmates supervised by the teacher and a research assistant. Adults filled in the questionnaire within the particular setting supervised by a research assistant. The research assistant checked the questionnaires when they were returned. Subjects who were not available on both measurement occasions were excluded (six adolescents and five young adults). All subjects (and the parents of the adolescents) signed an informed consent.

DATA ANALYSIS

The test-retest reliability of the AQuAA questionnaire was determined by comparing the results on the two separate occasions the questionnaire was filled in. The Intra Class Correlation coefficient (ICC) was calculated for the AQuAA score, and for the amount of time spent on sedentary, light, moderate and vigorous intensity activities, respectively. This was done for adolescents and young adults separately. An ICC<0.40 was rated as poor agreement, 0.40-0.75 as fair to good agreement, and values >0.75 as excellent agreement.
The concurrent validity of the AQuAA was assessed by comparison with the Actigraph accelerometer model 7164 (Manufacturing Technologies Inc., Fort Walton Beach, FL, USA). The Actigraph is small (5x5x1.5 cm), lightweight (56.7 g) and can be carried on the wrist, ankle or hip. In the present study the Actigraph was worn on the right hip attached to a belt. Although the Actigraph underestimates some activities, such as weight-bearing activities and cycling, it is recognized as a reasonably valid tool to assess PA objectively in adolescents as well as adults.43,85,109

A sample of 65 adolescents was recruited from four secondary schools in the Netherlands. A sample of 56 young adults was recruited from three different companies in the Netherlands (McDonalds headquarters, Solvay Pharmaceuticals and NS Dutch Railways). All subjects (and the parents of the adolescents) signed an informed consent. Adolescents filled in the questionnaire in the classroom with classmates supervised by the teacher and a research assistant. Adults filled in the questionnaire at their worksite supervised by a research assistant. The research assistant checked the questionnaires when they were returned. All included participants received instruction to wear the Actigraph during two weeks from the time they woke up until they went to sleep, and to take it off when taking a shower or during watersports participation. The Actigraph was set to collect acceleration data with an interval of one minute. At the end of the two weeks all participants returned their Actigraph and immediately filled in the AQuAA. Vertical acceleration measures of the Actigraph were converted into activity counts per minute. With the regression equation of Freedson et al.77 these counts were categorized as light, moderate or vigorous intensity PA based on age-specific cut-off points. Subsequently, minutes spent on sedentary, light, moderate and vigorous PA were calculated. The total Actigraph score was determined by dividing the total counts during at least light intensity activities of the Actigraph by the number of minutes a person had worn the Actigraph. The median difference and 25th–75th percentile for time spent on sedentary, light, moderate and vigorous intensity activities between the Actigraph and the questionnaire we subtracted the minutes according to the Actigraph by the minutes according to the questionnaire, for the respective categories. This was done both for adolescents and for young adults. Probability (p) values less than 0.05 were considered significant. All analyses were done using the Statistical Package of Social Sciences, version 11.1 for Windows (SPSS inc, Chicago, Illinois, USA).

The following hypotheses were tested to assess concurrent validity:

1. Previous studies validating self-administered questionnaires recalling 7 days against accelerometer found correlations between -0.26 and 0.40 in youth and between 0.23 and 0.36 in adults.42,34 Therefore, we expect the correlation between the time (min/wk) spent on sedentary, light, moderate and vigorous intensity activities according to the AQuAA and Actigraph will be at least 0.30 in adolescents as well as adults.

2. The correlation between time spent on vigorous activity according to the AQuAA and the Actigraph will be higher than the correlation between time spent on moderate or light intensity activities according to the AQuAA and Actigraph. Since the scores were not distributed normally we computed Spearman correlation coefficients to test hypotheses 1 and 2. In addition, to assess the group level-validity of the AQuAA the median difference and 25th–75th percentile for time spent on sedentary, light, moderate and vigorous intensity activities between the Actigraph and the questionnaire we subtracted the minutes according to the Actigraph by the minutes according to the questionnaire, for the respective categories. This was done both for adolescents and for young adults.

RESULTS

TEST-RETEST RELIABILITY STUDY

The test-retest reliability study included 53 adolescents (30 male, 23 female with a mean age of 14.1 ± 1.4 yrs) and 58 young adults (17 male, 41 female with a mean age of 28.9 ± 3.5 yrs). Table 2 shows the AQuAA score, minutes per week spent on sedentary behaviors, light, moderate and vigorous intensity PA at test one and test two and the corresponding ICCs. For adolescents the ICCs for the AQuAA score, sedentary behaviors, moderate and vigorous intensity PA ranged from 0.44 to 0.59, representing fair to moderate agreement. For the time spent on light PA the agreement between the two tests was poor. For adults the ICCs for time spent on sedentary behaviors, light and moderate intensity PA ranged from 0.49 to 0.60, representing fair to moderate agreement. For the AQuAA score and time spent on vigorous PA the agreement between the two tests was poor.
Table 2. Test-retest correlations of the AQuAA score, and time spent on sedentary, light, moderate and vigorous activities for the adolescents and adults.

<table>
<thead>
<tr>
<th></th>
<th>Adolescents (N=53)*</th>
<th>Adults (n=58)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>ICC</td>
</tr>
<tr>
<td>AQuAA score</td>
<td>17980</td>
<td>0.44</td>
</tr>
<tr>
<td>(MET*min/wk)</td>
<td>(12801;29519)</td>
<td>(9476;14966)</td>
</tr>
<tr>
<td>Sedentary activities</td>
<td>3750</td>
<td>0.57</td>
</tr>
<tr>
<td>(min/wk)</td>
<td>(2858;4965)</td>
<td>(2220;3893)</td>
</tr>
<tr>
<td>Light activities</td>
<td>1250</td>
<td>0.30</td>
</tr>
<tr>
<td>(min/wk)</td>
<td>(578;2115)</td>
<td>(554;1450)</td>
</tr>
<tr>
<td>Moderate activities</td>
<td>540</td>
<td>0.50</td>
</tr>
<tr>
<td>(min/wk)</td>
<td>(295;1268)</td>
<td>(275;275)</td>
</tr>
<tr>
<td>Vigorous activities</td>
<td>140</td>
<td>0.59</td>
</tr>
<tr>
<td>(min/wk)</td>
<td>(0.563)</td>
<td>(0.420)</td>
</tr>
</tbody>
</table>

* Cut-off values for sedentary (<2 MET), light (2-5 MET), moderate (5-8 MET) and vigorous (≥8 MET) intensity physical activities for adolescents.**

** Cut-off values for sedentary (<2 MET), light (2-4 MET), moderate (4-6.5 MET) and vigorous (≥6.5 MET) intensity physical activities for adults.***

Table 3 shows the sample characteristics of the adolescents and adults. Time spent on sedentary activities was lower compared to the accelerometer. Times spent on all physical activities were higher based on the questionnaire compared to the accelerometer.

Table 3. Sample characteristics for the validity study (mean ± SD or median (25th-75th percentile)).

<table>
<thead>
<tr>
<th></th>
<th>Adolescents (n=42)</th>
<th>Adults (n=47)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (yr)</td>
<td>13.4 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>167 ± 10</td>
</tr>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>55 ± 11</td>
</tr>
<tr>
<td></td>
<td>BMI (kg/m²)</td>
<td>19.7 ± 2.4</td>
</tr>
<tr>
<td>AQuAA</td>
<td>AQuAA score (MET*min/wk)</td>
<td>8464 (5146;8465)</td>
</tr>
<tr>
<td></td>
<td>Sedentary activities (min/wk)</td>
<td>3000 (2415;3600)</td>
</tr>
<tr>
<td></td>
<td>Light activities (min/wk)</td>
<td>810 (600;1335)</td>
</tr>
<tr>
<td></td>
<td>Moderate activities (min/wk)</td>
<td>565 (348;1019)</td>
</tr>
<tr>
<td></td>
<td>Vigorous activities (min/wk)</td>
<td>35 (0;155)</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>Counts/min</td>
<td>430 (339;510)</td>
</tr>
<tr>
<td></td>
<td>Sedentary activities (min/wk)</td>
<td>4838 (4602;5076)</td>
</tr>
<tr>
<td></td>
<td>Light activities (min/wk)</td>
<td>910 (764;1165)</td>
</tr>
<tr>
<td></td>
<td>Moderate activities (min/wk)</td>
<td>43 (11;66)</td>
</tr>
<tr>
<td></td>
<td>Vigorous activities (min/wk)</td>
<td>1 (0;4)</td>
</tr>
</tbody>
</table>
Validity of the AQuAA

Hypothesis 1 and 2:
The correlations between the AQuAA and Actigraph are presented in table 4. In adolescents, the Spearman correlation coefficients between the time spent on sedentary, light, moderate and vigorous activities according to the AQuAA and the comparable accelerometer data were 0.23, 0.11, -0.21 and 0.21, respectively (not significant). For adults, the Spearman correlation coefficients between the time spent on sedentary, light, moderate and vigorous activities according to the AQuAA and the accelerometer were 0.15, 0.07, -0.06 and 0.12, respectively (not significant).

Table 4. Spearman correlation coefficients for the associations between the AQuAA score and counts/min, and time spent on sedentary, light, moderate and vigorous intensity activities based on the AQuAA compared to the Actigraph accelerometer for adolescents and adults.

<table>
<thead>
<tr>
<th></th>
<th>Adolescents (n=42)</th>
<th>Adults (n=47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary activities</td>
<td>0.23</td>
<td>0.15</td>
</tr>
<tr>
<td>Light activities</td>
<td>0.11</td>
<td>0.07</td>
</tr>
<tr>
<td>Moderate activities</td>
<td>-0.21</td>
<td>-0.06</td>
</tr>
<tr>
<td>Vigorous activities</td>
<td>0.21</td>
<td>0.12</td>
</tr>
<tr>
<td>AQuAA score</td>
<td>0.13</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

Comparison of the AQuAA with the Actigraph accelerometer suggests that both adolescents and adults underestimated the time spent on sedentary activities, and overestimated their levels of activities. In adolescents the median difference between accelerometer and questionnaire was 1868 minutes (25th; 75th percentile 1579; 2729) for sedentary activities; -90 (-451; 418) for light activities, -540 (-987; -240) minutes for moderate activities; and -35 (-153; 0) for vigorous activities.

In adults, the median difference between accelerometer and questionnaire was 2216 minutes (25th; 75th percentile 1579; 2729) for sedentary activities, -502 (-1051; 121) minutes for light activities, -108 (-286; 84) minutes for moderate activities and -314 (-440; -148) for vigorous activities.

DISCUSSION

A new, self-administered measure of adolescents’ and adults’ physical and sedentary activities was developed, the Activity Questionnaire for Adults and Adolescents (AQuAA). In adolescents the test-retest reliability for time spent on light intensity physical activities was poor (ICC=0.30). For the other scores, test-retest reliability was fair to moderate, with ICCs ranging from 0.44 to 0.59. In adults the test-retest reliability was fair to moderate for the time spent on sedentary, light and moderate intensity activities (ICCs ranging from 0.49 to 0.60), but poor for the total AQuAA score and time spent on vigorous activities.

The correlations between the AQuAA and Actigraph were generally low and non-significant. Thus, concurrent validity between the AQuAA and Actigraph could not be confirmed. Absolute comparison of the AQuAA with an accelerometer shows that both adolescents and adults report higher levels of activity than as registered by the Actigraph. Few studies evaluated absolute validity using accelerometers as criterion measure. Most of these studies indicated higher estimates of PA by self-reports both in youth as well as in adults, particularly regarding vigorous intensity activities. This finding is in agreement with our results and suggests that self-reports may not be acceptable measures when absolute amount of PA needs to be assessed.

The fair to moderate test-retest reliability may be due to true differences in activity patterns because at both administrations the questionnaire recalled a different week. About half of the participants mentioned that their activity level was more or less active than usual. Time spent on all activities was consistently lower in the second week. A plausible explanation for this finding is the fact that the second week included several bank holidays. Another explanation may be that participants were more aware of the time spent in different activities due to filling out the questionnaire the first time. Questionnaires recalling a habitual week will most likely have higher test-retest reliability.

The lack of significant correlation coefficients between AQuAA and Actigraph suggests, assuming that the Actigraph can be considered as the criterion standard, that both our age groups had problems with accurately recalling the duration and intensity of the activities they performed in the past seven days compared to accelerometry. A recent review summarized validity correlations for seven PA measures evaluated in adults. Validation correlations for summary measures of adults’ habitual or global PA were generally low, ranging from 0.14 to 0.36. A recent review in children and adolescents found validity correlations between self-reports and accelerometers ranging from -0.26 and 0.40. In the light of these review findings, it should be concluded that the AQuAA questionnaire showed a lack of overall concurrent validity with the Actigraph.

The correlation between the AQuAA and accelerometer was higher for the time spent on vigorous activities compared to moderate and light intensity activities. In general higher validity for self-report of vigorous activities is observed. This is likely due to the structured and habitual nature of organized sports that make up most of the time spent on vigorous activities. The planned nature of these activities makes them easier to remember.
The low correlations between the AQuAA and the Actigraph was disappointing. A possible explanation for the low correlation between the AQuAA and the accelerometer is the design of the study. The accelerometers were worn for two weeks and after these two weeks the AQuAA was administered. Possibly, participants answered the questionnaire over the past two instead of one week.

Another explanation for the low concurrent validity is the choice of the cut-off points for categorizing activities as light, moderate, or vigorous intensity PA as suggested by Freedson. The low levels of moderate (43 and 108 min/wk, respectively) and vigorous (1 min/wk) intensity PA both in adolescents and adults suggest that these cut-off points may have been incorrect.

Evaluation of the criterion validity of PA questionnaires is problematic because there is no gold standard available. Neither of the methods used to assess PA in this study is a gold standard, and both have their shortcomings. The Actigraph accelerometer underestimates certain activities such as weight-bearing activities, cycling and swimming. In the Netherlands cycling is a common activity both in adolescents and adults. Adolescents aged 15-17 cycle the most, on average over six kilometers per day, adults about 2 km per day.

According to Sallis et al comparison of a questionnaire with an accelerometer will consistently underpredict the ability of a questionnaire to accurately assess total PA. High correlations will therefore not be found since both measures concern only a component of the behavior. Numerous limitations of self-reports have been discussed such as social desirability and recall bias. Furthermore, respondents and investigators must share understanding of ambiguous terms such as physical activity, moderate intensity and leisure time. In the present study the correlations between the AQuAA and Actigraph were low and non-significant. This might be interpreted as if both measures measure different PA constructs. The AQuAA provides qualitative information about the different activities performed in the last seven days, while the Actigraph provides objective estimates of the duration and intensity of activities.

This study has a number of limitations. In the reliability study questionnaires were administered in different settings, which could have influenced the results. Also the two tests did not recall the same week. In both the reliability as well as the validity study our focus was on adolescents and young adults. Additional research in larger groups of adolescents and adults with a large age range is needed, where the accelerometer is worn only during the same seven days as the AQuAA is questioning about.

In summary, we found this self-administered PA questionnaire to be moderately reproducible while the validity compared to an accelerometer was poor. The questionnaire combines information on intensity, duration, and frequency of both physical as well as sedentary activities of both adults as adolescents in one instrument. The agreement in time spent on sedentary, light, moderate and vigorous activities was small but comparable between adults and adolescents.
Appendix 1. Activity Questionnaire for Adults and Adolescents (AQuAA)

Think about the past week (seven days). Please indicate how many days in this week you performed the following activities, how much time on average you were engaged in this per day, and (if applicable) how strenuous this activity was for you?

1. COMMUTING ACTIVITIES

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking to/from work and school</td>
<td>…day(s) …hour(s), …minutes</td>
<td>slow/moderate/fast</td>
</tr>
<tr>
<td>Bicycling to/from work and school</td>
<td>…day(s) …hour(s), …minutes</td>
<td>slow/moderate/fast</td>
</tr>
<tr>
<td>Public transport, car or motor scooter to/from work and school</td>
<td>…day(s) …hour(s), …minutes</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

2. ACTIVITY AT WORK AND SCHOOL

Walking during lunch breaks should be filled in part 4: leisure time activities

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Moderate work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Intense work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
</tbody>
</table>

3. HOUSEHOLD ACTIVITIES (in and around the house)

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light household work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Moderate household work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Intense household work</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>E.g. walking (the stairs) carrying heavy objects like a heavy bag/schoolbag</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
</tbody>
</table>

4. LEISURE TIME ACTIVITIES

Commuting activities to/from work or school excluded. Active sports should be filled in at part 6.

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>…day(s) …hour(s), …minutes</td>
<td>slow/moderate/fast</td>
</tr>
<tr>
<td>Bicycling</td>
<td>…day(s) …hour(s), …minutes</td>
<td>slow/moderate/fast</td>
</tr>
<tr>
<td>Gardening/Odd jobs</td>
<td>…day(s) …hour(s), …minutes</td>
<td>light/moderate/intense</td>
</tr>
</tbody>
</table>

5. SEDENTARY LEISURE TIME ACTIVITIES

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watching television</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Using the computer</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Reading</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
<tr>
<td>Other sedentary activities</td>
<td>…day(s) …hour(s), …minutes</td>
</tr>
</tbody>
</table>

6. ACTIVE SPORTS

Write down the sports you performed the last week (maximum of 3 sports). Start with the most active sport. E.g. tennis, fitness, skating, swimming and dancing.

<table>
<thead>
<tr>
<th>Days per week</th>
<th>Average time per day</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. …………………………………………………</td>
<td>…day(s) …hour(s), …minutes</td>
<td>light/moderate/intense</td>
</tr>
<tr>
<td>2. …………………………………………………</td>
<td>…day(s) …hour(s), …minutes</td>
<td>light/moderate/intense</td>
</tr>
<tr>
<td>3. …………………………………………………</td>
<td>…day(s) …hour(s), …minutes</td>
<td>light/moderate/intense</td>
</tr>
</tbody>
</table>

* example for adults only

* example for adolescents only
CHAPTER 4

PROMOTING PHYSICAL ACTIVITY USING AN ACTIVITY MONITOR AND A TAILORED WEB-BASED ADVICE: DESIGN OF A RANDOMIZED CONTROLLED TRIAL
ABSTRACT

BACKGROUND
Ageing is associated with a decrease in physical activity. This decrease particularly occurs during specific transitional life stages. Especially during adolescence and young adulthood a steep decrease in physical activity is observed. Inactive people are often not aware of their inactivity. Providing feedback on the actual physical activity level by an activity monitor can increase awareness and may in combination with an individually tailored physical activity advice stimulate a physically active lifestyle.

METHODS
In a randomized controlled trial the effectiveness of providing an activity monitor in combination with a personal physical activity advice through the Internet will be examined. Outcome measures are level of physical activity, determinants of physical activity, quality of life, empowerment, aerobic fitness and body composition. Participants are relatively inactive adolescents and young adults who are measured at baseline, after 3 months intervention and 5 months after the end of the intervention. In addition, facilitating and hindering factors for implementation of the intervention will be investigated.

DISCUSSION
The use of a physical activity monitor in combination with web-based assisted individually tailored health promotion offers a good opportunity to work interactively with large groups of adolescents and young adults and provide them with advice based on their actual activity level. It has great potential to motivate people to change their behavior and to our knowledge has not been evaluated before.

BACKGROUND

REALIZATION OF THE RESEARCH PROJECT.
In 2002, PAM B.V. (Doornwerth, The Netherlands) introduced a commercially available innovative product and concept to promote physical activity (PA). This concept consists of a physical activity monitor (PAM) as well as a specially designed website (PAM COACH) which gives personalized PA advice, based on the amount of PA measured by the PAM. After consultation with PAM B.V. (Dr. E.P.N. Damen), the VU University Medical Center (VUMc) and the National Institute for Public Health and the Environment decided to evaluate this concept by scientific research. An application for funding was made and granted by The Netherlands Organization for Health Research and Development (ZonMW), a non-profit organization. In order to conduct the PAM project, PAM B.V. sold the required PAMs to VUMc against market price and facilitated access to the PAM COACH website, and provided us with technical PAM support. PAM B.V. was not a partner in the research proposal and in the further execution and processing of the study. The PAM project started in 2003 and ended mid-2006.

ARGUMENTS FOR PUBLISHING THE DESIGN OF A STUDY PROTOCOL
This article describes the design of a randomized controlled trial (RCT). Publishing the study design before the results are available has some important advantages. It offers the possibility to elaborate on the content of the intervention. This broad information gives users of similar interventions insight in the practicalities of the intervention and may promote wider implementation of the intervention if proven effective. Furthermore, it offers the opportunity to consider the methodological quality of the study more objectively, irrespective of the results.

