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# interactive Journal of Medical Research

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A general medical journal, focusing on innovation in health and medical research  
Volume 3 (2014), Issue 4 ISSN: 1929-073X

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## Contents

### Original Papers

Perceived Reasons, Incentives, and Barriers to Physical Activity in Swedish Elderly Men ([e15](#))

Camilla Sjörö, Stephanie Bonn, Ylva Trolle Lagerros, Arvid Sjölander, Katarina Bälter. . . . . 2

Validity and Usability of Low-Cost Accelerometers for Internet-Based Self-Monitoring of Physical Activity  
in Patients With Chronic Obstructive Pulmonary Disease ([e14](#))

Martijn Vooijs, Laurence Alpay, Jiska Snoeck-Stroband, Thijs Beerthuizen, Petra Siemonsma, Jannie Abbink, Jacob Sont, Ton Rövekamp. . .  
1 2

Original Paper

# Perceived Reasons, Incentives, and Barriers to Physical Activity in Swedish Elderly Men

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## Abstract

**Background:** Knowledge about factors influencing physical activity behavior is needed in order to tailor physical activity interventions to the individual.

**Objective:** The aim of this study was to explore and describe the perceived reasons, barriers, and incentives to increased physical activity, as well as preferable activities, among elderly men in Sweden.

**Methods:** In total, 150 men aged 50-86 years responded to a Web-based questionnaire. Men who reported that they exercised sometimes or often received questions about reasons for physical activity (n=104), while men who reported that they never or seldom exercised received questions about barriers (n=46).

**Results:** The most frequent perceived reason for being physically active was health (82%), followed by enjoyment (45%), and a desire to lose/maintain weight (27%). Lack of interest/motivation was identified as the primary perceived barrier (17%). Incentives for increasing the level of activity included becoming more motivated and having a training partner. Walking was the most preferred activity.

**Conclusions:** Enjoyment and maintaining a good health were important reasons for engaging in physical activity among Swedish elderly men.

(*Interact J Med Res* 2014;3(4):e15) doi:[10.2196/ijmr.3191](https://doi.org/10.2196/ijmr.3191)

**KEYWORDS**

Internet; exercise; motivation; barrier; aged; men

## Introduction

Levels of physical activity decrease with age. This tendency is unfortunate since an active lifestyle offers many health benefits such as improvement of weight control, reduced risk of cardiovascular disease, some cancers, type 2 diabetes, osteoporosis, and falls as well as reduced symptoms of depression [1-3]. The World Health Organization rates physical inactivity as one of the leading risk factors of death in the world [3]. Among Swedish men aged 45-84 years, 36% report they are physically active less than 30 minutes per day [4]. To reverse

this negative trend, effective interventions promoting physical activity and preventing sedentary behavior in elderly are needed. Considering that men are under-represented in most physical activity intervention trials, there is a need to target this specific group [5,6].

Two previous review articles have summarized results from intervention studies on older adults [7,8]. One review suggested that an intervention program should include activities at a moderate intensity level that were convenient to engage in and reasonably inexpensive [7]. The other showed that the success of an intervention depended on motivation, social support,

health, beliefs, and education of participants [8]. Therefore, when designing an intervention aimed at increasing individuals' physical activity level, it is important to understand the reasons behind being physically active or not [9]. Physical activity interventions for older adults should include flexible programs tailored to the health status, preferences, and barriers of participants [7,8,10,11]. Among elderly in general, including both men and women, a wide range of barriers have been reported, including perceived poor health and physical disabilities, unsafe neighborhoods or no accessible physical activity environment, fear of injury, and lack of time [7,8,10,11]. Given that elderly highly respect their physician's advice, health care professionals have a unique and underutilized possibility to encourage physical activity [7,8, 10,11]. A belief in health benefits is a common reason to adopt an active lifestyle, and in order to sustain the behavior, knowledge about health benefits needs to be accompanied with feelings of enjoyment [10]. However, few studies have assessed perceived reasons and barriers among elderly men specifically.

This study assessed perceived reasons for being physically active among active elderly men, and perceived barriers for being physically active in insufficiently active men. A similar approach has been used in previous studies [12-14], enabling a more direct assessment of perceived reasons and barriers in these specific groups. Sending out a questionnaire to prospective participants in the initiation phase of an intervention could be a feasible way to gain knowledge on perceived reasons, incentives and barriers in the target group. The aim of the present study was to explore the perceptions of reasons, incentives, and barriers to physical activity among Swedish elderly men, as well as their preferable activities.

## Methods

### Study Design

In September 2012, 1348 men who had agreed to be contacted for future substudies after having enrolled in an earlier cohort study [15], were invited to participate in this study via email, of which 31 had an invalid email address. In total, 167 men agreed to participate and attended a meeting at the study center. All participants were given oral and written information about the study and gave their written informed consent, and the questionnaire was then sent out via email. In total, 164 men answered the questionnaire, of which 5 did not respond to the question about perceived reasons/barriers and were excluded from further analysis. Additionally, 9 men younger than 50 years of age were excluded. In total, 150 men were included in the analysis. The study was approved by the Regional Ethics Committee at Karolinska Institutet, Stockholm, Sweden.