INTRODUCTION
The positive health benefits of PA in people of all ages have been extensively studied and are now commonly accepted. There is compelling evidence that regular PA increases physical functioning, aerobic fitness and quality of life and favorably influences many risk factors for chronic diseases, such as coronary heart disease, colon cancer and type 2 diabetes mellitus. Nonetheless, people in industrialized countries continue to reduce their energy expenditure in daily living and at work. Leisure time activities have become more sedentary, with television watching, playing videogames, and personal computer usage among the most popular sedentary pastimes. Especially during adolescence and young adulthood a steep decrease in PA is seen. Adolescents are recommended to perform at least moderate intensity PA with a minimum of one hour a day. In 2004, only 31% of the male and 18% of the female adolescents (12-17 years) in the Netherlands complied with this guideline, according to data of Statistics Netherlands. Adults are advised to perform at least moderate intensity PA for a minimum of 30 minutes on at least five days of the week. In 2004, only 50% of the Dutch young men and 55% of the women (25-35 years) were sufficiently active according to this guideline. An effective intervention to promote PA in these specific age-groups could therefore provide enormous health gains. In a cross sectional study among 2600 adults in the Netherlands was shown that 60% of the people that did not meet 30 minutes of PA on at least five days of the week, overestimated their own PA levels. Hence, feedback on the actual amount of PA per day may overcome this problem of poor self-evaluation and thereby positively affect the PA level among inactive persons.
One way to provide direct feedback on the actual amount of PA is via a physical activity monitor. Physical activity monitors can be worn without major inconvenience, requires little effort of the user and are compatible with most daily activities, making it a practical and socially acceptable measure of PA. Moreover, in a study of Rooney et al, an increase in awareness of daily activity and increased PA was found, after wearing a pedometer for eight weeks. Another way of providing feedback is via the computer. Computer-tailored interventions showed to be an acceptable, feasible and efficacious tool for promoting PA. Furthermore, in a study of Brug et al computer tailored information appeared to have a greater impact in motivating people to change their diet than a general advice. The computer tailored information was more likely to be read, remembered and experienced as personally relevant compared to standard materials.

Internet websites enable to deliver tailored PA information on participants’ desired moments and have the capability to easily reach large numbers of participants. Therefore, web-based tailored interventions for PA could have great potential. However, until this point there is little evidence about the effectiveness of web-based-tailored interventions on PA. In an eight-week pilot intervention study of McKay, the intervention group received personalized feedback, received and could post messages to an on-line “personal coach”, and were invited to participate in peer group support areas. This study found an overall moderate improvement in PA levels within both intervention and control conditions, but no significant between-group difference. In our study we hypothesize that the use of a physical activity monitor combined with an individually tailored PA advice will increase awareness and subsequent PA among inactive people. Users of the physical activity monitor will receive personal feedback and a personal PA advice. The use of a PA monitor in combination with a personal PA advice through the Internet is an innovative intervention that has not been evaluated before. The intervention is assumed to be attractive for adolescents and young adults. To date 84% of Dutch adolescents (aged 12-17 years) and 71% of young adults (aged 25-34 years) make use of the internet on a computer at home. This underlines that the current generation of young people is accustomed to using computers and the Internet, and have the skills to participate in this intervention.

In this randomized controlled trial the effectiveness in promoting PA of the PAM-accelerometer (PAM, B.V., Doorwerth, The Netherlands) in combination with an individually tailored PA advice (PAM COACH) is evaluated in relatively inactive adolescents and young adults.

**METHODS**

**STUDY DESIGN**

The PA level of 300 adolescents and 300 young adults will be monitored for two weeks. Based on these two monitor weeks, 50% relatively inactive adolescents and young adults will be selected for the intervention study. In the intervention study (RCT) the effectiveness of a distributed physical activity monitor coupled to a tailored physical activity advice through the Internet among adolescents and young adults in stimulating PA will be evaluated. Effects on determinants of PA, quality of life, empowerment, aerobic fitness and body composition will be examined as well. In addition, a process evaluation will be performed. See figure 1 for the flow chart of the participants.

![Figure 1. Flowchart of the participants](image-url)
THE PAM-CONCEPT
The physical activity monitor used in this study is the PAM accelerometer (model AM101, 28 gr, 59x43x10 mm). The PAM is a uni-axial accelerometer in the vertical direction and comparable to the accelerometer developed by Meijer et al. The PAM can be attached easily to a belt and is worn on the right hip. The PAM produces a cumulative score, which is a proxy measure of total daily PA. The PAM score is displayed continuously on the PAM. Via a docking station, which must be connected to a computer with an Internet connection, the user can upload his personal PAM scores through PAM software to the PAM COACH database any time of the day. The PAM COACH database is part of the PAM COACH website. At first login on the PAM COACH website, the users register themselves by filling out a form with personal data and a one time brief questionnaire with 12 yes-no questions (e.g. Do you think you are able to walk to your work when it is raining?). Entering the PAM COACH website, the user is asked to formulate an activity goal along with the PAM COACH, based on the users’ PAM score and age. On every subsequent login the PAM COACH website presents all the collected PAM scores in orderly graphs per day which is supported by practical information on user preferred activities (e.g. daily an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash). In addition, the user receives on subsequent logins tailored feedback on determinants of PA based on the answers of the one time questionnaire at registration. Next to the feedback on the PAM COACH website, the users can easily monitor their progress in daily PA by reading their score on the display of the PAM itself. Users can thus compare their progress with their set personal activity goal.

Furthermore some features are changed with the cooperation of PAM B.V at the original PAM COACH website in aid of the intervention. Unlike the original PAM COACH website, the intervention PAM COACH website will neither formulate a weight goal, nor give nutritional advice. The Pam coach website is supported by practical information on user preferred activities (e.g. daily an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash). The Pam can be attached easily to a belt and is worn on the right hip. The Pam produces a cumulative score, which is a proxy measure of total daily PA. The Pam score is displayed continuously on the Pam. Via a docking station, which must be connected to a computer with an Internet connection, the user can upload his personal Pam scores through Pam software to the Pam COACH database any time of the day. The Pam COACH database is part of the Pam COACH website. At first login on the Pam COACH website, the users register themselves by filling out a form with personal data and a one time brief questionnaire with 12 yes-no questions (e.g. Do you think you are able to walk to your work when it is raining?). Entering the Pam COACH website, the user is asked to formulate an activity goal along with the Pam COACH, based on the users’ Pam score and age. On every subsequent login the Pam COACH website presents all the collected Pam scores in orderly graphs per day which is supported by practical information on user preferred activities (e.g. daily an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash). In addition, the user receives on subsequent logins tailored feedback on determinants of PA based on the answers of the one time questionnaire at registration. Next to the feedback on the Pam COACH website, the users can easily monitor their progress in daily PA by reading their score on the display of the Pam itself. Users can thus compare their progress with their set personal activity goal.

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STUDY POPULATION
The study will include relatively adolescents adolescents, aged 12 to 18 years old and young adults, aged 25 to 35 years old. Inclusion criteria are ability to walk (without aid), speak Dutch and not being pregnant. The study protocol is approved by the Medical Ethics Committee of VU University Medical Center before the start of data collection. The adolescents are instructed to take the consent materials home to their parents, read the materials with their parents, and return the consent, signed by both the parent and the adolescent if they are willing to participate in the study. Informed consent are also requested from the young adults.

RECRUITMENT ADOLESCENTS
Adolescents will be recruited from secondary schools in the surroundings of Amsterdam. Enrolling students at a school site has the following benefits:

- All ages in the age-range from 12 to 18 years are represented;
- Students have fixed classes according to a fixed time schedule which facilitate the measurements;
- Different educational levels can be selected;
- At school students have access to computers with Internet connection at school.

Schools in the surroundings of Amsterdam with a minimum of 1000 students and with different educational levels will be randomly selected and approached by phone. In all schools first the physical education (PE) staff will be contacted. If the PE staff is interested in participating, an appointment is made for a personal interview. The PE teachers are asked to assist with the recruitment and facilitation of the outcome measurements. After approval of the school-board and the PE section, the project is presented to the children during the PE-class by the study staff. The adolescents receive an information leaflet with consent materials. The adolescent and his parents have one week to hand in the informed consent forms, which will be collected at the day of the first measurement for the selection of the intervention. At each school one regular school day in the week will be selected to reach a broad range of different ages and educational levels.

YOUNG ADULTS
Young adults will be recruited from worksites in the surrounding of Amsterdam. It was decided to include office workers, since they perform mostly sedentary work and are constrained to their work place. This simplifies recruitment of the participants and measurements at the worksite. Companies with mainly office workers will be randomly selected, and either their occupational health and safety coordinator or an employee of human resources will be approached by phone. If the company will be interested, a face-to-face meeting is arranged. If all stakeholders are informed and have given their approval, information on the project is distributed to the employees according to the companies’ policy. The company is asked for assistance with the recruitment and to facilitate the measurements. Every employee receives identical information about the project; i.e. a recommendation letter of the occupational health and safety coordinator and an information brochure with a consent form. The consents will be collected at the day of the first measurement. The measurements of the selection for the intervention as well as the measurements of the intervention take place during working hours at the worksite.

SELECTION FOR INTERVENTION
The target group for the intervention study is relatively inactive subjects. In order to select these subjects, 300 adolescents and 300 young adults will be asked to wear a Pam accelerometer during their daily activities for two weeks. The Pam display is blinded during this period. After this two weeks-period all participants will be asked to fill in a short PA questionnaire, the Activity Questionnaire for Adults and Adolescents (AQuAA, an adapted version of the SQUASH questionnaire 10). The adolescents and young adults will be divided in an active and inactive group by means of a combined PA score. Physical activity data of the Pam and the AQuAA will be divided in four quartiles, stratified for educational level. The first quartile will includes the most inactive subjects. For each subject the quartile-numbers of both the Pam and AQuAA will be summed up. Those who are classified as ‘inactive’ (combined score lower than 5) will be invited for participation in the intervention study. When the combined score is five, the AQuAA quartile plays a decisive role (See figure 2).
The Activity Questionnaire for Adolescents & Adults (AQuAA) is a short questionnaire developed to assess PA and sedentary activity at work, at school, during leisure time and transportation. The structure of the AQuAA is obtained from the SQUASH-questionnaire. Information on light (range for adolescents, 2-5 MET and adults 2-4 MET), moderate (range for adolescents, 5-8 MET and adults 4-6.5 MET) and vigorous (adolescents, >8 MET and adults >6.5 MET) intensity PA is obtained, as well as information on sedentary behavior (<2 MET), such as TV viewing and computer usage. The AQuAA refers to activities in the past week (7-day recall). Physical activity will be expressed in minutes per week and in a total activity score. The total activity score will be calculated by multiplying the minutes per week by the actual MET score of the specific activity (MET·min⁻¹·week⁻¹).

**Determinants of physical activity**

In this questionnaire, the enquired determinants of physical activity refer to three categories of activity: sport, transportation and sedentary activities. To minimize time spent filling in the questionnaire for each determinant of physical activity a selection of two or three relevant questions is made. The following determinants of PA are assessed in both age groups:

- **Behavioral intention** is the cognitive representation of a person’s readiness to perform physically active behavior, and it is considered to be the immediate antecedent of behavior. Behavioral intention was measured with one item (i.e. ‘Do you intend to play sport more in the following three months?’ with response categories ranging from 1=’no, certainly don’t’ to 5=’yes certainly do’).

- **Attitude**, the beliefs that are associated with PA behavior and the evaluations of these beliefs. The questionnaire contains two questions about attitude (i.e. ‘Do you like playing sports?’ with response categories ranging from 1=’strongly disagree’ to 5=’strongly agree’).

- **Social influences** such as social norms, social expectations, modeling and imitating. Social norms are determined by the normative beliefs of significant others about PA behavior and the individual motivation to comply with these persons. The questionnaire of the young adults contains five questions about social influences, the questionnaire of the adolescents contains four questions regarding social influences (i.e. ‘My friends think I should play sports’ with response categories ranging from 1=’no, certainly don’t’ to 5=’yes certainly do’). According to the Theory of Planned Behavior, behavior in general is determined primarily by behavioral intention and postulates that this intention is determined by three constructs: attitude, subjective norms and perceived behavioral control.

- **Personal barriers**, many personal variables, including physiological, behavioral, and psychological

**INTERVENTION**

The subjects classified as relatively inactive will be invited to take part in the intervention study. For the intervention study they will be required to fill in a questionnaire and to participate in physical measurements (i.e. baseline measurements). After completion of the baseline measurements the participants will be randomly assigned to the intervention or the control group by choosing sealed envelopes. Participants in the intervention group receive the PAM accelerometer and have access to their personal website (PAM COACH) for a 3-month period. The participants are given written and verbal instructions and practical demonstrations on how to wear the PAM and how to use the PAM COACH. Special attention is paid to:

- placing the PAM on the hip;
- connecting the docking station to the computer;
- installing the PAM software on the computer;
- registering and logon to the PAM COACH website;
- setting a PAM goal and reading the results at the PAM coach website.

The control group receives a single written information brochure with general recommendations and guidelines for PA. Telephone numbers and an e-mail-address are provided in case questions arise. At each intervention site at least one computer with PAM software will be arranged.

**MEASUREMENTS**

The primary outcome of the intervention study is the level of PA assessed by the AQuAA. Secondary outcomes are determinants of PA, quality of life, empowerment, aerobic fitness and body composition. A compact questionnaire is constructed to maximize the response and minimize time spent filling in the questionnaire. All measurements are performed at baseline and after three months intervention. Five months after the end of the intervention only the questionnaire is repeated.
factors, may affect our plans to become more physically active. Three items about personal barriers are asked (i.e. ‘Do you think you can manage to play sports when it rains?’ with response categories ranging from 1 ‘no, certainly don’t’ to 5 ‘yes certainly do’). Awareness of physical activity. One item is included in the questionnaire (i.e. ‘Do you think you spend enough time playing sports?’ with the response categories yes and no). Awareness of the actual level of activity will be assessed by comparing the outcomes of the questions about PA perception with the total minutes per week of the concerning activity (i.e. sport, walking/cycling) from the PA questionnaire.

Quality of life
The quality of life of the adolescents is assessed by the Dutch version of the KIDSCREEN-10 Index. The KIDSCREEN is a health related quality of life measure (HRQOL) and applicable for healthy children aged from 8 to 18 years. The KIDSCREEN assesses 10 HRQOL dimensions (i.e. Physical-, Psychological Well-being, Moods and Emotions, Self-Perception, Autonomy, Parent Relations and Home Life, Peers and Social Support, School Environment, Bullying, Financial Resources) by 11 items on a five-point scale, ranging from 1 “completely not” to 5 “completely”. From the total score t-values and percentages are calculated by age and gender. The quality of life of the young adults is assessed by the short-form 36 health survey (SF-36). The SF-36 provides a health related quality of life measure and is applicable for adults. The SF-36 is composed of 36 questions and standardized response choices, organized into eight multi-item scales: physical functioning, role limitations due to physical health problems, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems and general mental health. All raw scale scores will be linearly converted to a 0 to 100 scale, with higher scores indicating higher levels of functioning or well-being. Item score and subscale scores are calculated.

Empowerment
In both age-groups, empowerment is assessed with a Dutch version of the Pearlin Mastery Scale. This scale refers to the extent to which a person has the feeling of being in control of his or her own life. The questionnaire consists of seven statements, such as ‘I have little control over the things that happen to me’, with response categories ranging from 1 ‘strongly disagree’ to 7 ‘strongly agree’. Higher scores on the scale indicate a greater sense of mastery. A total score will be calculated.

Process evaluation
Among the participants of the intervention group experience with the use of the Pam and the Pam coach website will be evaluated. This will be assessed with a brief questionnaire with both qualitative and quantitative questions about the usage of the Pam and the Pam coach website and possible problems that may have been experienced. Reasons for complying or not complying will be collected also, in order to obtain insight into the potential success or failure of implementation.

Physical measures
Aerobic fitness
In adolescents, the aerobic fitness is assessed by the 20 meter shuttle-run test (SRT). The SRT is a maximal aerobic running test. The test starts at a speed of 8.0 km/h, which increases each minute by 0.5 km/h. To perform the test, the subject runs a 20-meter course back and forth. The pace is set by an audio signal. The test has been shown to be reliable and valid field test to estimate maximal aerobic capacity. Changes in SRT score will be used as a measure for changes in aerobic capacity. The SRT is chosen for adolescents because the test can easily be carried out during the PE classes and most of the students are acquainted with the test. In young adults, the aerobic fitness is assessed by the Chester Step Test (CST). Prior to every test each participant is screened with the Physical Activity Readiness Questionnaire (PAR-Q), a safe preliminary screening for exercise testing and prescription. The CST is a sub-maximal test to predict aerobic capacity. The CST consists of increasing paces of stepping on and off a bench (on, on, off, off). The height of the bench is determined based on the age and self-reported physical activity in the past week of the employee. The CST starts at the relatively slow pace of 15 steps per minute and increases every two minutes to 20, 25, 30 and 35 steps per minute. The stepping rate is set by a metronome (Yamaha Corporation, QT 1B). Throughout the test the heart rate is monitored continuously with a heart rate monitor (Polar S610i, Electro Oy, Kempele, Finland). After each stage the subject will be asked to rate his perceived exertion on the Borg scale which is a 15-point numerical rating scale, ranging from 6 “very very light” to 20 “exhaustion”. The test is terminated when the subjects’ heart rate reaches 80 percent of the age predicted maximal heart rate (i.e. 220 minus age), or when the subject rates 14 on the Borg scale. Aerobic capacity is predicted by the provided Chester Step Test calculator (ASSIST creative resources Limited, WWE, nh). Changes in the CST score are used as a measure for changes in aerobic capacity. The CST is chosen for employees because the test is easy to perform at the worksite and it takes little time of the participants’ time.

Body composition
Weight is measured in light clothing without shoes to the nearest 0.2 kg using a digital balance (Seca, model 888, Seca GmbH & Co, Hamburg, Germany) and height is measured to the nearest 0.1 cm with a stadiometer (Seca, model 125, Seca GmbH & Co, Hamburg, Germany). BMI (kg/m²) will be used as an index of relative weight. Waist-circumference will be measured at the level of the belly button and the hip-circumference at the level of the trochanter-major. Both circumferences will be measured using a spring loaded measuring tape (Seca, model 200, Seca GmbH & Co, Hamburg, Germany) to the nearest 0.1 cm. The four skin folds (biceps, triceps, subscapular and supra-iliac) will be measured twice with a Harpenden skin fold caliper (model HSBI, British Indicators, West Sussex, UK) and averaged, according to earlier research for adolescents and young adults. If the difference between these two measurements is more than 1 mm, the measurement is done a third time and skin fold thickness will be taken as an average over the three measurements.

Sample size
The aim of the study is to establish a difference between the intervention and the control group of 20% in the proportion of subjects who are active according to the Dutch guidelines. Significance between the groups can be established with 80% (1-β) probability and a significance level of 0.05 (α). To be able to detect a difference of 20% in PA level, two groups of 50 subjects for each age group are required. Since we expect a dropout rate of 33%, approximately 150 adolescents and 150 employees will be invited for the intervention.
STATISTICAL ANALYSIS
The primary analysis will be a comparison of the change in PA between the intervention and control group following the “intention to treat” principle. Standard linear regression analysis will be used to test the differences between intervention and control group at follow-up. Intention to treat analyses will also be performed for the secondary outcomes; determinants of physical activity, quality of life, empowerment, aerobic fitness and body composition. Pre-planned subgroup analyses will be performed for adolescents and adults and separate for gender. Where appropriate, adjustments will be made for differences at baseline values. Per protocol analyses will also be carried out.

DISCUSSION
The use of a physical activity monitor in combination with web-based health promotion offers a good opportunity to work interactively with large groups. This intervention method includes feedback on actual behavior and is tailored to the individual. Since the advice given is developed interactively and takes preferences of the user into account, it is expected that PA can be included more easily in daily life. Additional advantages for the user of this individualized intervention are the direct feedback on the display and the flexibility of the PAM COACH website system, i.e. the participants can decide when to login and monitor their stepwise progression in PA according to feedback information. The results of the intervention and process evaluation will contribute to the development of an effective preventive intervention and underpin the consideration whether introduction of such an intervention should be conducted at a larger scale, in the context of efficient and effective health care.
CHAPTER 5

DISAGREEMENT IN PHYSICAL ACTIVITY ASSESSED BY ACCELEROMETER AND SELF-REPORT IN SUBGROUPS OF AGE, GENDER, EDUCATION AND WEIGHT STATUS

ABSTRACT

BACKGROUND
The purpose of this study is to compare self-reported time (by questionnaire) and objectively measured time (by accelerometer) spent on physical activity at moderate (MPA) and vigorous intensity (VPA) in subgroups of age, gender, education and weight status.

METHODS
In total, 236 adolescents (aged 12-18) and 301 adults (aged 22-40), completed the questionnaire and wore an accelerometer for two weeks.

RESULTS
Adolescents reported exceptionally more time spent on MPA (mean difference 596 ± 704 min/wk) and VPA (mean difference 178 ± 315 min/wk) than was assessed objectively by the accelerometer. Based on the questionnaire, high educated adolescents spent more time on MPA (205 min/wk, p=0.002) and VPA (120 min/wk, p=0.01) than low educated adolescents, but according to the accelerometer they spent less time on MPA (149 min/wk, p=0.001) and VPA (47 min/wk, p=0.001). Among adults there was moderate agreement between self-reported time and objectively measured time spent on MPA, but in general the reported time spent on MPA (mean difference 107 ± 334 min/wk) and VPA (mean difference 169 ± 250 min/wk) exceeded the time measured with the accelerometer. Overweight adults reported significantly more VPA (57 min/wk, p=0.001) than normal weight adults, but this was not confirmed by the accelerometer data.