### Questionnaire

The questionnaire included short, structured questions, predefined answers as well as skip and follow-up patterns. Individual user names and passwords served as identifiers. Year of birth, height, weight, education, and current occupation were self-reported in the questionnaire. The questions about perceived reasons and barriers were identified from previously validated scales, including the Decisional Balance measure for exercise (DB) [16,17], the Exercise Benefits/Barriers Scale (EBBS)

[18,19] and the Motivation for Physical Activity Measure (MPAM) [20,21]. In addition, we also included statements on rehabilitation and fear of injury. All statements were modified and combined in order for the questions to suit a Swedish population and contained a maximum of 10 statements in total to increase the user-friendliness and be compatible with the web design of the questionnaire.

Participants were initially asked to select an activity level and were categorized as physically active if they answered that they exercised *occasionally or often* and insufficiently active if they *never or seldom* exercised. Men answering *none of the alternatives apply to me* or that they *cannot exercise due to illness* did not receive a follow-up question about perceived reasons/barriers and were excluded. The physically active men received a follow-up question with ten predefined statements regarding reasons for exercising, and the insufficiently active men received a follow-up question with nine statements regarding barriers. Participants were asked to indicate on a 5-point scale to what extent they agreed to each statement. The statements were presented in random order to each respondent.

All participants responded to a question about incentives for increasing physical activity. They were asked to select all response alternatives that applied to them from eight predefined statements, or if they thought they were physically active enough, or did not know. All men (except those responding to being physically active enough) received a follow-up question where they selected which specific activities they would prefer to do from eight predefined alternatives.

### Statistical Analysis

Descriptive results are presented as means and standard deviations (SD) or numbers of participants (n) and percentages. To assess potential differences between physically active and insufficiently active participants, *t* test was used on continuous variables (age, weight, height, body mass index) and Fisher's exact test on categorical variables (occupation, education, body mass index, and incentives for increasing physical activity). These tests were used because they do not rely on asymptotic theory, which is an important advantage given our small sample size. Fisher's exact test was also used to assess potential differences between younger and older men regarding perceived reasons and barriers. The significance level was set to  $\alpha=.05$ . Analyses were performed using STATA 12 (STATA Corporation, College Station, TX, USA).

## Results

### Characteristics of Participants

Characteristics of the study participants are presented in Table 1. The mean age was 66.6 years (range 50 to 86). Almost 70% of the participants were physically active and received a follow-up question about perceived reasons to physical activity. The remaining 30% were classified as insufficiently active and received a follow-up question about perceived barriers.