CONCLUSIONS
We observed large differences in time spent on MPA and VPA measured by questionnaire and accelerometer in adolescents but quite good agreement in adults. Differences between methods varied by gender, education and weight status. This finding raises serious questions about the use of questionnaires to quantify MPA and VPA in adolescents. There is a clear need in advanced valid assessments of PA in adolescents.
Disagreement between PAM and AQuAA

inactive adolescents and young adults. The PAM project is described in more detail elsewhere in chapter 4. The study protocol of the PAM project was approved by the Medical Ethics Committee of the VU University Medical Center. All participants and their parents gave their informed consent.

PROCEDURES

Body height and weight were obtained on the first day of measurement. Body weight was measured in light clothing without shoes to the nearest 0.2 kg, using a digital balance (model Seca 888, Seca GmbH & Co, Hamburg, Germany). Body height was measured to the nearest 0.1 cm with a stadiometer (model Seca 225, Seca GmbH & Co, Hamburg, Germany). Educational level and date of birth were assessed by questionnaire. The participants received an accelerometer together with written and verbal instructions and a practical demonstration on how to wear the accelerometer. For practical considerations, the participants were asked to wear the accelerometer for fourteen consecutive days during waking hours. After this period the participants completed a short PA questionnaire and were asked if they had worn the accelerometer during sports. Participants who completed all measurements were given a small incentive.

ASSESSMENT OF PHYSICAL ACTIVITY

Physical Activity Questionnaire

The Activity Questionnaire for Adolescents & Adults (AQuAA, chapter 3) is a short questionnaire, developed to assess PA and sedentary behavior at work, at school, during leisure time and transport. The structure of the AQuAA is based on the SQUASH-questionnaire with two adaptations made. First, the AQuAA also registers time spent on light intensity activities and sedentary behaviors whereas the SQUASH does not. Second, the questions in the AQuAA refer to activities performed in the previous seven days and the SQUASH refers to an average week in the past few months. Based on the assumption that one sleeps 8 hours per day, sixteen hours (960 minutes) was considered the maximum amount of time per day a person can spend on PA. Five (2%) adolescents and three (1%) adults were excluded because they exceeded this maximum time.

Unpublished data of a validation study (Chapter 3) show that the test-retest reliability of the AQuAA was moderate in both adolescents (intra-class correlations; ICCs ranging from 0.30 to 0.59) and adults (ICCs ranging from 0.49 to 0.60). Spearman correlation coefficients between the time spent on sedentary, light, moderate and vigorous activities compared to the MTI Actigraph accelerometer were low and non-significant for adolescents whereas the SQUASH does not. Second, the questions in the AQuAA refer to activities performed in the previous seven days and the SQUASH refers to an average week in the past few months. Based on the assumption that one sleeps 8 hours per day, sixteen hours (960 minutes) was considered the maximum amount of time per day a person can spend on PA. Five (2%) adolescents and three (1%) adults were excluded because they exceeded this maximum time.

Unpublished data of a validation study (Chapter 3) show that the test-retest reliability of the AQuAA was moderate in both adolescents (intra-class correlations; ICCs ranging from 0.30 to 0.59) and adults (ICCs ranging from 0.49 to 0.60). Spearman correlation coefficients between the time spent on sedentary, light, moderate and vigorous activities compared to the MTI Actigraph accelerometer were low and non-significant for adolescents (0.23, 0.11, -0.21 and 0.21 respectively) and for adults (0.15, 0.07, -0.06 and 0.12 respectively).

Accelerometer

The PAM accelerometer (PAM, model AM101, PAM B.V., Doorwerth, The Netherlands) is an uni-axial accelerometer that can be easily clipped to a belt or waistband. The PAM converts vertical accelerations by a piezoelectric sensor into an activity score, i.e. the PAM score. The PAM also offers the possibility to monitor the number of minutes spent on moderate (MPA) and vigorous intensity physical activity (VPA) per day. PAM data can be easily downloaded via a docking station to a personal computer. The validity of the PAM accelerometer has been tested in a laboratory setting and has shown results to be similar to the MTI Actigraph for estimating energy expenditure in walking and stair walking (Chapter 2). The PAM shows high reliability (ICC=0.80) at a frequency of 3 Hz. Before the study, all PAMs were calibrated on a shaking machine at 3 Hz and thresholds for MPA and VPA were set-up by using the manufacturer equation (PAM score=(MET*0.9-1)*100).

The participants were asked to wear the accelerometer always on the right hip (sagittal line) for 14 days during waking hours, accept during water sports and bathing because the PAM is not waterproof. During the fourteen days the PAM registered, the PAM scores were not visible for the participants in order to minimize the influence of wearing the accelerometer. Due to technical problems, accelerometer data could not be read of 23 (8%) adolescents and 13 (4%) adults. Daily PAM scores below five were converted to missing values because this is an indication that the PAM was not worn. Eighteen adolescents (7%) and 7 adults (2%) did not wear the accelerometer for at least three days in the last week and were therefore excluded. As a consequence, 236 adolescents and 301 adults were included in the analyses.

DATA ANALYSIS

Educational level was categorized into low and high educational level, according to the Dutch educational system. A high educational level comprised of secondary schools preparing for college or university. All other levels of education were defined as low educational level. BMI (kg/m²) was used to categorize the participants as either normal weight or overweight. Adolescents were categorized as being overweight based on the gender and age specific Cole criteria. Adults were defined as being overweight when their BMI was ≥25 kg/m².

For the purpose of this study, cut off points for MPA (range for adolescents, 5-8 metabolic equivalents, MET, and adults 4-6.5 MET) and VPA (adolescents, >8 MET and adults >6.5 MET) were used based on the Dutch Public Health Physical Activity recommendation. The minutes spent in MPA and VPA per day registered by the accelerometer were averaged over the number of days the participant had worn the accelerometer in the last week. This average was multiplied by seven days. Minutes per week of MPA, VPA and MVPA from the questionnaire were calculated by frequency times duration of the activities.

Bicycling is an important mode of transportation in the Netherlands but poorly registered by the accelerometer. Therefore the agreement between the minutes registered by the accelerometer on MVPA were compared to AQuAA data with and without the inclusion of self-reported minutes of cycling.

Because the distribution of self-reported and objectively measured MPA, VPA and MVPA was skewed, we presented data as medians and inter-quartile ranges, per age-group. We used non-parametric tests to test differences in questionnaire and the accelerometer, and to test the differences within the subgroups of gender, educational level and weight status.

In a multivariate regression model gender, educational level, BMI, and age were added as independent variables and disagreement between both methods (AQuAA minus PAM) was the dependent variable. Bland-Altman plots with 95% limits of agreement were calculated as the main measures of agreement between (and within) the instruments. Statistical significance was set at p<0.05.
RESULTS
CHARACTERISTICS OF THE STUDY POPULATION
Figure 1 represents the flowcharts of the exclusion of recruited adolescents and adults in the study. The excluded subjects did not differ significantly from the final sample with respect to gender, education and weight status. The average age of the adolescents and adults was 15 (SD=1) and 31 (SD=3) years, respectively. Sample characteristics are shown in table 1. Ninety-six adolescents (41%) and 158 adults (52%) have worn the accelerometer for seven consecutive days in the last week.

Table 1. Sample characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adolescents (n = 236)</th>
<th>Adults (n = 301)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>142 (60%)</td>
<td>169 (56%)</td>
</tr>
<tr>
<td>Higher education</td>
<td>163 (69%)</td>
<td>206 (68%)</td>
</tr>
<tr>
<td>Overweight</td>
<td>21 (9%)</td>
<td>112 (37%)</td>
</tr>
</tbody>
</table>

AGREEMENT BETWEEN REPORTED AND OBJECTIVELY MEASURED PHYSICAL ACTIVITY LEVEL
Median with 25th and 75th percentiles of MPA, VPA, MVPA (including and excluding reported minutes spent on cycling) are displayed for the different subgroups of adolescents and adults in table 2 and 3, respectively. Table 2 and 3 present the minutes of MPA, VPA and MVPA assessed by the accelerometer expressed as percentage of the self-reported minutes. Time spent on MPA, VPA and MVPA according to questionnaire was practically always higher than recorded by the accelerometer and differed significantly (p<0.05) in all subgroups of adolescents and adults. The Bland-Altman plots of these data on MPA, VPA and MVPA, in figure 2 and 3, show overall higher readings from the questionnaire than the accelerometer, but considerable variation in the individual differences between the questionnaire and accelerometer estimates. Among adolescents, in a multivariate model level of education remained a statistically significant predictor of disagreement in MPA (304 min/wk) and MVPA (361 min/wk). For VPA, gender was a significant predictor (135 min/wk). Among adults, overweight was a significant predictor of disagreement in VPA (78 min/wk) and MVPA (114 min/wk) between AQuAA and PAM.

Figure 1. The flowcharts of the exclusion of recruited adolescents and adults.

![Flowchart](image-url)
Table 2. Median (25\(^{th}\) and 75\(^{th}\) percentiles) physical activity (min/wk) assessed by questionnaire (AQuAA) and accelerometer (PAM) among adolescents.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method</th>
<th>Total</th>
<th>Male</th>
<th>Female</th>
<th>p</th>
<th>Low Educated</th>
<th>High Educated</th>
<th>p</th>
<th>Normal Weight</th>
<th>Overweight</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>min/wk</td>
<td>528 (276-896)</td>
<td>503 (279-936)</td>
<td>532 (274-870)</td>
<td>.93</td>
<td>360 (120-787)</td>
<td>565 (360-928)</td>
<td>.002</td>
<td>530 (280-883)</td>
<td>480 (170-1009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% *</td>
<td>18</td>
<td>22</td>
<td>15</td>
<td>56</td>
<td>9</td>
<td>15</td>
<td>15</td>
<td>34</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>min/wk</td>
<td>93 (30-193)</td>
<td>112 (38-233)</td>
<td>79 (25-161)</td>
<td>.04</td>
<td>200 (120-255)</td>
<td>51 (21-120)</td>
<td>.001</td>
<td>81 (28-178)</td>
<td>162 (97-259)</td>
</tr>
<tr>
<td>VPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>min/wk</td>
<td>60 (0-300)</td>
<td>180 (0-460)</td>
<td>0 (0-270)</td>
<td>.001</td>
<td>0 (0-268)</td>
<td>120 (0-330)</td>
<td>.01</td>
<td>60 (0-325)</td>
<td>0 (0-208)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% *</td>
<td>23</td>
<td>7</td>
<td>14/0</td>
<td>54/0</td>
<td>6</td>
<td>20</td>
<td>29/0</td>
<td>29/0</td>
<td>.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>min/wk</td>
<td>14 (3-50)</td>
<td>13 (3-58)</td>
<td>14 (3-45)</td>
<td>.74</td>
<td>54 (16-97)</td>
<td>7 (2-8)</td>
<td>.001</td>
<td>12 (3-48)</td>
<td>29 (9-65)</td>
</tr>
<tr>
<td>MVPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>min/wk</td>
<td>723 (408-1234)</td>
<td>775 (460-1519)</td>
<td>653 (366-1074)</td>
<td>.02</td>
<td>510 (195-1200)</td>
<td>760 (475-1260)</td>
<td>.02</td>
<td>740 (443-1249)</td>
<td>553 (268-1044)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% *</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>43</td>
<td>8</td>
<td>13</td>
<td>13</td>
<td>30</td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>min/wk</td>
<td>108 (34-220)</td>
<td>122 (35-289)</td>
<td>100 (34-206)</td>
<td>.15</td>
<td>217 (129-307)</td>
<td>61 (25-139)</td>
<td>.001</td>
<td>96 (33-216)</td>
<td>166 (110-262)</td>
</tr>
<tr>
<td>MVPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td>(excluding cycling)</td>
<td>min/wk</td>
<td>460 (103-1148)</td>
<td>480 (203-1144)</td>
<td>363 (180-660)</td>
<td>.07</td>
<td>310 (118-750)</td>
<td>475 (235-783)</td>
<td>.03</td>
<td>420 (185-783)</td>
<td>420 (170-690)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% *</td>
<td>23</td>
<td>25</td>
<td>28</td>
<td>70</td>
<td>13</td>
<td>23</td>
<td>23</td>
<td>40</td>
<td>.07</td>
</tr>
</tbody>
</table>

* The minutes of activity assessed by the accelerometer expressed as percentage of the minutes of activity by questionnaire.

Note: MPA: moderate physical activity, VPA: vigorous physical activity, MVPA: moderate-to-vigorous physical activity.
Table 3. Median (25<sup>th</sup> and 75<sup>th</sup> percentiles) physical activity (min/wk) assessed by questionnaire (AQuAA) and accelerometer (PAM) among adults.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method</th>
<th>Total</th>
<th>Male</th>
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<th>p</th>
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<th>p</th>
<th>Normal Weight</th>
<th>Overweight</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.40</td>
<td>100</td>
<td>100</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>%</td>
<td>70</td>
<td>68</td>
<td>70</td>
<td>56</td>
<td>70</td>
<td>.75</td>
<td>84 (30-152)</td>
<td>82 (30-162)</td>
<td>.75</td>
</tr>
<tr>
<td></td>
<td>min/wk</td>
<td></td>
<td>120 (0-300)</td>
<td>120 (0-360)</td>
<td>120 (0-286)</td>
<td>120 (0-360)</td>
<td>120 (6-360)</td>
<td>.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.63</td>
<td>135 (60-300)</td>
<td>170 (59-321)</td>
<td>.62</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>% *</td>
<td>9</td>
<td>15/0</td>
<td>7</td>
<td>13</td>
<td>8</td>
<td>.32</td>
<td>18 (0-68)</td>
<td>13 (0-68)</td>
<td>.58</td>
</tr>
<tr>
<td></td>
<td>min/wk</td>
<td></td>
<td>14 (0-68)</td>
<td>15 (1-75)</td>
<td>12 (0-55)</td>
<td>18 (0-68)</td>
<td>13 (0-68)</td>
<td>.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.18</td>
<td>300 (161-660)</td>
<td>360 (178-593)</td>
<td>.67</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>% *</td>
<td>42</td>
<td>39</td>
<td>44</td>
<td>45</td>
<td>41</td>
<td>.93</td>
<td>134 (72-257)</td>
<td>149 (78-240)</td>
<td>.65</td>
</tr>
<tr>
<td></td>
<td>min/wk</td>
<td></td>
<td>144 (77-250)</td>
<td>142 (77-250)</td>
<td>144 (76-245)</td>
<td>134 (72-257)</td>
<td>149 (78-240)</td>
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<tr>
<td>MVPA</td>
<td>AQuAA</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>.11</td>
<td>240 (120-505)</td>
<td>258 (118-510)</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>% *</td>
<td>58</td>
<td>48</td>
<td>69</td>
<td>56</td>
<td>58</td>
<td>.63</td>
<td>56</td>
<td>58</td>
<td>.63</td>
</tr>
<tr>
<td>(excluding cycling)</td>
<td>248 (120-510)</td>
<td>293 (120-540)</td>
<td>210 (105-490)</td>
<td>240 (120-505)</td>
<td>258 (118-510)</td>
<td>240 (120-505)</td>
<td>258 (118-510)</td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td>%</td>
<td>58</td>
<td>48</td>
<td>69</td>
<td>56</td>
<td>58</td>
<td>.63</td>
<td>56</td>
<td>58</td>
<td>.63</td>
</tr>
</tbody>
</table>

* The minutes of activity assessed by the accelerometer expressed as percentage of the minutes of activity by questionnaire.

Note: MPA: moderate physical activity, VPA: vigorous physical activity, MVPA: moderate-to-vigorous physical activity.
Figure 2. Bland-Altman plots of MPA and VPA assessed by AQuAA and PAM accelerometer among adolescents and adults.

Disagreement between PAM and AQuAA
Figure 3. Bland-Altman plots of moderate-to-vigorous physical activity (min/wk) assessed by AQuAA (with and without reported cycling) and PAM accelerometer among adolescents and adults.

Bland-Altman plot of AQuAA and PAM accelerometer on MVPA among adolescents

Bland-Altman plot of AQuAA and PAM accelerometer on MVPA (minus cycling) among adolescents

Bland-Altman plot of AQuAA and PAM accelerometer on MVPA among adults

Bland-Altman plot of AQuAA and PAM accelerometer on MVPA (minus cycling) among adults

Chapter 5

Disagreement between PAM and AQuAA
GENDER
The accelerometer measurement showed that adolescents boys were more active on MPA compared to adolescents girls (112 vs. 79 minutes, p=0.04), however the opposite was found for the self-report (503 vs. 532 minutes, p=0.03). Adolescent boys also reported significantly more minutes of VPA (180 vs. 0 minutes, p<0.001) than girls, but this difference was again not confirmed by the accelerometer data (13 vs. 14 minutes, p=0.74). Among adults, self-reported and measured MPA and VPA did not differ significantly between men and women.

EDUCATION
According to the questionnaire, adolescents with a low educational level were less active on MPA (360 vs. 565 minutes, p=0.002) and VPA (0 vs. 120 minutes, p=0.012) compared to higher educated adolescents. However, the accelerometer measurement showed for both MPA (200 vs. 51 minutes, p=0.001) and VPA (54 vs. 7 minutes, p=0.001) the opposite. Among adults, no significant differences in reported or measured MPA and VPA between educational levels were found.

GENDER COMBINED WITH EDUCATION
Figure 4 shows the disagreement in MPA and VPA among subgroups of gender and level of education for adolescents and adults. According to the questionnaire, lower educated girls spent less time on MPA (350 vs. 625 minutes, p=0.03) and VPA (0 vs. 60 minutes, p=0.05) than their higher educated peers. In boys a similar pattern between low and high-educated subjects is seen in MPA (405 vs. 540 minutes, p=0.19) and VPA (140 vs. 180 minutes, p=0.87). However, the accelerometer data for both boys and girls in MPA and VPA show the opposite (p<0.001). Among adults, similar results for subgroups were found for MPA for both measures, with exception of the lower educated men who reported two times more minutes of MPA compared to the accelerometer. For VPA, the reported minutes (range 120 to 180 minutes) were higher than the recorded minutes by the accelerometer (range 9 to 28 minutes) between subgroups.

WEIGHT STATUS
According to the questionnaire normal weight adolescents were more active in MPA and VPA than their overweight peers (non-significant), but according to the accelerometer normal weight adolescents were less active in MPA (81 vs. 162 minutes, p=0.008) and VPA (12 vs. 29 minutes, p=0.05). On the contrary, overweight adults reported more VPA than those with normal weight (185 vs. 128 minutes, p=0.04), but this was not confirmed by the accelerometer (9 vs. 18 minutes, p=0.25).

MVPA WITH AND WITHOUT REPORTED CYCLING
Multivariate regression analyses showed that minutes spent on cycling were a significant contributor to the disagreement between both PA measures among adolescents and adults. According to the questionnaire adolescents spent 230 minutes per week (median) on cycling. Moreover, adolescents with a high educational level spent more time cycling (median 250 vs. 135 minutes per week, p=0.001) compared to lower educated adolescents. Among adults, median time spent on cycling was 40 minutes. Table 2 and 3 show the relative disagreement of both PA measures in MVPA with and without reported cycling. As anticipated, disagreement of MVPA without cycling was overall smaller than MVPA with cycling. Figure 5 shows the disagreement in MVPA with and without reported cycling among subgroups of gender and level of education for adolescents and adults. In the total group and subgroups of adolescents and adults, PA patterns were similar for both MVPA.
In our study we found that 7 to 22% of the time spent on mPA and vPA reported by adolescent boys and girls was objectively confirmed by the PAM accelerometer. Contrary to what was observed among adults, the disagreement among adolescents with a high educational level was greater than adolescents with a low educational level. This disagreement was greater among girls than boys. Among adults there was generally better agreement between both measures with regard to MPA than among adolescents. However, there was also a strong disagreement with regard to VPA, particularly among overweight adults.

Neither the questionnaire nor the PAM accelerometer is a gold standard for measuring PA and disagreement between the instruments is a result of weaknesses in both instruments. Therefore, we can only make a relative comparison between the instruments.

Since self-reported PA is prone to misreporting and the correlations between the AQuAA questionnaire and accelerometer were low, results should be interpreted with caution. Based on the fair reproducibility and the low validity of the AQuAA we may conclude that the disagreements between self-report and accelerometer found in our study are relevant, however the magnitude of this disagreement remains unclear.

Potential misreporting in the questionnaire may be the result of the fact that most daily activities are intermittent and may involve significant breaks or rest periods. This may lead to inaccurate recall and significant overestimation of time spent on daily activities. Measurement errors of the accelerometer may also have led to the disagreement between both instruments. Our study showed that cycling was a significant contributor to this disagreement. Analyses without reported time spent on cycling showed that the difference in time spent on MVPA between both measures only remained significant in subgroups of education among adolescents. Likewise, disagreement between the questionnaire and the accelerometer may also be partly due to not wearing the accelerometer during playing sports however this adherence did not differ between the subgroups.

Continuous behaviors with a higher perceived intensity than objectively measured could also contribute to the disagreement between the two PA methods. Misclassification of activity intensity may be related to the application of MET cut-offs to both self-report and accelerometer data. For instance, when a light activity is classified as moderate by respondents to the questionnaire, misclassification is introduced. Since most of the respondents are not familiar with the MET metric and can not differentiate between the 3 MET and 4 MET, we have provided example activities (based on the compendium of Ainsworth) along with the questions to enable the respondent to make an estimation of the activity intensity.