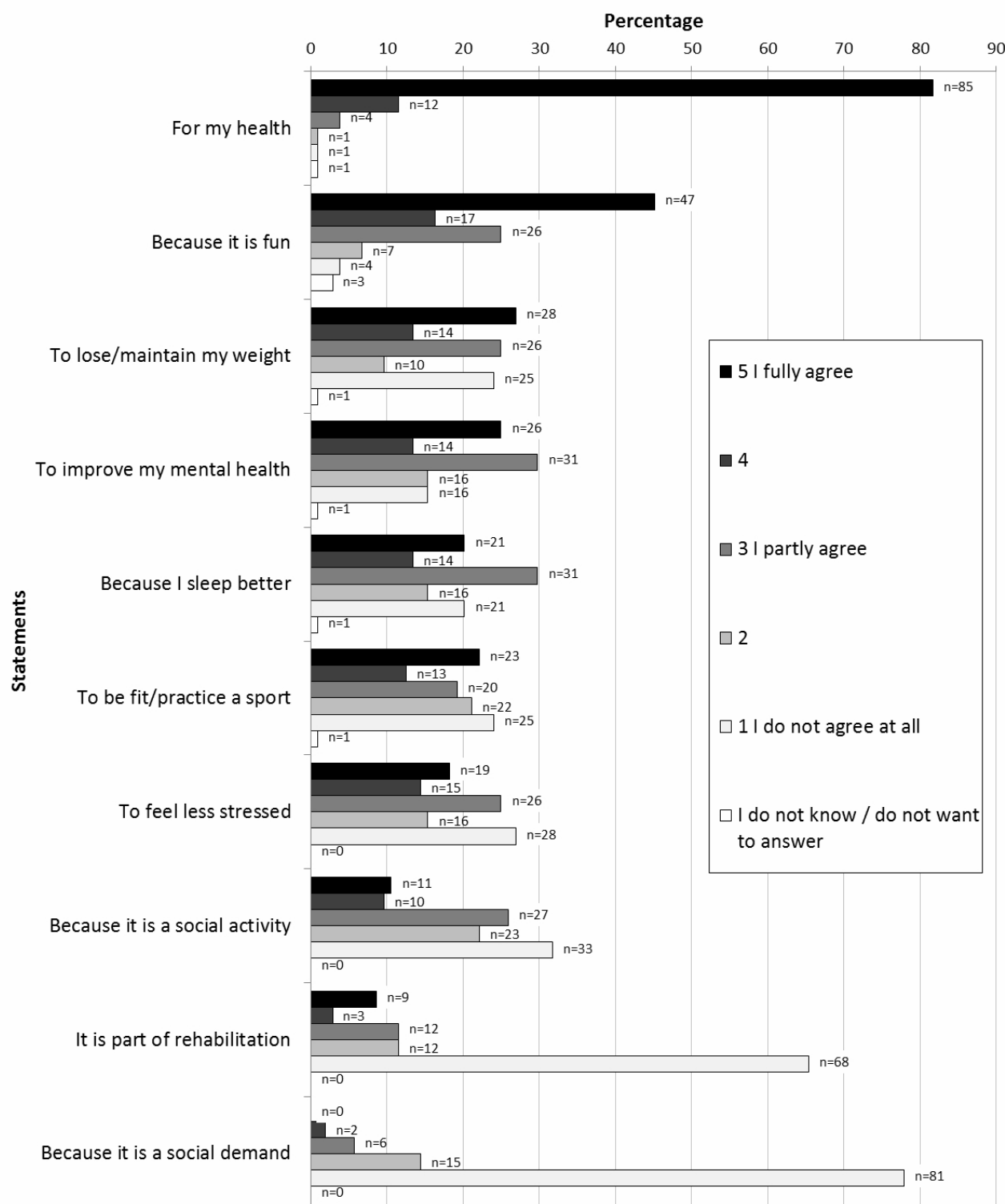
### Perceived Reasons for Exercise

Health factors was the most frequent perceived reason for physical activity (82%), followed by enjoyment (45%) and a

desire to lose/maintain weight (27%) (Figure 1). There was a statistically significant difference between men younger than 65 years and men older than 65 years with regards to reporting

of health and enjoyment as reasons. Younger men (aged 50-65) reported health factors and reducing stress levels more often than older men who reported enjoyment to a greater extent.

**Figure 1.** Identification of different perceived reasons for activity among physically active men (n=104).



**Table 1.** Characteristics of the study population.

Characteristics	All participants (n=150)		Physically active (n=104)		Insufficiently active (n=46)		P
	Mean (SD) or n (%)		Mean (SD) or n (%)		Mean (SD) or n (%)		
Age (years)	66.6	(7.5)	65.7	(7.0)	68.6	(8.2)	.03
Weight (kg)	82.4	(10.6)	81.3	(9.2)	84.8	(12.9)	.05
Height (cm)	179.1	(6.3)	179.3	(6.3)	178.6	(6.6)	.51
Body mass index (kg/m <sup>2</sup> )	25.6	(2.8)	25.3	(2.6)	26.5	(3.0)	.011
<b>Body mass index, kg/m<sup>2</sup></b>							.012
<25 (normal weight)	63	(42.0)	51	(49.0)	12	(26.1)	
≥25 (overweight and obese)	87	(58.0)	53	(51.0)	34	(73.9)	
<b>Occupation</b>							.21
Work	84	(56.0)	62	(59.6)	22	(47.8)	
Do not work/retired	66	(44.0)	42	(40.4)	24	(52.2)	
<b>Education, years</b>							.19
≤ 9	24	(16.0)	14	(13.5)	10	(21.7)	
>9-12	43	(28.7)	29	(27.9)	14	(30.4)	
>12	70	(46.7)	49	(47.1)	21	(45.7)	
Other	13	(8.7)	12	(11.5)	1	(2.2)	

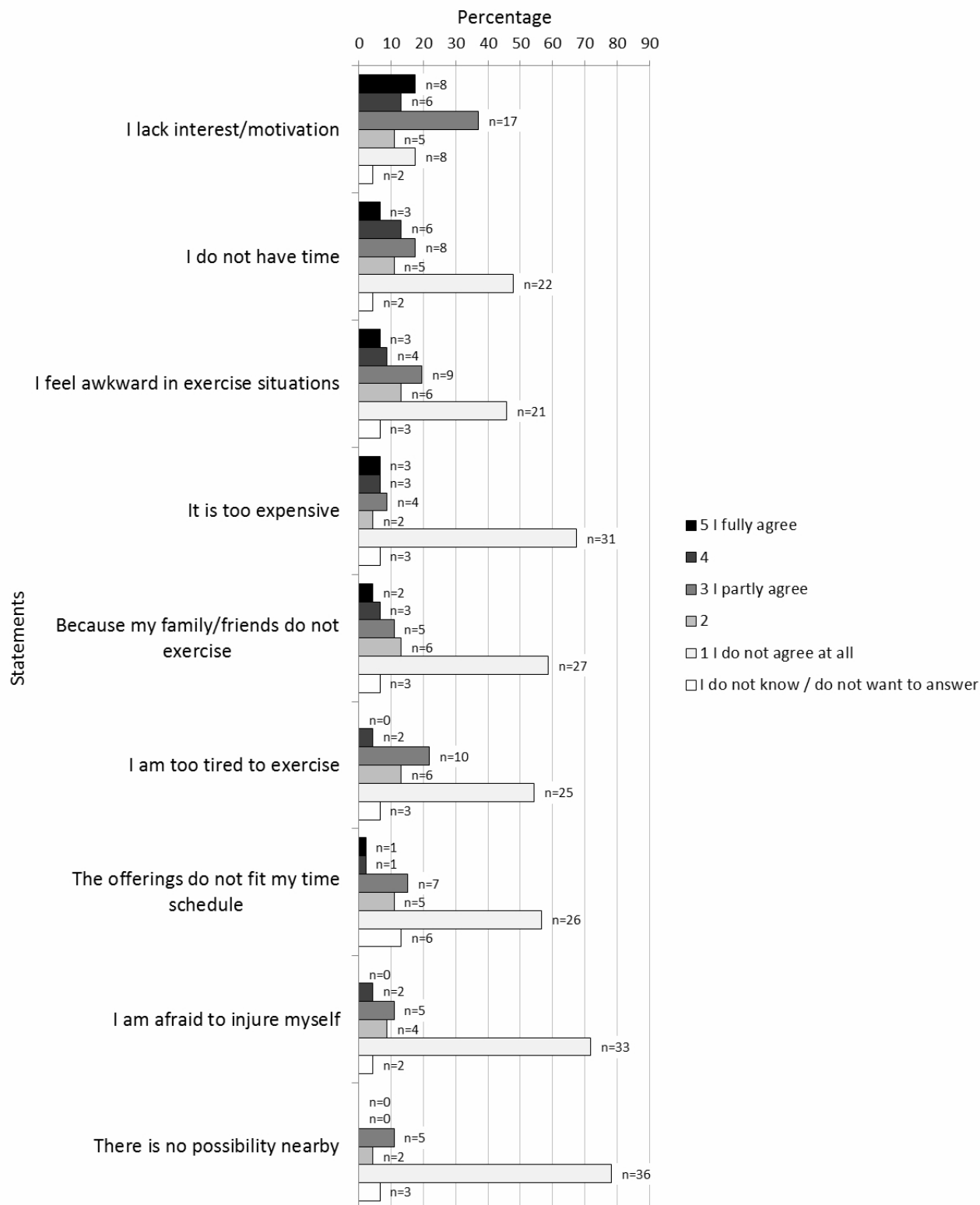
### Perceived Barriers for Exercise

Lack of interest/motivation was the most frequent perceived barrier, fully agreed by 17% of the insufficiently active men (Figure 2), followed by lack of time and feeling awkward. The majority of the insufficiently active participants did not agree with any of the remaining barriers. We did not detect any clear patterns when testing for differences between younger and older men with regards to perceived barriers of physical activity.

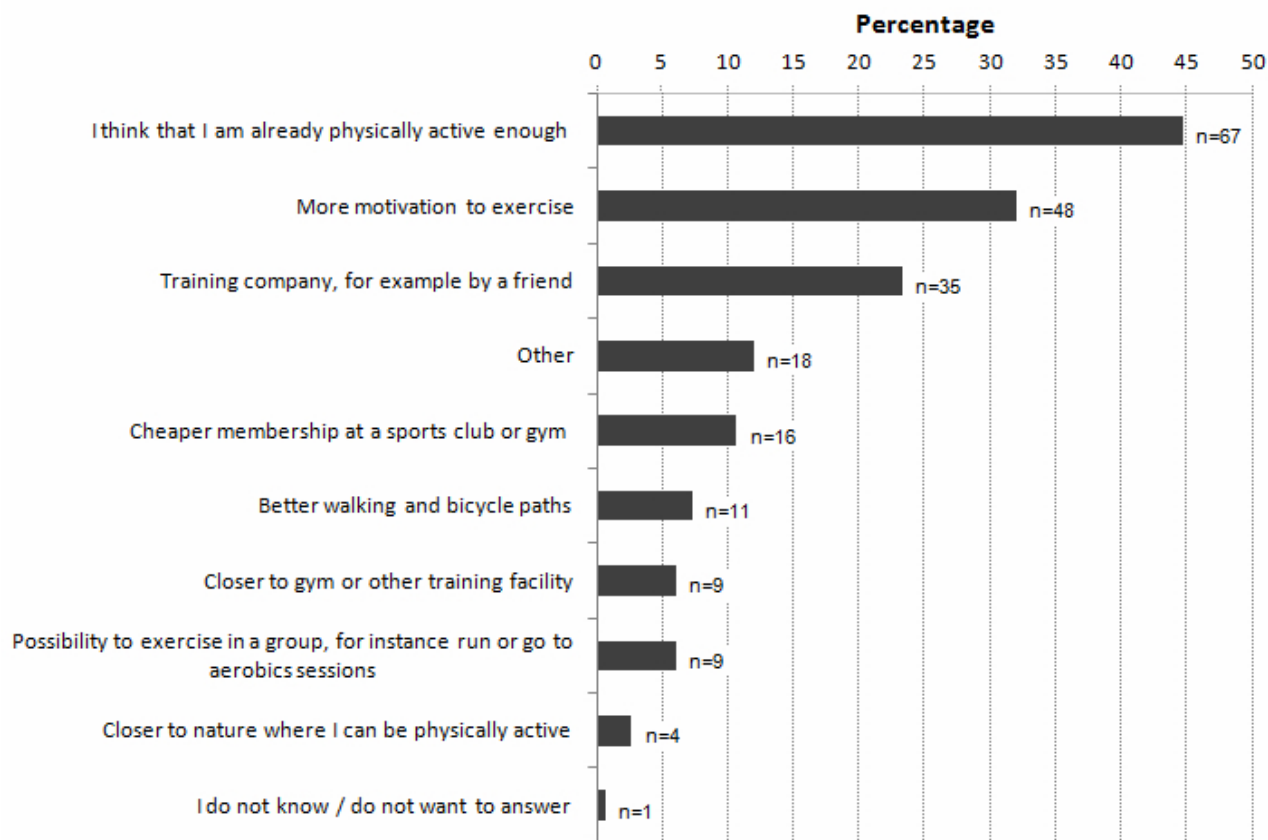
Nearly half of the men, 45%, reported that they thought they were physically active enough (48% of the active and 37% of the insufficiently active men). Incentives for increasing physical