Few studies have examined and compared the variation between an objective and a subjective PA measure. An earlier study of Sallis et al, showed ethnic and gender differences among adolescents in disagreement of PA assessments. In our study, the disagreement with respect to MPA was greatest for higher educated adolescents,
especially in girls. Possibly higher educated adolescents reported more social desirable answers or they were involved in different moderate intensity activities than their peers which caused greater disagreement.

In adults, there was greater disagreement between the two measures among overweight adults with respect to VPA. Although all respondents experience difficulty estimating the activity intensity and the duration of activity, overweight adults may rate an activity more easily as VPA than normal weight adults. This finding for VPA and MVPA in overweight people is also found in other studies and is relevant information by interpreting PA trends in subgroups of weight status.\textsuperscript{15,17} So, using questionnaires on a population level to assess PA levels may underestimate the difference in VPA between people with a normal weight and people with overweight.

A considerable strength of the study is the high compliance for wearing the accelerometer. Applying the Spearman-Brown prophecy formula on the separate age-groups, there can be concluded that a minimum of 5 days of measurement was required to achieve a reliability level of 80%.\textsuperscript{41} In our study, 90% of the adolescents and 92% of the adults wore the accelerometer for at least five out of the seven days in the last week. This compliance is high compared with previous studies (range 62 -75%).\textsuperscript{38,42}

Subjects were recruited from different schools and companies in the surroundings of Amsterdam, which favors the generalizability of the study results. However, since our findings are based on one particular accelerometer and one questionnaire, the results cannot be generalized to other accelerometers and questionnaires. Also, since, our study participants also consented to participate in an intervention study aimed at increasing PA (see method section), our study sample may be more health conscious than the general population. Both aspects may limit the generalizability of the findings.

In summary, we observed considerable disagreement in time spent on MPA and VPA measured by an objective measure compared to a subjective measure in adolescents. Adolescent girls with a high educational level extremely over-reported MPA and boys over-report VPA relative to accelerometer registered time. In adults there was moderate agreement between both measurement methods with regard to MPA but not to VPA. Disagreement on time spent on MPA was largest among men with a low educational level and disagreement on time spent on VPA was largest among overweight adults. However, since both measures are not a gold standard, it is not possible to determine the exact size of the misclassification of the instruments. The results of this study raise serious questions regarding the use of questionnaires or accelerometers for assessing physical activity in adolescents. Readings from the questionnaire were often opposite to readings from the accelerometer among subgroups of gender and educational level in adolescents. There is a clear need in advanced valid assessments of MPA and VPA in adolescents.
CHAPTER 6

FEASIBILITY AND EFFECTIVENESS OF AN ONLINE PHYSICAL ACTIVITY ADVICE BASED ON A PERSONAL ACTIVITY MONITOR

Accepted for publication as: Slootmaker SM, Chin A Paw MJ, Schuit AJ, Seidell JC, van Mechelen W. Feasibility and effectiveness of an online physical activity advice based on a personal activity monitor. Journal of Medical Internet Research.
ABSTRACT

BACKGROUND
Inactive people are often not aware of the fact that they are insufficiently active. Providing insight in their actual physical activity levels may raise awareness and could, in combination with a tailored physical activity (PA) advice, stimulate a physically active lifestyle.

OBJECTIVE
This study evaluated the feasibility and effectiveness of a 3-month intervention in which Dutch office workers were provided with a personal activity monitor (PAM), coupled to a simple and concise web-based tailored physical activity advice (PAM COACH).

METHODS
Study outcome measures were changes in PA, determinants of PA, aerobic fitness and body composition. Participants were randomly assigned to the 3-month PAM intervention or they received a single written information brochure with brief general PA recommendations. Follow-up measurements were performed after three months intervention and five months after the end of the intervention period.

RESULTS
Hundred-and-two workers, 23 to 39 years old, completed the baseline measurement at the worksite. Seventy-three percent of the participants in the PAM-intervention group reported to have worn the PAM regularly and the PAM COACH was used almost once a week. Seventy-four percent of the PAM-users read the advice, of whom 39% found the advice given appealing. No significant intervention effect was observed on any of our outcome measures.

CONCLUSIONS
The intervention appeared to be easily applicable in real-life settings. The intervention was ineffective in improving PA behavior or its determinants in healthy office workers. More attention should have been given to the quality and appropriateness of the tailored advice.

BACKGROUND
According to the current Public Health physical activity (PA) recommendation adults should accumulate a daily amount of at least 30 minutes of moderate intensity PA, on at least five days of the week or a minimum of 20 minutes of vigorous-intensity aerobic PA on three days each week to promote and maintain health.6 Surveillance data from the Netherlands and the United States have shown consistent but low adherence (55% and 45% respectively) to this recommendation among adults in general but have shown also large differences between sub-populations.140,158,169,160

It is suggested that adults in full-time employment, or going through life events such as marriage and having children, are more at risk to become physically inactive due to increased commitments.162

Inactive subjects are often not aware of the fact that they are insufficiently active. This was recently shown in a survey among about 2600 Dutch adults.154 No less than 60% of the people that did not meet the recommendation believed that they were sufficiently active. The use of a physical activity monitor that continuously registers and displays the actual PA level of the user may raise awareness and could thus overcome the problem of poor self-evaluation.34 Hence, objective instant feedback by a PA monitor (e.g. pedometer, accelerometer) could positively affect the PA level in inactive subjects.55,56 Hultquist et al. found that sedentary women who were given pedometers and who were instructed to walk 10,000 steps a day walked almost 2000 steps per day more than women who were instructed to go for a brisk 30-minute walk each day.160 Physical activity monitors can be worn without major inconvenience, require little effort of the user and are compatible with most daily activities, making it a practical and socially acceptable measure of PA.43

Internet-based self-management interventions for PA have been shown to have potential because they can reach large numbers of participants at-risk in a variety of settings at any time and location.69-71 There is evidence that health-related behavior is more affected by a tailored approach than by general health promotion activities.120,163 Computer-tailored PA promotion programs are relatively new.43 They provide respondents with individually adapted feedback about their current PA level and additionally provide individualized suggestions to change sedimentary behavior and to promote daily PA. To date, little evidence is available on the feasibility and effectiveness of Internet-based tailored interventions coupled to an activity monitor.72,73

The PAM concept (PAM B.V., Doorwerth, The Netherlands) combines the use of a personal activity monitor (PAM) with simple and concise web-based tailored PA advice (PAM COACH). The PAM (model AM101) is an uni-axial accelerometer in the vertical direction which can be easily attached to a belt. The validity of the PAM accelerometer has been tested in a laboratory setting and has shown results similar to the MTI Actigraph for estimating energy expenditure in walking and stair walking (Chapter 2).114 The PAM produces a single index score which accumulates during the day and is a proxy measure of total daily PA. The PAM shows the PAM score continuously on its display. Via a docking station, which must be connected to a computer with an Internet connection, the user can upload his personal PAM scores through PAM software to the PAM COACH website at any time throughout the day. On the PAM COACH website users can interactively plan and evaluate their own PA advice, based on their actual PAM scores and their personal activity goals and preferences.
The objective of this study is to evaluate the feasibility and effectiveness of providing a PA monitor coupled to a simple and concise web-based personalized PA advice on the daily PA level of young Dutch inactive office workers in a randomized controlled trial. In addition the effects on determinants of PA, aerobic fitness and body composition were examined. We hypothesized that the use of the PAM combined with the PAM COACH will increase awareness and subsequent PA levels of inactive office workers.

METHODS

STUDY DESIGN AND STUDY POPULATION

This randomized controlled trial (RCT) is part of the PAM–project, which is described extensively elsewhere.\(^1\)\(^2\) Mainly office workers in the age of 20 to 40 years old, all apparently healthy, with differential educational level were recruited from eight worksites in the surrounding of Amsterdam, the Netherlands. For all worksites the same recruitment protocol was used. Inclusion criteria were ability to walk without aid, Dutch speaking and not pregnant. First, PA levels were monitored for two weeks by means of a PAM and a PA questionnaire. Based on these two weeks, the study population (N=302) was divided in an ‘active’ (most active 50% of the population) and ‘inactive’ (least active 50% of the population) half. The relatively inactive adults were invited to participate in the RCT. To be able to detect a between-group difference of 20% in PA level (80% probability and a significance level of 0.05), two groups of 50 participants were required. Randomization to the intervention or control group was performed at individual-level by choosing sealed envelopes after the baseline measurements. This study was approved by the Medical Ethics Committee of VU University Medical Center. All participants gave their informed consent.

INTERVENTION

After randomization, participants in both the intervention and control group were advised to increase their PA levels. The control group received a single written information brochure with brief general PA recommendations. This print brochure is published by the Netherlands Heart Foundation and contains brief general information on the health benefits of PA and the PA recommendation. Everyone can obtain the brochure free of charge.

The intervention group received the PAM and was provided with web-based tailored PA advice (PAM COACH; www.pam.com) for a 3-month period. Figure 1 and table 1 show the sitemap of the PAM COACH website. First, the participant had to install the PAM-software on the computer to use the PAM reader. When reading the PAM, the participant is automatically directed to the PAM COACH website. The user can register on the PAM COACH website by filling out a form with personal data (i.e. username and password) and 12 questions on perceived PA barriers. Upon entry of the PAM COACH website, the user formulates a PAM-goal score for the three months intervention period. Based on the users’ uploaded PAM score of the first week, the PAM COACH assigns a lower goal which increases daily until the PAM-goal score is reached at the end of the intervention period. The PAM-goal score can be changed by the user throughout the intervention. On every subsequent login, the PAM COACH website presents all the uploaded PAM scores and coupled PAM-goals in orderly graphs per week or month. The uploaded PAM scores are automatically accompanied by a tailored PA advice on the computer screen as well as motivational tips for increasing PA. The advice includes information on how to reach the PAM-goal, which is based on 1) user preferred activities (e.g. daily an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash), and 2) user perceived PA barriers. Furthermore, the feedback is given in a stimulating way (e.g. “You are doing better, but to reach your goal you have to do more”). If the PAM is not worn during certain activities (e.g. swimming), these minutes can be added manually to the PAM score on the PAM COACH. Apart from the short feedback on the PAM COACH website, the users can easily monitor their progress in daily PA by reading directly their PAM score on the display of the PAM. The participants received written and verbal instructions and practical demonstrations on how to use the PAM and how to use the PAM COACH website (i.e. set of a personal goal and favorite activities). Participants were instructed to register and upload PAM-data in the first week of the intervention, to check if the system worked properly. After that, the participant could make use of the PAM and PAM COACH website as much as they wanted. At all worksites at least one computer with PAM software and access to Internet was available, except at one worksite, where ICT policies did not allow PAM software on their network. Participants from this worksite accessed the PAM COACH website at home only.

Figure 1. Functionalities of the PAM COACH website
Table 1. Contents of the PAM COACH website.

<table>
<thead>
<tr>
<th>Website section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homepage</td>
<td>Presentation of the latest PAM weekscore, hyperlink to complete advice and motivational PA tips.</td>
</tr>
<tr>
<td>Goal Setting</td>
<td>Setting the PAM goalscore, indicated by deficiency in minutes per day for their preferred activities.</td>
</tr>
<tr>
<td>Activity Logg</td>
<td>Presentation of all uploaded PAM scores (per day/week/month).</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>Twelve questions on perceived PA barriers (yes or no).</td>
</tr>
<tr>
<td>Preferred activities</td>
<td>Categories: transport, school activities, in and around the house, individual and team sports.</td>
</tr>
</tbody>
</table>
| Individualized PA Advice |  - Translation of PAM goalscore in the deficiency of minutes per day for their preferred activities.  
  - Feedback on their answers to the questionnaire.  
  - Stimulating feedback.  
  - Comparison of users’ PAM score to their peers in the intervention group.                                                                                                                                                                                                                                                                                                                         |
| Usage information     | Information about the use of the PAM and PAM COACH website, including a demonstration.                                                                                                                                                                                                                                                                                                                                                                                  |
| Project information   | The aim of the project and contact information.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| FAQ’s                 | Answers to frequently asked questions about the (use of) PAM and PAM COACH website.                                                                                                                                                                                                                                                                                                                                                                                        |

MEASUREMENTS

All measurements took place during working hours at the worksite at baseline, after three months intervention and five months after the end of the intervention period. The measurements are described in detail elsewhere. Gender, age and educational level were obtained at baseline. Educational level was categorized into low and high educational level. High educational level comprised of higher vocational education or university degree. All other levels of education were defined as low educational level.

PRIMARY OUTCOME MEASURES

Level of physical activity

The activity questionnaire for adolescents & adults (AQuAA, Chapter 2) was used to assess the amount of minutes per week spent on light (2–4 metabolic equivalents, MET), moderate (4–6.5 MET) and vigorous (>6.5 MET) intensity physical activities, as well as time spent sedentary (<2 MET), such as TV viewing and computer usage. The AQuAA refers to activities in the past week (seven day recall).

SECONDARY OUTCOME MEASURES

Determinants of physical activity

A short questionnaire was developed to assess behavioral intention to participate in sports more often; attitude, social influences, self-efficacy expectations and personal barriers towards sport (Cronbach’s alpha: 0.49, 0.85 and 0.78 respectively). For each determinant a selection of two or three relevant questions was made, based on previous studies. Answering formats were 5-point Likert scales (very low to very high). Per determinant, multiple items were converted into summary scores.

Awareness of complying with the Public Health PA recommendations was assessed by self-report ‘On how many days of the week did you spent at least 30 minutes of moderate activity’ and ‘Do you think you spend enough time participating in sports?’ (Yes or No). According to a method described by Ronda, respondents were allocated to four categories of awareness (under-estimators, over-estimators, realists adequate or realists inadequate), based on their self-rated compliance with the PA recommendations and the results of the PA questionnaire. In the analyses, awareness was dichotomized in non-realists (under-estimators and over-estimators) and realists (realists adequate and realists inadequate). Participants were classified as complying with the recommendation when they reported at least 150 minutes (=5 days x 30 minutes) of moderate to vigorous intensity activity per week. Subjects’ knowledge of the PA recommendation was tested by the question ‘How much time per day do you have to spend on physical activity to stay healthy?’

Aerobic fitness

A sub-maximal test, the Chester Step Test (CST), was used to predict maximal aerobic capacity. The CST consists of five increasing paces of stepping on and off a bench. A step height of 30 cm was used for active and 20 cm for inactive participants. The CST starts at the relatively slow pace of 15 steps per minute and increases every two minutes to 20, 25, 30 and 35 steps per minute. Throughout the test the heart rate is monitored. After each stage the subject is asked to rate his perceived exertion on the Borg scale which is a 15-point numerical rating scale, ranging from 6 “very very light” to 20 “exhaustion”. The test is terminated when the
adherence on the outcomes by performing regression analyses among intervention participants including the login frequency. Analyses were performed using SPSS (version 14.0, SPSS Inc., Chicago, Illinois, USA).

RESULTS

STUDY POPULATION AND BASELINE MEASUREMENTS

Of the 152 invited adults, 102 (67% response rate) completed the baseline measurement and were randomly assigned to either the intervention (n=51) or the control group (n=51). The flow of subjects through the RCT and the distribution of non-responders is shown in figure 2.

Table 2 shows baseline characteristics of both the intervention and control group. Participants were predominantly female (60%) and had a higher education (65%). Participants in the intervention and control group were comparable except for age (the intervention group was on average 1.3 years older; P=0.05) and intention to participate in sports at baseline (higher in control group; P=0.005). About 67% of the total sample met the PA recommendation at baseline (78% of the men and 59% of the women).

PROCESS MEASURES

After the 3-month intervention, PAM users were asked to evaluate
1) the PAM (i.e. appreciation of the PAM score, frequency of wearing the PAM)
2) the PAM COACH website (i.e. appreciation of website, use of activity goal and favorite activities), and
3) the tailored advice (i.e. reading and appreciation of the advice).
The uploaded PAM scores and the login frequency to the PAM COACH website were registered for each participant in the intervention-group.

DATA ANALYSIS

To compare baseline values, chi square was used for gender, education and awareness distributions. Non-parametric testing (Mann-Whitney U-test) was used for PA data. Independent samples t-test was used to analyze all other demographic variables, determinants of PA, aerobic fitness and body composition. The effect of the intervention was estimated based on the intention-to-treat principle including all participants who had attended at least one follow-up measurement. Logistic regression analysis was used for the dichotomous outcome measure, awareness of meeting the PA and sports-recommendation (0= non-realists; 1=realists). For all other outcome measures, standard linear regression analysis was used to test the differences between intervention and control group at follow-up. The follow-up measurements were defined as dependent variable. Baseline values of the particular dependent variable were always included as covariate. The parameters of interest are the regression coefficients (β), indicating the effect of the intervention compared to the control group. In a second analysis, gender (0=male, 1=female), age (continuous), education (0=low, 1=high) and BMI (continuous; not added in the analyses for body composition outcome measures) were considered as possible confounder or effect-modifier. If the interaction between group allocation and the variable concerned had a p-value below 0.10 than subgroup analyses were performed. Additionally, we adjusted for program adherence on the outcomes by performing regression analyses among intervention participants including the login frequency. Analyses were performed using SPSS (version 14.0, SPSS Inc., Chicago, Illinois, USA).
Figure 2. Flowchart of the intervention (I) and control subjects (C) in the randomized controlled trial

Table 2. Baseline characteristics of total sample, PAM and control group.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n=102)</th>
<th>PAM (n=51)</th>
<th>Control (n=51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age in years ± SD</td>
<td>31.8 ± 3.5*</td>
<td>32.5 ± 3.4</td>
<td>31.2 ± 3.5</td>
</tr>
<tr>
<td>Female (%)</td>
<td>60</td>
<td>61</td>
<td>59</td>
</tr>
<tr>
<td>High educated (%)</td>
<td>65</td>
<td>63</td>
<td>67</td>
</tr>
<tr>
<td>Familiar with PA recommendations (%)</td>
<td>63</td>
<td>59</td>
<td>67</td>
</tr>
<tr>
<td>Compliance with PA recommendations (%)</td>
<td>67</td>
<td>69</td>
<td>65</td>
</tr>
<tr>
<td>Determinants of participating in sports (Mean ± SD, 5-point likert scale)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>4.25 ± 0.69</td>
<td>4.30 ± 0.75</td>
<td>4.25 ± 0.64</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>3.34 ± 0.71</td>
<td>3.22 ± 0.70</td>
<td>3.45 ± 0.71</td>
</tr>
<tr>
<td>Intention</td>
<td>3.44 ± 1.23*</td>
<td>3.10 ± 1.20</td>
<td>3.78 ± 1.19</td>
</tr>
<tr>
<td>Awareness of compliance with recommendations (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realist inadequate</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Underestimator</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Overestimator</td>
<td>10</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Realist adequate</td>
<td>40</td>
<td>39</td>
<td>41</td>
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<tr>
<td>Awareness of sports participation (%)</td>
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</tr>
<tr>
<td>Realist inadequate</td>
<td>62</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>Under-estimator</td>
<td>3</td>
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<tr>
<td>Over-estimator</td>
<td>27</td>
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</tr>
<tr>
<td>Realist adequate</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Aerobic fitness (Mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO_{2}max (ml O_{2}kg^{-1}min^{-1})</td>
<td>41.4 ± 7.5</td>
<td>41.7 ± 8.4</td>
<td>41.2 ± 6.7</td>
</tr>
<tr>
<td>Body composition (Mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.7 ± 14.6</td>
<td>79.0 ± 15.6</td>
<td>76.5 ± 13.6</td>
</tr>
<tr>
<td>BMI (kg m^{-2})</td>
<td>25.2 ± 4.1</td>
<td>25.9 ± 4.5</td>
<td>24.4 ± 3.5</td>
</tr>
<tr>
<td>Sum of skin folds (mm)</td>
<td>65.3 ± 31.6</td>
<td>69.4 ± 36.2</td>
<td>61.2 ± 25.8</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>27.1 ± 7.6</td>
<td>27.9 ± 8.0</td>
<td>26.4 ± 7.2</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>85.4 ± 11.6</td>
<td>86.4 ± 11.9</td>
<td>84.5 ± 11.4</td>
</tr>
</tbody>
</table>

* Difference at baseline between intervention and control group (P<0.05). Abbreviations: PA: physical activity; ml O_{2}kg^{-1}min^{-1}: milliliter oxygen per kilogram bodyweight per minute; BMI: body mass index.
### PRIMARY OUTCOME MEASURES

In the total study sample our 3-month intervention did not significantly affect PA levels (table 3). However, because of effect-modification by education we conducted subgroup analyses. These analyses showed that the 3-month intervention resulted in a relative lowering of light PA (2-4 MET) among higher educated participants (adjusted difference between intervention and control group: -349 minutes/week (95% CI: -632; -66; p=0.017). This effect did not sustain until five months after the intervention. A higher adherence to the program did not result in increased levels of PA (data not shown in table).