activity among the remaining 55% included becoming more motivated, having a training partner, less expensive memberships at health clubs, and improved paths for walking or biking. Insufficiently active men reported becoming more motivated and having a training partner to a greater extent than physically active men (50 vs 24%, and 35 vs 18%, respectively) (Figure 3).

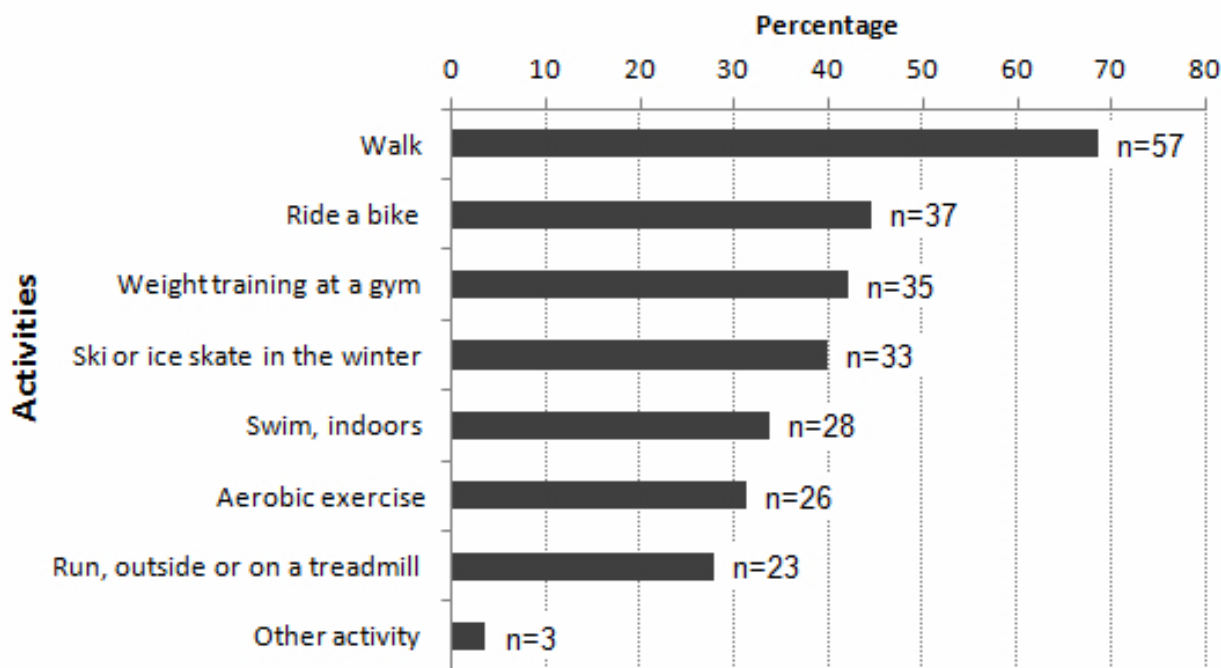
Men wanting to be more physically active received a follow-up question about preferred activities (Figure 4). The most preferred activities were walking, biking, weight training and skiing/skating.

**Figure 2.** Identification of different perceived barriers to physical activity among insufficiently active men (n=46).

**Figure 3.** Incentives that would make the participants more physically active (n=150). The 18 men answering “Other” received a follow-up question with the possibility to write down what would make them more physically active. Eight of the men answered less pain during exercise and six needed more leisure time.