Table 3. Median physical activity (PA) scores and mean PA change (min week⁻¹) and sedentary time at baseline, at 3 and 8-month follow-up for PAM and control group.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>PAM (n=46) (median, IQR)</th>
<th>Control (n=49) (median, IQR)</th>
<th>Crude Difference* β (95% CI)</th>
<th>Adjusted difference** β (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary time</td>
<td>Baseline 3390 (2580; 3810)</td>
<td>3375 (2870; 3855)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 months 3400 (2850; 3840)</td>
<td>2470 (2495; 3941)</td>
<td>101.0 (-338.0; 540.1)</td>
<td>10.0 (-435.2; 455.2)</td>
<td></td>
</tr>
<tr>
<td>8 months 2925 (2358; 4206)</td>
<td>3342 (2741; 3998)</td>
<td>-173.5 (-720.7; 373.8)</td>
<td>-267.3 (-802.5; 267.8)</td>
<td></td>
</tr>
<tr>
<td>LPA</td>
<td>Baseline 630 (480; 1320)</td>
<td>720 (450; 1220)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 months 636 (345; 950)</td>
<td>678 (408; 1320)</td>
<td>-83.8 (-290.9; 123.3)</td>
<td>-129.0 (-336.9; 78.75)</td>
<td></td>
</tr>
<tr>
<td>8 months 500 (326; 994)</td>
<td>593 (323; 1020)</td>
<td>-17.8 (-220.6; 185.1)</td>
<td>-2.0 (-210.0; 205.9)</td>
<td></td>
</tr>
<tr>
<td>MPA</td>
<td>Baseline 90 (5; 240)</td>
<td>120 (10; 203)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 months 75 (20; 180)</td>
<td>90 (8; 240)</td>
<td>-21.7 (-96.2; 52.6)</td>
<td>-13.0 (-88.5; 62.5)</td>
<td></td>
</tr>
<tr>
<td>8 months 120 (19; 241)</td>
<td>90 (8; 278)</td>
<td>97.1 (-46.7; 241.0)</td>
<td>102.8 (-41.9; 247.6)</td>
<td></td>
</tr>
<tr>
<td>VPA</td>
<td>Baseline 170 (60; 315)</td>
<td>120 (30; 240)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 months 80 (20; 210)</td>
<td>113 (41; 290)</td>
<td>-4.1 (-71.2; 63.0)</td>
<td>-6.2 (-74.9; 62.4)</td>
<td></td>
</tr>
<tr>
<td>8 months 120 (50;259)</td>
<td>115 (30; 303)</td>
<td>-17.3 (-96.5, 61.8)</td>
<td>-28.0 (-109.1;53.8)</td>
<td></td>
</tr>
<tr>
<td>MVPA</td>
<td>Baseline 320 (120; 510)</td>
<td>240 (75; 443)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 months 197 (100; 480)</td>
<td>281 (150; 488)</td>
<td>-27.4 (-122.9; 68.0)</td>
<td>-22.7 (-121.1; 75.5)</td>
<td></td>
</tr>
<tr>
<td>8 months 223 (150; 548)</td>
<td>263 (145; 420)</td>
<td>81.3 (-109.2; 271.9)</td>
<td>73.5 (-119.4; 266.5)</td>
<td></td>
</tr>
</tbody>
</table>

*Baseline values of the particular dependent variable were always included as covariate. **Adjusted for gender, age, education and BMI at baseline. Abbreviations: IQR: interquartile range between 25th and 75th quartile; β: regression coefficient, indicating the difference between the intervention and control group; 95% CI: 95 percent confidence interval.

### SECONDARY OUTCOME MEASURES

For the determinants of physical activity, no statistically significant intervention effect was observed in the total study sample (table 4), however an intervention effect was observed in subgroups of BMI. The proportion of subjects being aware of their adherence to the sports recommendation increased among overweight participants in the intervention group (adjusted odds ratios between intervention and control group: 16.4 (95% CI: 1.3; 214; P=0.017). This significant effect did not sustain until five months after the intervention. No statistically significant intervention effect was observed on aerobic fitness or body composition. However, subgroup analyses showed a decrease in body weight among low educated intervention participants, compared to their peers in the control group (adjusted difference: -1.6 kg (95% CI: -2.8; -0.4, p=0.009). This difference sustained until five months after the intervention (adjusted difference: -2.1 kg (95% CI: -4.4; 0.3, p=0.08).

Table 4. Effectiveness of the three months PAM-intervention on determinants of physical activity, aerobic fitness and body composition: results of regression analyses.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Crude difference* β (95% CI)</th>
<th>Adjusted difference** β (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determinants of playing sports (5-point Likert scale)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>-0.18 (-0.40; 0.04)</td>
<td>-0.20 (-0.43; 0.02)</td>
</tr>
<tr>
<td>Social influence</td>
<td>-0.01 (-0.31; 0.28)</td>
<td>-0.05 (-0.36; 0.24)</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>0.64 (-0.14; 0.27)</td>
<td>0.05 (-0.15; 0.26)</td>
</tr>
<tr>
<td>Intention</td>
<td>0.27 (-0.20; 0.74)</td>
<td>0.30 (-0.20; 0.80)</td>
</tr>
<tr>
<td>Aerobic fitness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂max (ml O₂ kg⁻¹ min⁻¹)</td>
<td>1.28 (-1.34; 3.90)</td>
<td>1.82 (-0.73; 4.39)</td>
</tr>
<tr>
<td>Body composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>-0.27 (-1.12; 0.57)</td>
<td>-0.36 (-1.23; 0.49)</td>
</tr>
<tr>
<td>Sum of skin folds (mm)</td>
<td>1.49 (-4.38; 7.38)</td>
<td>1.34 (-4.62; 7.30)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>-0.51 (-1.85; 0.82)</td>
<td>-0.73 (-2.10; 0.63)</td>
</tr>
<tr>
<td>Awareness (%) OR (95% CI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compliance with recommendations</td>
<td>1.45 (0.62; 3.37)</td>
<td>1.33 (0.54; 3.27)</td>
</tr>
<tr>
<td>Sports participation</td>
<td>0.81 (0.31; 2.11)</td>
<td>0.62 (0.22; 1.75)</td>
</tr>
</tbody>
</table>

*Baseline values of the particular dependent variable were always included as covariate. **Adjusted for gender, age, education and BMI at baseline. BMI at baseline was not added as confounder in the analyses for the body composition outcome measures. Notes: Awareness was analyzed with logistic regression (non-realists=0, realists=1). Abbreviations: β: regression coefficient, indicating the difference between the intervention and control group; 95% CI: 95 percent confidence interval; ml O₂ kg⁻¹ min⁻¹: milliliter oxygen per kilogram bodyweight per minute; OR: Odds ratio; PA: physical activity.
**PROCESS MEASURES**

Seventy-three percent of the PAM users reported to have worn the PAM regularly to often (table 5). This finding was supported by the login frequency (almost once a week) of the PAM data to the PAM COACH website. The majority of the PAM users set a personal goal (52%) and entered their favorite activities (72%) on the website. Main reasons for not using these items were lack of interest or not able to find the item on the website. The tailored advice was read by 74% of the PAM users, of whom 61% did not find the advice appealing. Main reasons given were; the advice was not personal or specific enough (n=9); the advice given was not applicable in their daily situation (n=6), little variety in the advice (n=3). Overall the participants rated the PAM monitor and the PAM COACH website as sufficient.

**Table 5. Process evaluation data of the PAM and the PAM COACH website.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Login frequency</td>
<td>47</td>
<td>0.9 ± 0.6</td>
</tr>
<tr>
<td>1st month intervention</td>
<td>47</td>
<td>3.8 ± 2.5</td>
</tr>
<tr>
<td>2nd month intervention</td>
<td>47</td>
<td>3.6 ± 2.6</td>
</tr>
<tr>
<td>3rd month intervention</td>
<td>47</td>
<td>3.4 ± 3.6</td>
</tr>
<tr>
<td>Mean uploaded PAM score</td>
<td>26</td>
<td>18.4 ± 7.8</td>
</tr>
<tr>
<td>1st month intervention</td>
<td></td>
<td>16.7 ± 7.5</td>
</tr>
<tr>
<td>2nd month intervention</td>
<td></td>
<td>17.8 ± 7.6</td>
</tr>
<tr>
<td>Appreciation PAM score*</td>
<td>47</td>
<td>6.4 ± 2.1</td>
</tr>
<tr>
<td>Appreciation PAM COACH website*</td>
<td>47</td>
<td>6.5 ± 1.9</td>
</tr>
</tbody>
</table>

**DISCUSSION**

This study investigated the feasibility and effectiveness of providing a personal activity monitor in combination with a simple and concise tailored PA advice through the Internet. The primary aim of the intervention was to improve daily PA, but we also examined effects on secondary outcomes such as determinants of PA, aerobic fitness and body composition. According to the intention-to-treat analysis, the PAM intervention did not result in increased PA levels of young Dutch office workers, nor did it improve any of the secondary outcomes. These results may partly be due to the fact that only 39% of the users found their PA advice appealing.

The use of a personal website seems to be applicable at every worksite with internet-connection and a proper mode for PA interventions among young employees. Yet, our intervention seemed ineffective to promote PA in the total study population. This is in contrast to previous controlled interventions which showed that a PA monitor helped sedentary participants to set goals and motivated them to increase their PA. However, these studies were not designed as RCT and included mainly overweight participants or patients with type 2 diabetes.

Although our study was not designed for subgroup analyses, we conducted them after observing significant effect modification. Among low educated intervention subjects we observed a decrease in body weight of 1.6 kilogram. This effect is considerable after three months and clinically relevant. Moreover, the proportion of realists increased among overweight subjects, which makes this concept of self-monitoring and web-based feedback interesting for future research in these specific target groups.

**LIMITATIONS**

The results of this study must be interpreted in light of its limitations. First, both our primary and part of our secondary outcomes were based on self-report and therefore prone to misreporting. However, since we looked at changes in PA behavior at least the bias associated with systematic errors is cancelled out. Nevertheless, we compared the self-reported total PA data with the objective uploaded PAM data among participants of the intervention group (data not shown). The PAM data confirm the decline in total PA as assessed by the self-report (change in median: -147 minutes per week) after 3-month intervention.

Second, our control group is not a truly non-intervention group because they received an information leaflet on PA. However, we do not expect changes in PA by providing such brochures only. Furthermore, our findings may reflect ceiling effects associated with a relatively active sample at baseline. Although the study was aimed at inactive employees, almost 69% of the PAM intervention group and 65% of the control group already met the PA guideline at baseline. This is supported by the fact that the percentage of subjects that was acquainted with the PA recommendation as well as the percentage of subjects that was classified as aware (realists) of their compliance with the PA recommendation and to participate regularly in sports, was high in both groups. In addition, our study results are mainly applicable to people who are employed by a workplace that allows recreational internet use which limits the generalizability of our study.
Finally, the practical advice given on the website was partly based on the objectively monitored PAM-score. Accelerometers are insensitive to certain types of movements, in particular, non-ambulatory physical activities with arm and or limb movements, such as cycling and weightlifting activities. This limitation of the accelerometer may have declined the accuracy and relevance of the advice given at the PAM COACH website, particularly for subjects who cycle a lot, which is common in the Netherlands. Although activities that are not accurately measured by the PAM can be included by hand on the PAM COACH website, a study has shown that recipients of negative or unexpected feedback responded by doubting the accuracy and credibility of the feedback information. This phenomenon may have discouraged our participants in achieving their personal PA-goal.

STRENGTHS
A strength of the study is its design, the easy to implement intervention and the low dropout. This RCT was set up as a short-term minimal intervention strategy, in order to make it easily applicable in real-life settings. During the intervention PAM users received a short personalized PA advice together with supportive practical advice to reach their personal PA-goal. In order to reach this PA-goal, the activity preferences of the user were taken into account, so that PA could be more easily implemented in their daily life. After registering, the user could decide when and how often to login to the PAM COACH website. In spite of the minimal contact during the intervention between the researcher and the participant, adherence was moderate to high. PAM-users logged in 10 times on average during the 3-month RCT, which is almost once a week and comparable with frequencies of website logins from previous studies (range 0.7 to 1.5 times per week). Moreover, during the intervention we observed a low drop-out rate, 6% and 2% for the intervention and control group respectively. The recurrent visits and low drop-out during the intervention suggests that participants were interested in new information and were acquainted with the technology.

The appreciation of intervention materials differed largely between the participants in the intervention group, most participants expected a more varied concrete advice and found the advice little feasible in daily life. This in spite of our aim to tailor the PA advice to a certain extent based on their actual PAM score in relation to their PAM goal. We strived for a content on the PAM COACH website with simple and concise PA advices and a variation of motivational tips.

To conclude, we hypothesized that the combination of a personal activity monitor combined with a tailored PA advice through the Internet would be potentially successful in increasing awareness and PA levels. However, we did not observe any significant effect on awareness, nor on PA level, its determinants, aerobic fitness or body composition among the total group of young healthy Dutch employees. This may be explained by the fact that we conducted a minimal intervention in a study population that largely (67%) met the PA recommendations at baseline. Moreover, a large part of the intervention population did not find the advice given appealing. Hence, the results of the present study do not give cause for wider implementation of this minimal intervention among healthy adults. Since we observed a tendency for a positive intervention effect on body weight among low educated adults, more research may be necessary to investigate the effectiveness of this type of interventions among people with overweight or a low socio-economic status. In this, attention should be given to the quality and appropriateness of the tailored advice.
CHAPTER 7

GADGETS AND INTERNET FOR PHYSICAL ACTIVITY PROMOTION IN YOUTH? FEASIBILITY AND EFFECTIVENESS OF A MINIMAL INTERVENTION

Submitted for publication as Slootmaker SM, Chin A Paw MJM, Seidell JC, van Mechelen W, Schuit AJ. Gadgets and Internet for physical activity promotion in youth? Feasibility and effectiveness of a minimal intervention.
ABSTRACT

BACKGROUND
Effective interventions strategies promoting physical activity (PA) are needed. We evaluated the feasibility and effectiveness of a 3-months minimal PA intervention in adolescents.

METHODS
A randomised controlled trial, including 87 inactive adolescents, aged 13-17 years, from five secondary schools. The participants in the intervention group were provided with a personal activity monitor (PAM), coupled to a web-based tailored PA advice (PAM COACH). The control group received a single brochure with general PA recommendations. Physical activity, determinants of PA and quality of life were assessed by questionnaire; aerobic fitness by a shuttle run test and anthropometrics using standard procedures. Measurements were performed at baseline, at three months (post-intervention) and at eight months.

RESULTS
Sixty-five percent of the participants in the intervention group reported to have worn the PAM frequently. Fifty-six percent of the PAM users uploaded their PAM scores to the PAM COACH, with a median of five times in three months. In girls of the intervention group, moderate intensity PA increased with 411 minutes/week (95% CI: 1; 824; p=0.04) compared with the control group but this effect dimished after eight months. In boys, a relative reduction in sedentary time of -1801 min/week (95% CI: -3545; -57; p=0.04) in the intervention group was seen at eight months.

CONCLUSIONS
Despite the disappointing low adherence to the intervention, the findings of our study suggest that promotion of PA by providing a personal activity monitor coupled to an online tailored PA advice seems promising for girls but less for boys.

BACKGROUND
The lack of physical activity (PA) during adolescence is associated with an increased cardiovascular risk, decreased bone health and decreased psychosocial well-being. Moreover, limited PA may also predispose youth to developing a sedentary lifestyle later in life. In 2007, only twenty-eight percent of adolescent boys and a 25% of adolescent girls in the Netherlands met the Dutch Public Health PA recommendation of 60 minutes of moderate to vigorous intensity PA per day. These low numbers are also found in other Western countries and are of great concern for public health. Therefore effective intervention strategies promoting an active lifestyle are needed.

One promising way to promote PA is by Internet-based self-management interventions. In Internet-based-tailored interventions, feedback is given on personal characteristics, personal preferences and individual health behaviour for example by e-mails or on computer screens. As a result of the rapid development of the Internet it is now possible to distribute tailored feedback to a wide range of people and settings in a cost-effective manner.

In adults it is known that inactive subjects are often not aware of the fact that they are insufficiently active, however these data are still unknown for adolescents. Regular feedback on PA levels may raise awareness of the level of PA. Thus, the use of a physical activity monitor that objectively registers and displays the actual PA levels of the user could positively affect the PA level in inactive subjects by increasing awareness. Therefore, an Internet-based program which automatically provides tailored feedback based on the results of a personal activity monitor could be a promising behavior modification tool for inactive subjects. Few studies, with similar concepts, have shown that PA can be increased via an automated Internet-based behavior change system. To date, no evidence is available on the feasibility and effectiveness of Internet-based tailored interventions coupled to an activity monitor among adolescents.

The PAM (model AM101, 28 gr, 59 x 43 x 10 mm, PAM B.V.) is an uni-axial accelerometer, that combines objectively measured PA with Internet-based tailored PA advice (PAM COACH). The PAM registers accelerations in the vertical direction and is worn on the hip. The PAM produces a cumulative activity score (PAM score), which is a proxy measure of total daily PA. Via a docking station connected to the computer, the user can upload his personal PAM scores to the PAM COACH website at any time of the day. The PAM COACH website provides the user with short individualized PA feedback based on their current PAM score and additionally provides personally adapted suggestions to promote daily PA. We hypothesized that this concept may especially be feasible in adolescents because it combines the use of the Internet (important communication channel for adolescents) with a new gadget, i.e. the PAM.

The objective of the present study was (1) to evaluate the feasibility of providing an activity monitor coupled to online individualized PA advice, and (2) to study the effectiveness of this intervention on the daily PA and its determinants, quality of life, aerobic fitness and anthropometrics of physically inactive adolescents in a randomized controlled trial.
METHODS

STUDY DESIGN AND STUDY POPULATION

This randomized controlled trial (RCT) is part of the PAM–project, which is described in detail elsewhere (Chapter 4).131 A convenience sample of apparently healthy adolescents (age 13-17 years), with differential educational level were recruited from five secondary schools in Amsterdam, The Netherlands. For all schools the same recruitment protocol was used.150 Inclusion criterion was ability to walk without aid. First, PA levels were monitored for two weeks by means of a personal activity monitor and a PA questionnaire. Based on these two weeks, the study population (n=286) was divided in an ‘active’ (most active 50% of the population) and ‘inactive’ (least active 50%) group. The relatively inactive adolescents were invited to participate in the RCT. To be able to detect a between-group difference of 20% in PA level (80% probability and a significance level of 0.05), two groups of 50 participants were required. Randomization was performed at individual-level by choosing sealed envelopes after the baseline measurements. This study was approved by the Medical Ethics Committee of VU University Medical Center. All participants gave their informed and parental consent.

INTERVENTION

After randomization, participants in both the intervention and control group were advised to increase their PA levels. The control group received a single written information brochure with brief general PA recommendations. The intervention group received the PAM and was provided with web-based tailored PA advice (PAM COACH; www.pam.com) for a 3-month period. After registration on the PAM COACH website the user first answers 12 questions on perceived PA barriers, uploads his PAM score and then formulates an activity goal based on this score. This activity goal can be changed by the user throughout the intervention. If the user does not formulate a goal, a standard goal is set. On every subsequent login, the PAM COACH website presents the uploaded PAM scores and goals in orderly graphs per week or month. The uploaded PAM scores are automatically accompanied by a tailored PA advice on the computer screen as well as motivational tips (n=21) for increasing PA. The advice includes information on how to reach the PAM-goal, which is based on 1) user preferred activities (e.g. daily an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash) 2) user perceived PA barriers. Apart from the short feedback on the PAM COACH website, the users can easily monitor their progress in daily PA by reading directly their PAM score on the display of the PAM. The participants received written and verbal instructions and practical demonstrations on how to wear the PAM and how to use the PAM COACH website (i.e. set of a personal goal and favorite activities). Participants were instructed to register and upload PAM-data in the first week of the intervention, to check if the system worked properly. After that, the participant could make use of the PAM and PAM COACH website as much as they wanted. At all schools at least one computer with PAM software and access to the internet was available.

MEASUREMENTS

All measurements took place during school hours at the school at baseline and after three months intervention. To evaluate possible long-term effects the questionnaire was administered again five months after the end of the intervention. Gender, age and educational level were obtained at baseline. Educational level was categorized into low and high educational level. Low educational level comprised of vocational education. All other levels of education were defined as high educational level.

LEVEL OF PHYSICAL ACTIVITY

The activity questionnaire for adolescents & adults (AQuAA) was used to assess the amount of minutes per week spent on light (2–5 metabolic equivalents, MET), moderate (5–8 MET) and vigorous (>8 MET) intensity physical activities, as well as time spent sedentary (<2 MET), such as TV viewing and computer usage. The AQuAA refers to activities in the past week (seven day recall), which were divided in five categories 1) transport to school; 2) physical activities at school; 3) household chores; 4) leisure time activities, and 5) active sports.