**Figure 4.** Preferred activities among men that would like to be more physically active (n=83).





## Discussion

### Principal Findings

Health and enjoyment were the main perceived reasons for maintaining a physically active lifestyle among the elderly men in this study, while lack of interest was the most common perceived barrier. Being more motivated and having a training partner were considered factors that would increase the level of physical activity.

### Perceived Reasons for Exercise

We found that maintaining good health is the main perceived reason for being physically active which is in line with results from previous studies of middle-aged and older men and women [1,13,22,23]. Staying physically independent in daily life has commonly been shown to be important for elderly [24-26]. One could speculate that some of the participants in the present study had this in mind when rating high agreement with the health statement.

In contrast to our findings, several studies report social reasons to be the most important [27,28] or second most important [1,13] reason for middle-aged and older men and women encouraging physical activity. However, men were under-represented in most of the studies mentioned above. Only a small proportion of the physically active men in our study reported being active for social reasons. Nevertheless, our results indicated that training partners are an important incentive when encouraging the insufficiently active men to become more physically active.

Enjoying exercise was the second most frequent perceived reason for activity in our study, similar to results from a previous study of elderly Iranian men and women [28]. Lifelong participation and enjoyment of physical activity were one of the main reasons in a review of motivational factors for increased activity level after retirement [23]. According to another overview, motives of fun were more likely to be reported by younger individuals than older adults [26]. Nonetheless, our results add to the number of studies showing the crucial role of enjoyment for physical activity adherence and maintenance [12,20,29,30]. Further, weight management was a statement highly agreed with in this study, which has also been seen previously [22,24]. In order to maintain the activity needed for weight loss, it is important that overweight men find activities they enjoy [20,30].

### Perceived Barriers for Exercise

We found that lack of interest/motivation was the main barrier to exercise which is in agreement with results from previous studies [31,32]. In contrast, Smith et al [33] did not find a relation between lack of motivation and nonparticipation in physical activity among healthy Canadian men above the age of 60 years. As almost 90% of the participating men did not identify any barrier, the authors concluded that barriers were not the limiting factor for absence of physical activity. Rather, they speculate that the cause for inactivity may instead have been underlying chronic health conditions.

Half of the men in our study did not perceive lack of time as a barrier to physical activity. Previous studies on the matter have

been conflicting. While some studies have reported that time barriers decrease upon aging [11,26,34], a number of studies have found time to be the main barrier for both middle-aged and older men and women [13,23,35,36].

Overall, a majority of the insufficiently active men did not identify themselves with the predefined barrier statements, indicating there were other barriers of importance not included in the questionnaire. For example, a vast number of studies have claimed that health problems are the main barrier for engagement in physical activity among elderly [1,14,25,31]. Those men who were not able to be physically active due to illness were excluded in this study. Nevertheless, in retrospect, inclusion of a statement about health problems would have been appropriate. Another explanation could be the fact that one-third of the men categorized as insufficiently active thought that they already had enough physical activity. The finding could also be due to low awareness of underlying barriers among participants. Interestingly, several previous studies have reported that participants did not identify any, or only a few, barriers for engagement in physical activity [1,12,24,33].

### Strengths and Limitations

There are further limitations and strengths that merit discussion. Our findings should be interpreted with caution, given that we have carried out a relatively large number of tests. We have chosen not to make explicit corrections for multiple tests; since those corrections are not uncontroversial [37]. Data for the present study were collected in a group of elderly men living in Stockholm and volunteering to be part of the study, likely being more health conscious than the rest of the population. Almost 50% of our participants had an education longer than 12 years compared to 27% in the general Swedish population of elderly men [38]. In addition, 58% were overweight/obese compared to 65% of Swedish men aged 55-74 years in general [39]. As a result, it is not possible to extrapolate the results. Although we derived our statements about perceived reasons and barriers from established scales, we did not validate them in our population. It should be highlighted that the stated reasons for being active are perceived motivational constructs, and not necessarily what is truly regulating the men's behavior. We cannot rule out that important reasons and barriers may have been missed in the survey. Nonetheless, the Internet allowed both flexibility and privacy for the participants and provided a quick and convenient way to assess information about the target group.

### Practical Implications

The success of an intervention depends on a wide variety of factors affecting physical activity behavior [7,8,10,11]; therefore, interventions among elderly men should be tailored to each individual. Given that elderly are positive towards receiving advice from health care professionals [10], physicians, physiotherapists, and nurses could play a key role in encouraging an active lifestyle, as is done in Sweden where Physical activity on prescription is used [40,41]. Assessing reasons, incentives, and barriers for physical activity may be useful both for health care professionals and during an intervention, to individually tailor support. However, a major challenge is that many insufficiently active older adults overestimate their physical



activity behavior and believe they are active enough [10,42]. These participants need to be made aware of the insufficiency of their current activity level to respond effectively to the intervention [42]. A tailored program should include a variety of physical activity options, including activities performed with training partners. Already active participants could receive help in goal setting, monitoring of progress, and self-reinforcement, which increases the likelihood of sustained behavior [10].