DETERMINANTS OF PHYSICAL ACTIVITY

A short questionnaire was developed to assess behavioral intention to promote a physically active lifestyle; attitude, social influences, self-efficacy expectations and personal barriers towards sport, walking and biking, and reducing screenbehavior. For each determinant a selection of two or three relevant questions was made, based on previous studies.122-124,164 Answering formats were 5-point Likert scales (very low to very high). Per determinant, multiple items were converted into summary scores. Awareness of complying with the Public Health PA recommendations was assessed by self-report ‘On how many days of the week did you spent at least 60 minutes of moderate activity’. Subjects’ knowledge of the PA recommendation was tested by the question ‘How much time per day do you have to spend on physical activity to stay healthy?’ According to a method described by Ronda, respondents were allocated to four categories of awareness (under-estimators, over-estimators, realists adequate or realists inadequate), based on their self-rated compliance with the PA recommendations and the results of the PA questionnaire.15 For instance, respondents who did not meet the PA recommendations and reported to be at least 60 minutes moderately active on 7 days were classified as over-estimators. In the analyses, awareness was dichotomized in non-realists (under-estimators and over-estimators) and realists (realists adequate and realists inadequate). Participants were classified as complying with the recommendation when they reported at least 420 minutes (=7 days x 60 minutes) on moderate to vigorous intensity activity per week.

QUALITY OF LIFE

The KIDSCREEN-10 Index was used to assess quality of life. The KIDSCREEN is a health related quality of life-measure (HRQOL) and applicable for healthy children aged 8 to 17 years.180,181 The KIDSCREEN measures 10 HRQOL dimensions on a 5-point Likert scale. The KIDSCREEN-10 Index showed good internal consistency in our study (Cronbach’s alpha = 0.76) and good test-retest reliability (r = 0.76). A summary score below 38 (out of 50) indicates that the perceived quality of life is low.

AEROBIC FITNESS

A maximal aerobic running test, the 20-meter shuttle run test, was used to classify adolescents on maximal aerobic capacity. The test starts at a speed of 8.0 km/h, increasing each minute by 0.5 km/h (stage). To perform the test, the subject runs a 20-meter course back and forth. The highest completed stage was used in the analyses. The test has been shown to be a reliable and valid field test to estimate maximal aerobic capacity.129,131

ANTHROPOMETRICS

Standard procedures were used to measure body weight, body height, waist and hip circumference, and thickness of four skin folds (biceps, triceps, sub-scapular and supra-iliac).150
Before the baseline measurement, intra-rater and inter-rater reliability for all four skin folds were determined. Intra-rater reliability and inter-rater reliability (ICC) varied between 0.83 and 0.98. Body weight was measured in light clothing without shoes. Body mass index (BMI) was calculated by dividing the weight (in kilograms) by height square (in meters).

**PROCESS MEASURES**

After the 3-month intervention, PAM users were asked to evaluate
1) the PAM (i.e. appreciation of the PAM score, frequency of wearing the PAM),
2) the PAM COACH website (i.e. appreciation of website, use of activity goal and favorite activities), and
3) the tailored advice (i.e. reading and appreciation of the advice). The uploaded PAM scores and the login frequency to the PAM COACH website were registered for each participant in the intervention-group.

**DATA ANALYSES**

To compare baseline values, chi square test was used for gender, education and awareness distributions. Non-parametric testing (Mann-Whitney U-test) was used for PA data. Independent samples t-test was used to analyze all other demographic variables, determinants of PA, aerobic fitness and anthropometrics.

The effect of the intervention was estimated based on the intention-to-treat principle including all participants who had attended at least one follow-up measurement. Logistic regression analysis was used for the dichotomous outcome measure, awareness of meeting the PA recommendation (0= non-realists; 1=realists). For all other outcome measures, standard linear regression analysis was used to test the differences between intervention and control group at follow-up. The follow-up measurements were defined as dependent variable. Baseline values of the particular dependent variable were always included as covariate. The parameters of interest are the regression coefficients (β), indicating the effect of the intervention of interest compared to the control group. The analyses were checked for effect modification by gender (p-value<0.10). Additionally, we adjusted for program adherence by performing regression analyses among intervention participants including the login frequency. Analyses were performed using SPSS (version 14.0, SPSS Inc., Chicago, Illinois, USA).

**RESULTS**

**BASELINE CHARACTERISTICS**

Of the 145 invited, 87 (60% response rate) completed the baseline measurement and were then randomly assigned to either the intervention (n=41) or the control group (n=46). Based on the PA data of the two week monitor, the invited participants who did not participate in the intervention (n=58) had a significantly higher level of moderate intensity PA than participants in the intervention (median 473 vs 285 minutes per week, p=0.01). The flow of subjects through the RCT and the distribution of non-responders is shown in figure 1.

Mean age of the participants was 15.1 years. Participants were predominantly female (63%) and followed a high educational level (61%). The intervention group consisted of 15 boys and 26 girls. Since gender was an effect-modifier we separated the analyses for boys and girls. Table 1 shows baseline characteristics of the intervention and control group for boys and girls separately.

Table 2 and 3 show that boys of the intervention group were comparable with boys of the control group except for LPA (higher in intervention group; p=0.01) and attitude to reduce screenbehaviour (higher in control group; p=0.02). Girls of the intervention group were comparable with girls of the control group except for social influence of reducing screen behaviour (higher in control group; p=0.02) and quality of life (higher in intervention group; p=0.02).
Table 1. Baseline characteristics (mean ± SD or %) of PAM and control group for boys and girls.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Boys (n=32, 37%)</th>
<th>Girls (n=55, 63%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAM (n=15)</td>
<td>Control (n=17)</td>
</tr>
<tr>
<td></td>
<td>PAM (n=29)</td>
<td>Control (n=26)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>15.3 ± 1.1</td>
<td>14.8 ± 1.4</td>
</tr>
<tr>
<td>High education (%)</td>
<td>87</td>
<td>59</td>
</tr>
<tr>
<td>Familiar with PA recommendation (%)</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Compliance with PA recommendation (%)</td>
<td>93</td>
<td>86</td>
</tr>
</tbody>
</table>

Abbreviations: SD: standard deviation; PA: physical activity.

Table 2. Median physical activity scores (min week⁻¹) and sedentary time at baseline, and at 3 and 8-month follow-up for PAM and control group.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAM (median, IQR)</td>
<td>Control (median, IQR)</td>
</tr>
<tr>
<td>Sedentary time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>4332 (2360; 4950)</td>
<td>2640 (1450; 4151)</td>
</tr>
<tr>
<td>3 months</td>
<td>2600 (2237; 4363)</td>
<td>2678 (1904; 3772)</td>
</tr>
<tr>
<td>8 months</td>
<td>2915 (1879; 3881)</td>
<td>3175 (1691; 5494)</td>
</tr>
<tr>
<td>LPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>1375 (925; 2340)</td>
<td>565 (401; 900)</td>
</tr>
<tr>
<td>3 months</td>
<td>585 (375; 968)</td>
<td>555 (180; 1130)</td>
</tr>
<tr>
<td>8 months</td>
<td>968 (646; 1313)</td>
<td>618 (310; 2069)</td>
</tr>
<tr>
<td>MPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>780 (420; 1495)</td>
<td>930 (523; 1558)</td>
</tr>
<tr>
<td>3 months</td>
<td>430 (153; 700)</td>
<td>505 (319; 1301)</td>
</tr>
<tr>
<td>8 months</td>
<td>530 (133; 840)</td>
<td>615 (404; 1029)</td>
</tr>
<tr>
<td>VPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>180 (5, 600)</td>
<td>55 (0, 528)</td>
</tr>
<tr>
<td>3 months</td>
<td>50 (0, 345)</td>
<td>33 (0, 363)</td>
</tr>
<tr>
<td>8 months</td>
<td>233 (0, 453)</td>
<td>63 (0, 420)</td>
</tr>
<tr>
<td>MVPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>1380 (720; 1650)</td>
<td>1120 (553; 1993)</td>
</tr>
<tr>
<td>3 months</td>
<td>600 (272; 1060)</td>
<td>920 (449; 1425)</td>
</tr>
<tr>
<td>8 months</td>
<td>825 (485, 1065)</td>
<td>840 (546; 1334)</td>
</tr>
</tbody>
</table>

Notes: Difference in change between groups is adjusted for age and baseline value of outcome measure. Abbreviations: : IQR: interquartile range between 25th and 75th quartile; 95%CI: 95 percent confidence interval.
### Table 3. Baseline values (mean ± SD or %) and the mean difference in change of the secondary outcome measures after three months intervention between PAM and control group for boys and girls.

<table>
<thead>
<tr>
<th>Determinants of participating in Sports*</th>
<th>Boys Baseline</th>
<th>Boys Difference in change between groups</th>
<th>Girls Baseline</th>
<th>Girls Difference in change between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>4.30 ± 0.59</td>
<td>0.26 (-0.15; 0.69)</td>
<td>4.01 ± 0.81</td>
<td>0.41 ± 0.70</td>
</tr>
<tr>
<td>Social Influence</td>
<td>3.42 ± 0.60</td>
<td>-0.34 (-0.81; 0.13)</td>
<td>3.21 ± 0.67</td>
<td>0.32 ± 0.71</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>3.50 ± 0.76</td>
<td>0.43 (0.01; 0.87)</td>
<td>3.45 ± 0.73</td>
<td>0.57 ± 0.71</td>
</tr>
<tr>
<td>Intention</td>
<td>3.07 ± 1.10</td>
<td>0.01 (-0.76; 0.79)</td>
<td>3.75 ± 0.84</td>
<td>0.45 ± 0.98</td>
</tr>
<tr>
<td>Walking and biking*</td>
<td>3.76 ± 0.65</td>
<td>-0.03 (-0.54; 0.48)</td>
<td>3.83 ± 0.77</td>
<td>4.13 ± 0.62</td>
</tr>
<tr>
<td>Social Influence</td>
<td>3.60 ± 0.71</td>
<td>-0.16 (-0.72; 0.38)</td>
<td>3.35 ± 0.69</td>
<td>3.73 ± 0.62</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>4.05 ± 0.81</td>
<td>0.10 (-0.25; 0.46)</td>
<td>3.84 ± 0.75</td>
<td>3.93 ± 0.82</td>
</tr>
<tr>
<td>Intention</td>
<td>2.60 ± 1.18</td>
<td>-0.29 (-1.0; 0.47)</td>
<td>3.54 ± 0.76</td>
<td>3.10 ± 1.14</td>
</tr>
<tr>
<td>Reducing screen behaviour*</td>
<td>3.63 ± 0.74</td>
<td>0.09 (-0.56; 0.38)</td>
<td>3.80 ± 0.61</td>
<td>3.72 ± 0.66</td>
</tr>
<tr>
<td>Social Influence</td>
<td>2.51 ± 0.48</td>
<td>0.09 (-0.42; 0.61)</td>
<td>2.57 ± 0.75</td>
<td>2.71 ± 0.46</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>2.76 ± 0.56</td>
<td>0.01 (-0.57; 0.61)</td>
<td>3.03 ± 0.59</td>
<td>3.20 ± 0.50</td>
</tr>
<tr>
<td>Intention</td>
<td>2.20 ± 0.86</td>
<td>-0.14 (-1.0; 0.71)</td>
<td>2.38 ± 0.94</td>
<td>2.83 ± 1.03</td>
</tr>
<tr>
<td>Quality of life</td>
<td>RISKSCREEN score</td>
<td>-0.7 (-1.7; 3.2)</td>
<td>39.6 ± 3.39</td>
<td>38.6 ± 3.39</td>
</tr>
<tr>
<td>Aerobic fitness</td>
<td>Shuttle run test, laps</td>
<td>-1.7 (-3.3; 0.85)</td>
<td>6.1 ± 1.6</td>
<td>6.5 ± 1.7</td>
</tr>
<tr>
<td>Body composition</td>
<td>BMI (kg m⁻²)</td>
<td>19.9 ± 1.5</td>
<td>20.8 ± 2.5</td>
<td>20.1 ± 1.9</td>
</tr>
<tr>
<td>Sum of skin folds (mm)</td>
<td>33.7 ± 13.3</td>
<td>0.06 (-1.8; 1.9)</td>
<td>44.8 ± 10.6</td>
<td>43.3 ± 12.0</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>74.9 ± 4.5</td>
<td>1.6 (0.34; 3.6)</td>
<td>71.9 ± 7.3</td>
<td>69.4 ± 5.0</td>
</tr>
<tr>
<td>Waist-Hip ratio</td>
<td>0.84 ± 0.03</td>
<td>0.01 (-0.01; 0.04)</td>
<td>0.75 ± 0.05</td>
<td>0.75 ± 0.04</td>
</tr>
<tr>
<td>Awareness (%)**</td>
<td>OR (95% CI)</td>
<td>33 (0.87; 13.0)</td>
<td>50 (0.07; 2.36)</td>
<td>62 (0.19; 2.14)</td>
</tr>
<tr>
<td>Realist inadequate</td>
<td>33</td>
<td>0.87 (0.15; 4.8)</td>
<td>50 ± 0.62</td>
<td>3.3 (0.87; 13.0)</td>
</tr>
<tr>
<td>Under-estimator</td>
<td>7</td>
<td>27 ± 0.28</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Over-estimator</td>
<td>40</td>
<td>12 ± 0.32</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Realist adequate</td>
<td>20</td>
<td>11 ± 0.7</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

** § p < 0.05; * 5-point Likert scale. ** Awareness of compliance with PA recommendations. Note: Difference in change between groups is adjusted for age, and baseline value of outcome measure. Abbreviations: SD: standard deviation; PA: physical activity; IQR: interquartile range between 25th and 75th quartile; CI: confidence interval; Screen behaviour: watching less television and do less computer related work; BMI: body mass index; OR: Odds ratio.**
Some limitations of the study need to be addressed. First, we assessed daily PA and its determinants by self-report. Since self-reported PA is prone to misreporting, the results should be interpreted with caution. However, since we looked at changes in PA behavior at least the bias associated with systematic errors is cancelled out.

Second, although the study was focused on inactive adolescents, according to self report 90% of the boys and 67% of the girls already met the PA guideline at baseline. This may partly explain the differential effect in boys and girls. Since girls were less active at baseline, they may have been more motivated to become physically active. Also attitude and self-efficacy scores towards PA at baseline were relatively high, and thus difficult to improve. Therefore, the necessity for most of the participants, to become physically more active, may not have been very obvious.

Third, the practical advice given on the website was partly based on the objectively monitored PAM-score. Accelerometers worn at the hip are insensitive to certain types of movements, in particular non-ambulatory physical activities with arm and or limb movements, such as cycling and rowing.41,43 This limitation of the accelerometer may have declined the accuracy of the advice given at the PAM COACH website, particularly for subjects who cycle a lot, which is a common mode of transport among adolescents in the Netherlands.70 According to the AQuAA, the intervention group cycled 260 minutes per week (median). Although activities that are not accurately measured by the PAM can be included by hand on the PAM COACH website, a study has shown that recipients of negative or unexpected feedback responded by doubting the accuracy and credibility of the feedback information.171 This phenomenon may have discouraged our participants in uploading the PAM data.

Finally, the study suffered from insufficient power. There was a high non-response of 40% (n=58) of invited participants. During the RCT, another 22% (n=19) and 10% (n=9) were not available for measurements at three and eight months follow-up, respectively. Furthermore, we had to separate the analyses for gender because of effect-modification, which lowered the power as well.

The findings of our study suggest that promotion of PA by providing a personal activity monitor coupled to an online tailored PA advice has limited effect in boys but not in girls. The few visits to the website and the high drop-out during the intervention suggest that participants were not interested in our PA promotion intervention as presented. We propose developing a more tailored and sophisticated advice to improve the feasibility and attractivity of such an intervention, which should be evaluated in a larger population using both objective as well as subjective measures of PA.
CHAPTER 8

GENERAL DISCUSSION
An adequate level of physical activity (PA) is associated with considerable health benefits.\textsuperscript{1-3,5} In the Netherlands, 74\% of the adolescent population and almost half of the adult population do not meet the public health guidelines for PA.\textsuperscript{4,5,11} Inactive subjects are often not aware of the fact that they are insufficiently active. As a result they may not be motivated to change their PA behavior. Awareness of personal activity levels may play an important role in increasing PA.\textsuperscript{4,5,1,13,182} Since most adolescents and adults spend approximately half their waking hours at school or work, schools and worksites are viable settings to conduct PA promotion interventions.

To promote PA by raising awareness, PAM B.V. introduced in 2002 a commercially available innovative concept to promote PA. This concept consists of a physical activity monitor (PAM) as well as a specially designed website (PAM COACH system) which gives tailored PA advice, based on the amount of PA measured by the PAM and on personal preferences.

This thesis describes the evaluation of the PAM as an instrument to objectively monitor PA, and the results of randomized controlled trials on the feasibility and effectiveness of the PAM-concept as an intervention tool to promote PA among adolescents and young adults in a real-life setting. We hypothesized that the use of a PAM combined with the PAM COACH system would increase awareness, the behavioral determinants of PA and subsequently actual PA behavior, among relatively inactive people. In this final chapter the main findings are summarized and discussed. At the end of this chapter the results are placed into perspective and final conclusions are drawn. Furthermore, recommendations for future research and implications for Public Health are given. But first a look behind the scenes is provided to describe on the struggles encountered during the course of this project. We believe this is important information for future projects in this field and it also puts the results of the project into perspective.

BEHIND THE SCENES
THE INTRODUCTION OF A NOVELTY

On behalf of PAM B.V, Dr. E.P.N. Damen approached the VU University Medical Center (VUmc) and the National Institute for Public Health and the Environment (RIVM) to evaluate the feasibility and effectiveness of the PAM-concept in monitoring PA and to stimulate PA. Since this device was considered promising at that time, a grant application was submitted and granted in 2002 by the Netherlands Organization for Health Research and Development (ZonMw).

In 2003, the preparations for the PAM project started and the VUmc bought 150 PAMs against market price. The first PAM model (AM 100) proved to be unreliable and the manufacturer promised to provide an improved PAM model (AM 101) in March 2003. However, due to physical conditions at the factory in Malaysia (i.e. calibration difficulties in a high temperature environment, wrong data input of the data-processor), it was not clear when this improved PAM could be delivered to the VUmc. It was decided to postpone the RCT and upon arrival to first evaluate the validity and test-retest reliability of the improved version of the PAM. Fortunately, in this validity study the PAM showed comparable results as the widely used MTI Actigraph accelerometer for walking, stair walking and cycling in a laboratory setting (see Chapter 2). When by the end of October 2003, the first batch of 150 improved PAMs arrived, we tested this batch on a transformed laboratory shaker, and in a field study among adolescents at a secondary school and researchers at the university. This experiment proved that this batch of PAMs was also not reliable. After consultation with PAM B.V., it appeared that the memory settings of the “improved” device were improperly set at the factory. These PAMs were sent back to be fixed and were received again February 2004. In the succeeding reliability tests, the fixed PAMs showed sufficient quality for continuation of the project with this version of the PAM (model AM101). Altogether, mechanical problems of the PAM resulted in a delay of 11 months.

MAIN FINDINGS
THE VALIDITY AND RELIABILITY OF THE PA MEASURES

The PAM accelerometer

We studied reproducibility and concurrent validity of the PAM accelerometer among 32 Dutch adults. The test-retest reliability of the PAM was high. Concurrent validity of the PAM accelerometer compared to oxygen consumption was good for both treadmill walking and stair walking in a controlled situation. Based on these results, we concluded that in a controlled situation the PAM accelerometer is comparable with the MTI Actigraph accelerometer in terms of assessing bodily movements during treadmill walking and stair walking.

The Activity Questionnaire for Adolescents and Adults (AQuAA)

AQuAA self-reported time spent on moderate and vigorous intensity physical activity was always significantly higher than recorded by PAM-recorded time both among adolescents and adults. Among adolescents, we observed that the PAM yielded different and often opposite information on PA than the AQuAA among subgroups of gender, education and weight status. Among adults we found quite good agreement between both methods in subgroups of gender, education and weight status. Based on these findings, we concluded that there is a clear need for advanced and valid assessment of PA among adolescents.

THE PAM COMPARED WITH THE AQUAA

AQuAA self-reported time spent on moderate and vigorous intensity physical activity was always significantly higher than recorded by PAM-recorded time both among adolescents and adults. Among adolescents, we observed that the PAM yielded different and often opposite information on PA than the AQuAA among subgroups of gender, education and weight status. Among adults we found quite good agreement between both methods in subgroups of gender, education and weight status. Based on these findings, we concluded that there is a clear need for advanced and valid assessment of PA among adolescents.

FEASIBILITY AND EFFECTIVENESS OF THE PAM INTERVENTION

The feasibility of the PAM intervention was good among adults and limited among adolescents. The adherence to the intervention was low among adolescents and moderate to high among adults. Among healthy Dutch adolescents and adults, the PAM intervention was ineffective in improving awareness of personal PA level. The effects of the intervention on PA levels and its behavioral determinants were limited. Positive intervention effects on primary outcomes were observed among smaller subgroups of adolescents only. In adolescent girls, the PAM intervention was effective in increasing moderate intensity PA, while in boys sedentary time was reduced.
METHODOLOGICAL ISSUES
In addition to what is already discussed in the previous chapters, some important issues relevant for future studies will be discussed.

RECRUITMENT
In the recruitment process of worksites and schools we experienced a number of difficulties.