## Conclusions

In the group of elderly men in Sweden who participated in this study, the main reasons for being physically active were enjoyment and maintaining good health. Incentives for increasing physical activity included having a training partner, and lack of interest/motivation was identified as the primary barrier. However, reasons, incentives, and barriers for physical activity differed significantly among the participants. As a result, we encourage the assessment of these ahead of an intervention study to enable individual tailoring.

## Acknowledgments

This work was supported by grants from the Swedish Research Council for Health, Working Life and Welfare. The authors thank Erica Björnström and Yanina Taynard for their invaluable contributions during the collection of data. We also thank those men who participated in this study.

## Conflicts of Interest

None declared.

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## Abbreviations

**DB:** Decisional Balance

**EBBS:** Exercise Benefits/Barriers Scale

**MPAM:** Motivation for Physical Activity Measure

*Edited by G Eysenbach; submitted 16.12.13; peer-reviewed by K Villaume, A Rebar; comments to author 28.04.14; revised version received 09.06.14; accepted 22.08.14; published 12.11.14.*

*Please cite as:*

*Sjörs C, Bonn SE, Trolle Lagerros Y, Sjölander A, Bälter K*

*Perceived Reasons, Incentives, and Barriers to Physical Activity in Swedish Elderly Men*

*Interact J Med Res 2014;3(4):e15*

*URL: <http://www.i-jmr.org/2014/4/e15/>*

*doi: [10.2196/ijmr.3191](https://doi.org/10.2196/ijmr.3191)*

*PMID: [25488655](https://pubmed.ncbi.nlm.nih.gov/25488655/)*

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Original Paper

# Validity and Usability of Low-Cost Accelerometers for Internet-Based Self-Monitoring of Physical Activity in Patients With Chronic Obstructive Pulmonary Disease

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## Abstract

**Background:** The importance of regular physical activity for patients with chronic obstructive pulmonary disease (COPD) is well-established. However, many patients do not meet the recommended daily amount. Accelerometers might provide patients with the information needed to increase physical activity in daily life.

**Objective:** Our objective was to assess the validity and usability of low-cost Internet-connected accelerometers. Furthermore we explored patients' preferences with regards to the presentation of and feedback on monitored physical activity.

**Methods:** To assess concurrent validity we conducted a field validation study with patients who wore two low-cost accelerometers, Fitbit and Physical Activity Monitor (PAM), at the same time along with a sophisticated multisensor accelerometer (SenseWear Armband) for 48 hours. Data on energy expenditure assessed from registrations from the two low-cost accelerometers were compared to the well validated SenseWear Armband which served as a reference criterion. Usability was examined in a cross-over study with patients who, in succession, wore the Fitbit and the PAM for 7 consecutive days and filled out a 16 item questionnaire with regards to the use of the corresponding device

**Results:** The agreement between energy expenditure (METs) from the SenseWear Armband with METs estimated by the Fitbit and PAM was good ( $r=.77$ ) and moderate ( $r=.41$ ), respectively. The regression model that was developed for the Fitbit explained 92% whereas the PAM-model could explain 89% of total variance in METs measured by the SenseWear. With regards to the usability, both the Fitbit and PAM were well rated on all items. There were no significant differences between the two devices.

**Conclusions:** The low-cost Fitbit and PAM are valid and usable devices to measure physical activity in patients with COPD. These devices may be useful in long-term interventions aiming at increasing physical activity levels in these patients.

(*Interact J Med Res* 2014;3(4):e14) doi:[10.2196/ijmr.3056](https://doi.org/10.2196/ijmr.3056)

**KEYWORDS**

accelerometers; activity monitoring; chronic obstructive pulmonary disease; validity; usability

## Introduction

In patients with chronic obstructive pulmonary disease (COPD) being physically active is considered of great importance in

adequate disease management. The importance of physical activity (PA) has been well-established in healthy people as it reduces the risk for chronic diseases, can favorably influence a broad range of physiological systems, and is associated with

significant improvements in overall psychological well-being [1]. The American College of Sports Medicine (ACSM) therefore recommends adults to perform moderate-intensity aerobic (endurance) physical activity for a minimum of thirty minutes on at least five days a week [2], which is an internationally accepted standard. In patients with COPD, being physically active is of even greater importance as regular PA and an active lifestyle were shown to be positively associated with higher exercise capacity [3]. In addition to these benefits, patients with COPD performing some level of regular PA have a lower risk of both COPD-related hospital admissions and mortality [4,5], than patients that are less physically active.

Despite the importance of PA in patients with COPD, it seems difficult for the majority of COPD patients to meet the recommended amount of PA [6-8]. Compared to healthy controls, patients with COPD have significantly reduced duration, intensity, and counts (number of movements per day) of PA [9]. Initially, the reduced level of physical activity in COPD was attributed to decreased exercise capacity. However, several studies [10,11] showed that improved exercise capacity after eight to twelve weeks of pulmonary rehabilitation did not lead to a more active lifestyle, implying that enhanced function in patients with COPD may not translate directly into behavioral change. However, after six months of pulmonary rehabilitation increased activity levels were demonstrated [10], suggesting that a longer period of support is needed to achieve a change in physical activity behavior. While pulmonary rehabilitation programs are elaborate and expensive, other methods of support including support with the aid of the Internet could be considered to help patients with COPD to enhance their PA.