WORKSITE LEVEL
The occupational health and safety coordinators at the worksites were very enthusiastic about the project, but it was very difficult and time-consuming to get permission of the higher management to participate in the intervention. Of the 36 companies approached for our worksite-based intervention, only 8 (22%) were willing to participate. The most important reasons for non-participation were (a) the requested time for measurements during working hours and (b) the extra work of facilitating the measurements. This low participation rate among worksites is common for studies on health promotion in the Netherlands and may be due to the low economic growth in the European Union during the recruitment. Three other large Dutch worksite health promotion programs experienced similar recruitment problems and reported participation rates among worksites ranging from 9 to 18%. Next, it was difficult to recruit participants within the worksites. Within the eight participating companies, response rates ranged from 7 to 44%. Furthermore, after the two-week monitor period, it appeared to be difficult to keep the participants motivated for further participation in the PAM-project.

Thus, in the development and implementation phase of future worksite PA interventions more attention must be paid to the barriers perceived by the members of the higher management, the occupational health and safety coordinators and the participants themselves to participate in a PA intervention. For example by clearly communicating the potential benefits for the company considering participation in a PA promoting intervention. More success to involve companies in the study can be attained by screening the companies on forehand. For instance, companies with high sick leave could be more interested. Whereas, participants in reorganizing companies can be expected to be less motivated to participate in a PA intervention. By combining research with periodical check-ups by occupational health and safety coordinators, measurements can be performed in a convenient and time efficient way for both the company and the worker. Another strategy to improve worker enrolment and compliance in worksite PA interventions might be offering additional benefits through health insurance companies against reduced prices to all participants who successfully completed the PA intervention. Insurance companies could benefit by implementing cost-effective PA interventions in their offers, taking direct and indirect costs into account.

SCHOOL LEVEL
The participation rate of schools was much higher in our study. However, just before the start of the intervention, one school (>1200 students) teaching at a low educational level withdraw from participation issued by the higher management of the school. This resulted in a relative under-representation of adolescents with a low educational level in the study population and in a 50% (n=5) participation rate of schools. Also in this case the extra work related to the measurement (e.g. collecting informed consents, performing the shuttle run test during classes) was the reason for withdrawal.

In principle, students consented to participate in both the monitor as well as the intervention study. Participation in both study components was low. First, about 50% of all invited students participated in the two-week monitor period. Subsequently, the ‘inactive’ students were invited to enroll in the 3-months intervention. Forty percent of these ‘inactive’ students did not respond to this invitation. Furthermore, 22% of those who did participate dropped-out during the intervention period. Combining an automated PA intervention with more face-to-face contact to motivate adolescents might increase the participation rate. The face-to-face contact could be gradually reduced during the intervention when participants are familiarized with the intervention. Although this strategy demands more manpower, it might reach more adolescents.

OUTCOME MEASURES
THE PAM ACCELEROMETER AS A PA MONITOR INSTRUMENT
In terms of appreciation and acceptability to wearing an accelerometer, the PAM seems feasible for monitor purposes in large-scale studies among adolescents and adults. However, like comparable uni-axial accelerometers, the PAM poorly registers cycling, which especially among adolescents, is a common mode of transport in the Netherlands. Due to this limitation, daily PA is likely to be underestimated among a great part of the Dutch population. Furthermore, contrary to the MTI Actigraph, the PAM does not record detailed, minute-by-minute, activity data, which makes it impossible to do comprehensive data analyses like pattern recognition. This makes it also impossible to monitor compliance to wearing the device properly and regularly. These issues make the PAM device less attractive for monitoring of PA for scientific purposes on a population level, but the PAM could still be interesting for individual consumers to monitor their walking activities.

WORKING WITH THE PAM ACCELEROMETER
At the moment the PAM project started, the PAM-concept was a pioneer in the field of combining self-assessment of objective PA with a tailored PA advice on a personal website. However, being a pioneer has its pros and cons in executing an intervention. The PAM is an electronic device and sensitive for both internal and external influences. During the course of the study, we encountered several technical errors (e.g. changes in calibration settings), unintentional resetting of the device (e.g. due to dropping on the ground), damage by water (e.g. accidentally falling in the toilet) and empty batteries. Also abuse of the device was a common problem (e.g. swinging on a cord, throwing or playing baseball with it). These influences resulted in unexpected loss of data and it took a considerable amount of manpower trying to save these data. During the two week monitor period the display was switched off to avoid influencing the PA behavior of the participant, but the buttons on the device were still functioning. Although all participants were asked not to touch the buttons and battery, a number of adolescents found out that by pushing all buttons at the same time, the display lightened up for a second which caused the PAM to reset. This example illustrates that the results during monitoring are also subject to limitations of the PAM accelerometer (i.e. no ability to disable the buttons on the PAM). When the latter issue is only present in specific groups of age or gender, this could introduce a bias. However we have no data to verify this.
SELF-REPORT PA MEASURES

In general, PA questionnaires have low validity among adolescents and adults.\textsuperscript{32,34} This accounts for the AQuAA as well. In our trial we found two significant intervention effects, namely an increase in moderate intensity PA of almost 7 hours per week among girls and a reduction in sedentary behavior of 30 hours per week among boys. Given the fair reproducibility and the low validity of the questionnaire we may conclude that the intervention was successful in increasing moderate intensity PA and decreasing sedentary behavior. However, we should be careful with conclusions about the magnitude of the effects. The reliance on self-reported PA can be considered a shortcoming of our study. Therefore our findings should be confirmed in future studies using, for example, a combination of accurate self-report and objective measures of PA.

AWARENESS OF ONE’S PA LEVEL

In our study we assessed awareness of one’s PA level by allocating respondents to four categories of awareness. These categories were based on self-rated PA level as compared with the results of the more objective assessment from the PA questionnaire. Respondents who did not meet the PA recommendation, but who rated their activity levels as adequate were classified as over-estimators. Our interventions did not bring about a significant decrease in the rates of under- and over-estimators. This could partly be due to the limitations of self-report in assessing this concept (e.g. recall bias and social desirable answers).

INTERVENTION

THE PAM ACCELEROMETER AS A MOTIVATIONAL INSTRUMENT

The PAM accelerometer was used as a self-assessment and motivational tool that automatically generates tailored PA advice based on the PAM outcomes (e.g. “to reach your goal you should daily spend an extra 60 minutes walking, or 25 minutes running, or 20 minutes playing squash”). Additional testing (data not presented in this thesis) among 25 adults showed that 30 minutes of treadmill walking at 4.5 km/h (MPA) corresponded with 3500 step counts and a PAM score of 6, which is a distinct -psychological- difference in magnitude. Although the 24 hours PAM score theoretically ranges from 0-255, average PAM scores in our study were 27 among adolescents and 23 among adults. The PAM might be more successful as a motivational tool when the activity score would be more easily interpretable with a greater magnitude (e.g. range 1 to 50,000), such as step counts.

A recent study has shown that using a pedometer alone (without counseling) to set daily step counts resulted in increased PA in relatively inactive adolescent girls.\textsuperscript{35} Results of a systematic review in adults by Bravata\textsuperscript{36} suggested that the use of a pedometer is associated with significant increases in PA and that setting a step goal and the use of a step diary may be key motivational factors for increasing PA. Additionally, a study in adults using a pedometer in combination with web-based, step count feedback resulted in increased walking.\textsuperscript{37} Although the PAM-concept as presented contains similar elements (e.g. self-monitoring, goal setting and PA feedback), comprehensible devices like step counters seem to be more effective. Future research should focus on the feasibility and effectiveness of step counters in combination with automatically generated PA advice among inactive people.

THE PAM COACH WEBSITE

Due to financial and time restraints, we could only make small textual changes to the feedback module on the PAM COACH website. Therefore the presented information and functionalities on the website were sub-optimal. The results of the process evaluation showed that the design of the PAM COACH website was positively evaluated among both age-groups. However, usability tests on health promoting websites have shown that users often give high satisfaction ratings even when they experienced serious performance problems on the website.\textsuperscript{187,188} Users of websites spend a considerable amount of time scanning rather than reading information on websites.\textsuperscript{187,188} In our intervention we tailored the PA advice to a certain extent (i.e. based on activity scores and preferences). The PA advice was presented in such a way to facilitate both scanning and reading the written information. However 50% of the adolescents and 61% of the adults who read the PA advice did not find the PA advice appealing. From this we could conclude that the extent of tailoring was insufficient. The personal relevancy and attractiveness of the PA advice might be improved by targeting the PA advice for specific groups based on age, gender and socio-economic status.

Our study underlines the importance of involving end users in the development and improvement of a PA promoting website. To evaluate the quality of the website by applying usability testing the website could be improved.\textsuperscript{187,188} This can be done by, for example, focus group interviews with the target group, online surveys or by including interactive elements on the website like (we)blogs.\textsuperscript{187,188}

AWARENESS OF ONE’S PA LEVEL

Important factors to become aware of unhealthy behavior are knowledge, risk perceptions, and cues that prompt people to become aware.\textsuperscript{189,190} In our intervention, we provided the PAM as a cue to prompt participants of their physically inactive behavior, and provided information on how to reach the PA recommendation. However in the information on the website we emphasized the benefits of PA and not the risks of physical inactivity. Perhaps, insufficient PA was not perceived as a relevant risk, or the participants did not know the risks of physical inactivity.

Although individual level interventions have been shown effective at increasing PA, they only affect a small percentage of the population. Viral marketing could induce awareness about the risks of insufficient PA in larger populations. Viral marketing facilitates (e.g. by interactive games or video clips on the Internet) and encourages people to pass along a health promotion message via their own social networks. Appealing ‘viral’ messages for specific segments of a population (e.g. inactive people who may not intend to increase their PA) have high probability of being passed along rapidly and could reach segments that are normally difficult to reach. The use of an Internet viral marketing platform proved to be effective in bringing thousands of web users to discover and explore a Canadian governmental health promotion website.\textsuperscript{190} However, the effectiveness of viral marketing on behavioral change and its health improvement effect still needs to be studied.

Creating health promotion campaigns using the newest communication technologies could be more successful in raising awareness by emphasizing the benefits of PA or the health risks of physical inactivity. Especially among the younger population as they are more sensitive and susceptible for these innovative technologies. Although mass media campaigns targeting broader audiences are often too diffuse to successfully impact individual behavior change, combining different media and techniques could support the first steps.
ADHERENCE STRATEGY
To resemble a real-life situation, participants’ adherence to the intervention was not encouraged by more contact with the research staff or incremental incentives. Maybe as a consequence, adherence to wearing the PAM and visiting the PAM COACH website was surprisingly low among adolescents, with 44% not uploading their PAM scores to the PAM COACH. Yet, low adherence to Internet-delivered interventions has been seen also in other interventions among adolescents.191,192 Nevertheless, our minimal intervention brought about beneficial effects on moderate intensity PA in adolescent girls and sedentary behavior in boys. It is not clear what the optimal dose of contact during an intervention is. We assumed that wearing the PAM regularly and reading the accompanying PA advice once a week at the PAM COACH would be sufficient to bring about an effect on PA.

STUDY DESIGN
A strength of our research is the evaluation of a computer-tailored PA intervention in a randomized controlled design. However, in this design, it is impossible to distinguish between the effect of using the PAM and receiving advice by the PAM COACH. Sometimes, just providing objective measurement of PA level may influence one’s behavior just as well.193

SELECTION BIAS AND GENERALIZABILITY
We aimed to recruit a physically inactive population. At baseline, 70% of the adolescents and 67% of the adults met the Dutch PA recommendation according to self-report. The fact that participation was voluntary probably resulted in a selective study group of physically active participants. Improving PA levels in this group is more difficult. From other studies, it is known that the majority of participants in studies promoting PA is already more health conscious than the general population, is more interested in PA or has been physically active in the past.168,169,194 Possibly because of the relatively active study population, the effects of the intervention may have been underestimated.

CONCLUSIONS
Regular physical activity has considerable health benefits. Therefore, interventions aiming at promoting PA in inactive people are of great relevance. In this thesis, we evaluated the PAM-concept for monitoring and intervention purposes among relatively inactive adolescents and young adults.

Using the PAM as an instrument to monitor PA is feasible
Using the PAM accelerometer to monitor PA among adolescents and adults is feasible. However, we have serious questions regarding the validity of the single use of the PAM for assessing PA. Well-known limitations of accelerometers are underestimation of certain PAs (e.g. cycling, swimming) and decreasing compliance rates to wearing the device on the long term and no information on type and context of activities.

The PAM-concept did not improve (awareness of) PA level
The feasibility of using the PAM as a motivational instrument to promote PA was good among adults and limited among adolescents. Among adolescents, the PAM-concept showed some beneficial intervention effects among girls (increase in moderate intensity PA) and boys (decrease in sedentary time). The adherence to the intervention is the greatest concern. Among adults, no increase in awareness or PA was observed.

DIRECTIONS FOR FUTURE RESEARCH AND IMPLICATIONS FOR PUBLIC HEALTH
This research has produced valuable insights in implementing a PA intervention among adolescents and adults. Based on the results of this thesis the following directions for future research and implications for public health practice can be made:

Develop stand-alone PA monitors which provide simple PA advice
Our intervention showed some beneficial effects among adolescents while their exposure to the PA advice was low. However most of the adolescents reported to have worn the PAM regularly. Perhaps alternative methods providing easy and quick feedback on demand in which uploading is not necessary could improve accessibility and exposure to the PA advice. Therefore we advise to develop and evaluate PA promoting interventions using easy-to-use stand-alone devices. These devices should provide a comprehensible output on daily PA (e.g. step counts or minutes of activity) and also provide a simple automatically generated tailored PA advice. For this purpose, devices with services and features like mobile Internet connectivity, a general positioning system and an accelerometer incorporated (i.e. cell phones) could be used. In these evaluations, special attention should be given to feasibility, in terms of usage and price, among populations at high risk to become inactive (e.g. low socio-economic status).

Improve PA assessment methods in adolescents.
We found low agreement between the AQuAA and MTI Actigraph in assessing PA for both adults and adolescents. In addition, we observed considerable disagreement between the PAM and the AQuAA especially among adolescents. Therefore, the development of a valid and reliable PA measure among adults and especially among adolescents for large-scale epidemiological studies is needed. Online questionnaires using more visual presentation of physical activities during the day could be promising. By presenting timelines the respondent is able to set time anchor-points (i.e. school breaks for school days and walking home from school) and can set realistic pastimes. By playing videos of different activity intensities on the site, respondents can estimate their physical activity intensity by comparing their intensity with these videos. Synchronizing these self-reported data with accelerometer data could give a better representation of PA levels.

Focus on appropriate interactive development of PA interventions.
It is important to give more attention to the quality and appropriateness of the intervention mode and the intervention materials. The Internet is a frequently used medium among adolescents and adults, which makes it a convenient and flexible channel for delivering PA advice and support for inactive people. In our study, however, adolescents made little use of the PAM COACH, the PA advice was rated as not appealing and intervention effects were only found in subgroups. This raises questions about the use of solely Internet-based elements to promote PA targeting broader audiences. Through health marketing, a better understanding of the needs, preferences and behaviors of specific target groups such as age, gender and socio-economic status can be obtained. Among adolescents, the focus should be on how do they communicate?, which media do they use? and what do they do with health information?
Future research should focus on systematic evaluation of which subgroups of individuals should...
be matched to which type of intervention mode to optimize sustained PA behavior change. Last, the exploration of web-based tailored systems should be expanded to more diverse, underserved populations.

**Promote PA in daily settings**

In the Netherlands, adherence to the Public Health PA recommendation among adolescents and young adults is low. Self-monitoring of PA may overcome the misconception among inactive persons about their perceived PA behavior and might bring about awareness on PA and motivate them to be more active. Schools and worksites can play an important role in raising awareness of one’s PA level and the encouragement of inactive people to become more active. Teachers could, for example, include objective monitoring of PA by self-assessment (e.g. by pedometry, accelerometry or heart rate monitoring) in physical education at schools during classes and daily life. At the worksite, self-monitoring could be included by occupational health and safety coordinators in periodical preventive medical checks. These professionals can provide inactive workers with personally relevant information on how to improve PA and support them with the facilities (on site). This could increase PA levels and subsequently benefit health, productivity and the participation of workers.


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SUMMARY

Nowadays, the choice for a sedentary lifestyle seems in most cases more obvious and attractive than the choice for a physically active lifestyle. People in industrialized countries continue to reduce their energy expenditure in their daily life and at work. Especially during adolescence and young adulthood a steep decrease in daily physical activity (PA) is observed. A physically inactive lifestyle is associated with serious health risks such as cardiovascular disease, non-insulin dependent diabetes mellitus, depression, some types of cancer, and all-cause mortality. These health risks are significantly reduced by engaging in regular PA. Adolescents are recommended to perform at least moderate intensity PA with a minimum of one hour a day. Adults are advised to perform at least moderate intensity PA for a minimum of 30 minutes on at least five days of the week. Nevertheless, about three quarters of the Dutch adolescent population and almost half of the Dutch adult population still does not meet the above-mentioned Public Health guidelines for PA. Substantial improvement in public health is possible through encouragement of PA among inactive groups of the population. To achieve public health benefits, we are faced with the task to establish awareness of physical (in)activity and to encourage PA, but also to enable people to include more PA in their daily life.

In 2002 PAM B.V. introduced an innovative concept that is able to monitor PA objectively by an physical activity monitor (PAM) but can also be used to stimulate PA using an expert system on the Internet (PAM COACH system). The PAM is a small instrument (i.e. an accelerometer), easily attached to a belt and worn on the waist. The PAM measures vertical accelerations as a measure of daily PA on a continuous basis and stores these PA data in a memory, which can be uploaded to the PAM COACH via a docking station. The more intense PA is the higher the PA score stored in the PAM. On the other hand when there is no PA there will be no PA stored in the PAM. The PAM COACH shows accumulated PA data over a period of time and interactively formulates PA goals based on the actual PA level and personal preferences (e.g. daily an extra 60 minutes walking or 25 minutes running or 20 minutes playing squash). Users can thus follow and compare their progress with their personal PA goals and receive personally tailored PA advice in reaching their goals. If this PAM-concept works, it is an interesting tool for professionals working in the field of PA promotion.

This thesis describes the evaluation of the PAM as a monitoring instrument as well as the feasibility and effectiveness of the PAM-concept as a tool to promote PA among adolescents and young adults in a real-life setting.

PHYSICAL ACTIVITY MEASUREMENTS

Accurate assessment of PA is necessary not only to assess the prevalence of PA in the population, but also to evaluate associated health benefits and to evaluate the effectiveness of interventions aimed at promoting PA. Chapters 2 and 3 describe the measurement properties of the PA measures used in this thesis, i.e. the PAM accelerometer and the Activity Questionnaire for Adults and Adolescents (AQuAA), respectively.

In Chapter 2 we compared the PAM accelerometer with a commonly used accelerometer, i.e. the MTI Actigraph accelerometer, using oxygen consumption as a reference. Oxygen consumption is considered as the gold standard for the measurement of energy expenditure. The study was conducted in 32 adults performing two activities: treadmill walking and stair walking. For both treadmill walking and stair walking, the PAM performed comparable to the MTI Actigraph. We also compared all three instruments in their calculated energy expenditure during the same activities. This comparison showed that both the PAM and MTI Actigraph underestimated actual energy expenditure substantially during treadmill and stair walking. Finally, we observed that PAM data were highly reproducible, using a test on a laboratory shaker at 3 Hertz. We concluded that the PAM is a valid device for ranking subjects in energy expenditure.

A second PA measure used in this thesis is the AQuAA questionnaire. The AQuAA is designed to 1) discriminate between people with high and low levels of PA, and 2) to assess changes in PA and sedentary behavior over time. The AQuAA combines information on intensity, duration, and frequency of both PA as well as sedentary behavior and is applicable for adolescents and adults. In Chapter 3 we compared the time spent on PA as assessed by the AQuAA and the MTI Actigraph among adolescents and adults. Thirty-three adolescents and 47 adults wore the MTI Actigraph during two weeks, and completed the AQuAA at the end of the two week period. Low and non-significant correlations were observed between the AQuAA and the MTI Actigraph.

Time spent on all physical activities was significantly higher according to the questionnaire compared with the MTI Actigraph (except for light intensity activities in adolescents), while time spent on sedentary behaviors was significantly lower. Furthermore we studied the test-retest reproducibility of the AQuAA. Fifty-three adolescents and 58 adults completed the AQuAA twice, with an interval of two weeks. We observed fair to moderate reproducibility for the time spent on PA among adolescents and adults, except for time spent on vigorous PA in adults, which was poorly reproducible. In summary, we found this self-report PA questionnaire to be modestly reproducible, while the comparison with the accelerometer was poor.

THE STUDY DESIGN

Inactive people are often not aware of their inactivity. The use of the PAM in combination with PAM COACH offers the opportunity to provide advice based on the actual PA level in large groups of people. Providing web-based feedback on the actual PA level by the PAM may increase awareness and may stimulate a physically active lifestyle. Chapter 4 presents the design of the study together with an extensive description of the study background, objectives and execution of the project.

The study included two phases: in the first phase, PA was assessed by means of the PAM and AQuAA in a group of adolescents and young adults, mainly office workers (described in Chapter 5). Based on this measurement, inactive subjects were selected and invited to participate in a 3-month randomized controlled PA intervention study.

In the second phase of the study (i.e. the intervention), the feasibility and effectiveness of providing the PAM accelerometer in combination with the PAM COACH system was evaluated (described in Chapter 6 and 7).
Although, 65% of the adolescents in the intervention group reported to have worn the PAM. The results of chapter 7 show limited feasibility of the PAM intervention among adolescents. Attention should be given to the quality and appropriateness of the tailored advice among adults. The PAM-users read the PA advice, 39% of which found the advice appealing. We concluded that at least once during the intervention with a mean of almost once a week. Seventy-four percent of adolescents regularly. In addition, all adults uploaded their PAM scores to the PAM COACH website at least once. The few visits to the website and the high drop-out during the intervention suggested that adolescents were not interested in our PA promotion intervention as presented. We propose developing a more attractive activity monitor and a more individually tailored advice to improve feasibility of such an intervention among adolescents.

**EFFECTIVENESS OF THE PAM INTERVENTION**

The PAM intervention was ineffective in improving awareness of personal PA level among healthy Dutch adolescents and adults. The effects of the intervention on PA levels and the secondary outcomes were limited. Positive intervention effects on PA were observed among small subgroups of adolescents only. In adolescent girls, the PAM intervention was effective in increasing MPA with 411 minutes per week, while in boys sedentary time was reduced with 1801 minutes per week, five months after the end of the intervention. Furthermore we observed a tendency for body weight loss (1.6 kilograms) among low educated adults. More research in a larger population is necessary to investigate the effectiveness of this type of interventions among adolescents, people with overweight and a low socio-economic status.

**DISCUSSION OF THE RESULTS**

The last chapter (Chapter 8) provides a summary of the main findings of this thesis and discusses some methodological issues (e.g. recruitment, outcome measures, and generalizability) derived from this thesis. Furthermore, it discusses whether the single use of an accelerometer is adequate for assessing or stimulating PA among adolescents and which elements of the PAM-concept are promising for PA promotion. Finally, directions for future research and implications for public health are formulated.

**WE CAN CONCLUDE THAT**

- using the PAM accelerometer to monitor PA among adolescents and adults is feasible but,
- promotion of PA by providing the PAM coupled to the web-based tailored PA advice given at the PAM COACH website is ineffective among adolescents and adults.

Therefore, the interventions described in this thesis do not give cause for wider implementation of the PAM-concept in its current form among Dutch adolescents and adults.
In 2002 introduceerde PAM B.V. een nieuw concept dat lichamelijke activiteit objectief kan meten met de PAM bewegingsmeter (PAM) en door middel van een interactieve website (PAM COACH) ook mensen kan stimuleren om meer te gaan bewegen. De PAM is een klein apparaatje inactieve leefstijl een risicofactor is voor het ontwikkelen van ziektes als hart- en vaatziekten, diabetes type II, depressie en sommige vormen van kanker. Dit risico kan verkleind worden door regelmatig te bewegen. Zo wordt kinderen en adolescenten aangeraden om tenminste een uur per dag matig intensief te bewegen. Volwassenen wordt geadviseerd om minimaal 30 minuten per dag matig intensief te bewegen op tenminste 5 dagen van de week. Uit landelijke registraties blijkt dat driekwart van de Nederlandse adolescenten en bijna de helft van de Nederlandse volwassenen niet aan deze richtlijnen voldoet. Ook blijkt dat inactieve mensen zich vaak niet bewust zijn van hun inactiviteit. Het stimuleren van inactieve mensen om meer te bewegen zou veel winst voor de volksgezondheid kunnen opleveren. Om deze volksgezondheidswinst te realiseren zullen de inactieve personen zich eerst bewust moeten worden van hun inactiviteit; daarnaast zullen ze moeten worden aangemoedigd en ondersteund om voldoende te bewegen in het dagelijks leven.

In hoofdstuk 2 beschrijft de vergelijking van de PAM met de MTI Actigraph, laatstgenoemde is een andere veelgebruikte versnellingsmeter. In deze studie hebben 32 volwassenen op een loopband gewandeld en trap gelopen. De resultaten van de PAM waren vergelijkbaar met de MTI Actigraph, voor zowel wandelen als traplopen. Omdat zuurstofverbruik gezien wordt als een gouden standaard om energieverbruik te meten, is het berekende energieverbruik van de versnellingsmeters met het zuurstofverbruik vergeleken. Deze vergelijking liet zien dat zowel de PAM als de MTI Actigraph het energieverbruik voor wandelen op een loopband en traplopen aanzienlijk oververtegenwoordigen. Uit deze resultaten concluderen we dat de PAM een valide instrument is om mensen in meer en minder actieve groepen in te delen maar niet om het energieverbruik nauwkeurig te meten. Tenslotte lieten testen op een schudbak zien dat de PAM gegevens goed te reproduceren zijn.

In hoofdstuk 3 vergelijken we de tijd besteed aan lichamelijke activiteit zoals door de deelnemers gemeten door de PAM en de AQuAA (zie hoofdstuk 5). Aan de hand van deze metingen worden inactieve deelnemers geselecteerd en uitgenodigd om deel te nemen aan een gerandomiseerd gecontroleerde interventie van drie maanden (fase 2). In deze tweede fase 2. In deze tweede
fase werd geëvalueerd of het dragen van een PAM in combinatie met de PAM COACH website haalbaar en effectief is om adolescenten en volwassenen te stimuleren tot een lichamelijke actieve leefstijl (zie hoofdstuk 6 en 7).

**HET MONITOREN VAN LICHAMELIJKE ACTIVITEIT**

Hoofdstuk 5 beschrijft de eerste fase van het onderzoek waarin inzicht wordt gegeven in het gebruik van de PAM versnellingsmeter als instrument om lichamelijke activiteit te monitoren. In deze fase is het lichamelijk activiteiteniveau van 236 adolescenten (in de leeftijd 12 tot 18 jaar) en 301 volwassenen (in de leeftijd 22 tot 40 jaar) gedurende twee weken gemeten met de PAM en de AQuAA. Vervolgens hebben we het aantal minuten matig en zwaar intensieve lichamelijke activiteit gemeten door de PAM en AQuAA met elkaar vergeleken. Adolescenten rapporteerden veel meer minuten besteed te hebben aan matig en zwaar intensieve lichamelijke activiteit dan de PAM werd geregistreerd. Verder zagen we dat hoog opgeleide adolescenten meer tijd rapporteerden voor matig en zwaar intensieve activiteiten dan laag opgeleide adolescenten terwijl de PAM-registraties het tegenovergestelde lieten zien. Aangezien beide meetinstrumenten geen gouden standaard zijn voor het meten van lichamelijke activiteit is niet te zeggen welke instrument het nauwkeurigst meet.

Bij volwassenen waren kwamen beide instrumenten meer overeen wat betreft het meten van matig en zwaar intensieve activiteiten. Bij het meten van matig intensieve activiteit was het verschil tussen beide meetmethodes het grootst bij mannen met een laag opleidingsniveau. Bij het meten van zwaar intensieve activiteit was het verschil tussen beide meetmethodes het grootst bij volwassenen met en zonder overgewicht.

**DE PAM INTERVENTIE**

In fase twee van het project werden 102 volwassenen van 8 bedrijven en 87 adolescenten van 5 middelbare scholen willekeurig toegewezen aan de 3 maanden durende PAM interventie groep of de controle groep. De deelnemers in de interventiegroep kregen de beschikking over de PAM en toegang tot de PAM COACH website. De controle groep kreeg eenmalig een brochure met daarin de eerder genoemde beweegrichtlijnen. Het effect van de interventie is geëvalueerd op verschil in lichamelijk activiteitenniveau (primaire uitkomstmaat) en determinanten van lichamelijke activiteit, kwaliteit van leven, empowerment, uitnodigingsvermogen en lichaamscomposieteen (secundaire uitkomstmaten).

**HAALBAARDHEID VAN DE PAM INTERVENTIE**

De PAM interventie bleek goed toepasbaar in het dagelijks leven van volwassenen (hoofdstuk 6). 73% procent van de volwassenen in de interventiegroep gaf aan de PAM regelmatig te hebben gedragen. Alle volwassenen ‘uploadden’ de PAM score tenminste één keer tijdens de interventie naar de PAM COACH website, met een gemiddelde van bijna eens per week. Van de deelnemers in de interventiegroep heeft 74% hun beweegadvies gelezen, hiervan waarderde 39% het advies positief. We concluderen daarom dat er bij volwassenen meer aandacht moet worden besteed aan de kwaliteit van het advies.

De haalbaarheid van de interventie bij adolescenten was beperkt. Hoewel 65% van de adolescenten in de interventiegroep aangaf de PAM regelmatig te hebben gedragen, ‘uploadde’ slechts 56% zijn of haar PAM scores naar de PAM COACH website. De weinige bezoeken aan de website en hoge uitval van deelnemers tijdens de interventie suggereren dat de adolescenten niet geïnteresseerd waren in de aangeboden interventie. Het ontwikkelen van een beweegadvies beter toepasbaar in het dagelijks leven zou de haalbaarheid en aantrekkelijkheid van de interventie bij adolescenten mogelijk verbeteren.

**EFFECTIVITYTEIT VAN DE PAM INTERVENTIE**

De PAM interventie leidde niet tot een verbetering in bewustzijn van het persoonlijke lichamelijk activiteiteniveau bij gezonde Nederlandse adolescenten en volwassenen. De effecten van de interventie op het lichamelijk activiteiteniveau en de secundaire uitkomstmaten waren eveneens beperkt. Alleen bij kleine subgroepen van adolescenten hebben we enkele positieve interventie effecten gevonden. Bij meisjes nam de matig intensieve lichamelijke activiteit met 411 minuten per week toe en jongens rapporteerden minder tijd (1801 minuten per week) aan zittend gedrag. Bij laag opgeleide volwassenen zagen we na drie maanden interventie een gewichtsenters van 1,6 kilogram. Deze effecten zouden in grotere groepen bevestigd moeten worden.

**DISCUSSIJE VAN DE RESULTATEN**

Het laatste hoofdstuk (hoofdstuk 8) geeft een samenvatting van de belangrijkste bevindingen beschreven in dit proefschrift. Ook worden enkele methodologische aspecten van het onderzoek kritisch besproken waaronder de werving, uitkomstmaten en generaliseerbaarheid. Tenslotte, worden aanbevelingen voor toekomstig onderzoek gedaan en enkele mogelijke toepassingen voor de dagelijkse praktijk besproken.

**WE CONCLUDEREN DAT:**

- het gebruik van de PAM versnellingsmeter haalbaar is bij adolescenten en volwassenen, maar het dragen van de PAM in combinatie met het advies op maat op de PAM COACH website is niet effectief in het bevorderen van lichamelijke activiteit bij adolescenten en volwassenen. De resultaten, zoals beschreven in dit proefschrift, geven vooral nog geen aanleiding voor brede implementatie van het PAM-concept bij Nederlandse adolescenten en volwassenen.
Al giorno d’oggi, uno stile di vita sedentario costituisce spesso una scelta più ovvia e atraente rispetto alla pratica regolare di un’attività fisica (AF). Nei Paesi industrializzati, si osserva una riduzione costante del dispendio di energia da parte della popolazione, sia nel lavoro sia nello svolgimento delle normali attività quotidiane. Si assiste ad una diminuzione importante dell’AF soprattutto tra gli adolescenti e i giovani adulti. Uno stile di vita sedentario comporta gravi rischi per la salute, tutti potenzialmente letali, quali malattie cardiovascolari, coronaropatie, diabete mellito non insulino-dipendente, depressione, e alcuni tipi di tumore. Tali rischi possono essere ridotti con un’attività fisica regolare. Per gli adolescenti, è raccomandata la pratica di un’AF almeno moderata per un minimo di un’ora al giorno. Per gli adulti si consiglia invece la pratica di un’AF almeno moderata per un minimo di 30 minuti al giorno e di cinque giorni a settimana. Tuttavia, il 74% degli adolescenti olandesi e quasi la metà della popolazione olandese adulta non osservano tali linee guida. Incoraggiando la pratica dell’AF presso gruppi inattivi della popolazione, sarebbe possibile ottenere un miglioramento sostanziale della salute pubblica. Al fine di ottenere tali benefici, è in primo luogo necessario rendere consapevoli della propria (in)attività i gruppi interessati, per poi incoraggiare, ma anche facilitare una maggiore pratica dell’AF nella vita quotidiana della popolazione.

Nel 2002, PAM B.V. ha introdotto un concetto innovativo, capace di misurare l’AF in modo oggettivo (PAM), che può essere impiegato anche per stimolare l’AF per mezzo di un sistema esperto su Internet (PAM COACH system). PAM è piccolo strumento, facile da fissare ad una cintura e indossare a vita. Lo strumento misura l’accelerazione in modo continuo e registra i dati rilevati in una memoria, che può in seguito essere caricata sul PAM COACH attraverso una docking station. Il PAM COACH mostra i dati relativi all’attività fisica accumulati durante un certo periodo di tempo e formula in modo interattivo obiettivi basati sul reale livello di attività e sulle preferenze personali del soggetto (p. es. 60 minuti di cammino in più al giorno o 25 minuti di corsa o 20 minuti di squats). In tal modo, gli utenti possono seguire i propri progressi e confrontarli con gli obiettivi personali, oltre a ricevere consigli personalizzati per raggiungere tali obiettivi.

Se il concetto PAM risulterà efficace, esso potrebbe rappresentare uno strumento interessante per i professionisti impegnati a promuovere l’attività fisica.

Questa tesi tratta della valutazione del PAM quale strumento di misurazione dell’attività fisica, nonché della fattibilità e dell’efficacia del concetto PAM quale strumento per la promozione dell’AF tra gli adolescenti e i giovani adulti in situazioni reali.

**MISURAZIONE DELL’ATTIVITÀ FISICA**

Una valutazione accurata dell’AF è necessaria non solo per tracciare un quadro dell’attività fisica della popolazione, ma anche per valutare i vantaggi per la salute associati all’attività fisica e l’efficacia degli interventi volti a promuovere l’AF. Nei capitoli 2 e 3 vengono descritte le caratteristiche degli strumenti utilizzati per la misurazione dell’AF ai fini di questa tesi, ovvero il misuratore di accelerazione PAM e il Questionario sull’Attività per Adulti e Adolescenti (AQuAA).

Nel capitolo 2, l’accelerometro PAM viene messo a confronto con un misuratore di accelerazione tradizionale, l’MTI Actigraph, prendendo il consumo di ossigeno come criterio di riferimento. Lo studio è stato condotto su 32 adulti impegnati in due attività: cammino su tapis roulant e salire le scale. In entrambe le attività, il PAM ha dato risultati simili all’MTI Actigraph. Nel corso delle due attività, abbiamo inoltre confrontato il consumo di ossigeno con il dispendio di energia calcolato dagli strumenti. Da tale confronto è risultato che sia il PAM sia l’MTI Actigraph sottovalutano in modo sostanziale il consumo di energia, sia durante il cammino su tapis roulant, sia durante la salita delle scale. Abbiamo infine osservato l’elevata riproducibilità dei dati forniti dal PAM, usando un agitatore da laboratorio a 3 Hertz. Si può quindi concludere che il PAM costituisce un valido strumento per ordinare i soggetti in base al loro consumo di energia.

Il secondo strumento impiegato per misurare l’AF in questa tesi è il questionario AQuAA. L’AQuAA è strutturato in modo tale da 1) distinguere i soggetti con un livello elevato di AF dai soggetti con un livello ridotto di AF e 2) valutare i cambiamenti di AF e comportamento sedentario nel tempo. Nel AQuAA, vengono combinate informazioni relative a intensità, durata e frequenze delle attività sia fisiche sia sedentarie, ed esso è applicabile ad adolescenti e adulti. Nel capitolo 3 viene effettuato un confronto tra il tempo dedicato all’attività fisica riportato nel AQuAA e quello rilevato dal MTI Actigraph per periodo di due settemani. Abbiamo osservato una riproducibilità sufficiente/buona per il tempo dedicato a tutte le attività sia per gli adulti sia per gli adolescenti, ad eccezione del tempo trascorso in attività sedentarie che è invece risultato poco riproducibile. In sintesi, il questionario di auto-valutazione dell’AF è risultato modestamente riproducibile, mentre il confronto con il misuratore di accelerazione ha dato scarsi risultati.

**L’IMPIANTO DELLO STUDIO**

Accade di frequente che i soggetti non attivi non siano consapevoli della propria inattività. L’uso combinato del PAM e del PAM COACH offre l’opportunità di fornire consigli basati sul reale livello di attività di grandi gruppi della popolazione. Grazie al feedback interattivo sul reale livello di AF misurato dal PAM, la consapevolezza dei soggetti potrebbe aumentare e risultare in uno stile di vita più attivo. Nel capitolo 4 viene descritto l’impianto dello studio, unitamente ad una descrizione di informazioni preliminari, obiettivi e realizzazione del progetto. Lo studio è composto da due fasi: nella prima fase, l’AF di un gruppo di adolescenti e di giovani adulti, perlopiù con un lavoro sedentario, è misurata per mezzo del PAM e del AQuAA (vedere anche capitolo 5). In base ai risultati di tale misurazione, i soggetti inattivi sono stati selezionati ed invitati a partecipare ad uno studio di intervento sull’AF randomizzato e controllato della durata di tre mesi. Nella seconda fase dello studio, ovvero l’intervento, sono state valutate la fattibilità e l’efficacia del misuratore di accelerazione PAM in combinazione con il sistema PAM COACH (vedere anche i capitoli 6 e 7).
Il capitolo 5 esamina in dettaglio l’uso dell’accelerometro PAM per la misurazione dell’AF. In questo studio, i livelli di AF di 236 adolescenti (di età compresa tra i 12 e i 18 anni) e di 301 adulti (22-40 anni) sono stati misurati per due settimane. Tutti i partecipanti hanno indossato il PAM per un periodo di due settimane e completato il AQuAA al termine di tale periodo. Si è poi proceduto a mettere a confronto il tempo misurato in modo oggettivo (per mezzo del PAM) e il tempo così come esso è stato percepito dai soggetti (riportato nel AQuAA) dedicato all’attività fisica moderata (AFM) e intensa (AFI). Tale confronto è stato effettuato tra adolescenti e giovani adulti, in sottogruppi ricavati in base a sesso, livello di istruzione e peso. Si è notato come il tempo dedicato ad AFM e AFI percepito dai soggetti sia sempre superiore al tempo misurato oggettivamente dal PAM. Ciò è vero sia per gli adolescenti sia per gli adulti.

Il capitolo 6 mostra come l’intervento fosse facilmente applicabile alla vita reale degli adulti. Il 45% dei soggetti li ha riferito di aver indossato il PAM con frequenza, solo il 56% ha caricato almeno una volta i propri risultati PAM sul sito del PAM COACH. Il numero limitato di visite al sito internet e l’alta percentuale di abbandoni nel corso dello studio indicano uno scarso interesse da parte degli adulti all’intervento di promozione dell’AF così come esso è stato formulato. È quindi auspicabile la formulazione di consigli più adeguati per migliorare la fattibilità e l’attrattiva di un intervento di questo tipo tra gli adolescenti.

La fattibilità dell’intervento PAM ha consentito di evidenziare che l’utilizzo dell’accelerometro PAM per la misurazione dell’AF negli adolescenti è fattibile e prendere in esame alcune questioni metodologiche (selezione dei partecipanti allo studio, misurazione e generalizzabilità, ecc.) derivanti dalla presente tesi. Si discute inoltre se il solo uso di un accelerometro sia adeguato per la valutazione o lo stimolo dell’AF tra gli adolescenti, così come quali elementi del concetto PAM siano positivi ai fini della promozione dell’AF. Vengono infine formulati suggerimenti per ricerche future e possibili applicazioni pratiche dei risultati ottenuti.
Lieve Simoon,

wilt u het toch heerlijk om met jou te leven! Jouw vrolijkheid, liefde en enthousiasme kun ik gewoon niet missen. We hebben zo naar dit moment toegeleden en nu is het zover! We gaan samen aan een nieuwe fase in ons leven beginnen. Ik heb er heel veel zin in!

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Luuk en Wijnand,

ik ben erg blij dat jullie als ervaringsdeskundigen mij tegemoet zijn met de laatste hoopjes, het podium en...het rest.

Mijn grootste fans.

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Thank you / Bedankt

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Sander Maris Slootmaker was born on February 18th, 1979 in Zaandam, the Netherlands. In 1997 he completed secondary school (VWO) at the Pascal College in Zaandam. From 1997 until 2002 he studied ‘Human Nutrition and Public Health’ at Wageningen University. As part of that study he conducted a research project on the effects of a carbohydrate mix on the post-prandial blood glucose response and on appetite feelings in healthy subjects. Furthermore, he performed two internships at the Netherlands Institute for Health Promotion and Disease Prevention (Woerden, the Netherlands) and at Deakin University (Melbourne, Australia). In September 2002, he received his master’s degree in Human Nutrition.

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In 2003, he started his PhD project at the EMGO Institute, Department of Public and Occupational Health, of which the results are described in this thesis. He participated in the Postgraduate Epidemiology Program (POE) of VU University medical center and received his master’s degree in Epidemiology in 2006.

Following he worked as researcher at the Public Health Service Flevoland (GGD) in Almere and the Consumer Safety Institute in Amsterdam. To date, he works at the latter, where he finished the writings for his dissertation.
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Sander Slootmaker