Pedometers or accelerometers are capable of measuring PA. While the former only measures steps, the latter can measure a wider range of activities. Internet-based self-monitoring of PA using accelerometers might be suitable to provide patients with the information and feedback needed to change PA behavior. Sophisticated accelerometers have proven valid in patients with COPD [12,13], and are recommended to assess patients' PA for instance in the context of rehabilitation programs [14]. However, as these devices are costly and not intended for long-term Internet-based monitoring, alternatives need to be considered. For long-term Internet-based monitoring of PA at home, devices such as Fitbit or Physical Activity Monitor (PAM) are fairly inexpensive and commercially available.

In PRACTISS (Pulmonary RehAbilitation in COPD; Trial of sustained Self-management Support), a large randomized controlled trial, we are studying the one-year cost-effectiveness of an Internet-based self-management support system (PatientCoach) for patients with COPD. In this Internet-based self-management platform, ambulatory monitoring of physical activity plays an important part and in this context we evaluated accelerometers that met our predefined requirements for incorporation into PatientCoach.

To effectively support patients to self-manage their physical activities using a low-cost accelerometer for a longer period of time, certain prerequisites should be met. First of all, the device used should provide valid information about performed PA. Secondly, in order to wear a certain device for longer periods, it should be comfortable to wear, easy to use, intended users should be motivated to monitor their physical activity, and wearing the device should not arouse negative or unpleasant feelings.

We hypothesized that low-cost accelerometers meet these prerequisites. Therefore, we performed a validity study to assess the performance and a usability study to assess usability of such devices.

## Methods

### Patient Recruitment

Patients with COPD from the pulmonary rehabilitation department of the Rijnlands Rehabilitation Center in Leiden, the Netherlands, were prompted to take part in the studies. All patients contacted were involved in an outpatient, multidisciplinary pulmonary rehabilitation program between January and December 2012. In total, 25 patients participated: 9 in the validity study and 16 in the usability study. Patients participated in one of the studies within eight weeks from baseline pulmonary rehabilitation tests.

We collected patient characteristics such as age, gender, FEV<sub>1</sub>(L), post-bronchodilator FEV<sub>1</sub>(% predicted), exercise capacity measured by cardiopulmonary exercise testing (Watts) and peak VO<sub>2</sub>(ml/min) from the patient records. Patient characteristics are shown in Table 1.



**Table 1.** Patient characteristics.

Variable	Validity study	Usability study
	COPD-patients (n=9)	COPD-patients (n=16)
	mean (SD)	mean (SD)
Age in years	66.2 (4.4)	63.9 (10.0)
<b>Gender</b>		
Male	5	6
Female	4	10
BMI kg/m <sup>2</sup>	28.2 (5.4)	25.1 (5.7)
FEV <sub>1</sub> (L)	1.46 (0.74)	1.61 (0.63)
FEV <sub>1</sub> (%predicted)	51.1 (20.5)	57.4 (17.8)
FEV <sub>1</sub> /VC	0.39 (0.13)	0.46 (0.12)
MRC dyspnea (1-5)	3.0 (1.1)	2.3 (1.1)
<b>GOLD stage</b>		
I	1	2
II	4	9
III	3	4
IV	1	1
<b>GOLD patient group</b>		
A	1	3
B	1	6
C	0	1
D	7	6
<b>Smoking</b>		
Smokers	2	5
Nonsmokers	7	11
Pack-years (packs per day × years as a smoker)	38.9 (15.6)	35.5 (11.8)



## The Devices

As we intended to incorporate the low-cost accelerometer into PatientCoach, the accelerometers had to meet our predefined requirements. First, data synchronization should be performed via wireless connection. Second, to enable PatientCoach to communicate with the external database, an Application Programming Interface (API) should be available. Finally, the cost of the accelerometer should not exceed US \$150.

Two low-cost accelerometers (Table 2) met our predefined requirements and were hence evaluated, namely the Fitbit Ultra (Fitbit Inc, San Francisco, USA) and the Personal Activity Monitor AM300 (PAM BV Doorwerth, Netherlands).

Both the Fitbit and the PAM are three-axis accelerometers that measure motion patterns in three different planes. Besides the accelerometer, the Fitbit (FB) is also equipped with an altimeter to calculate the number of stairs climbed. The two low-cost accelerometers are both Internet-connected. This means that the data from these devices are uploaded to the Internet through wireless connection every time the device is in the vicinity of the included wireless receiver that is connected to a personal computer. The FB was worn in the right front trouser pocket, and the PAM on the waistband near the right hip as recommended by the manufacturers of the devices.

**Table 2.** Low-cost accelerometers.

Device	Technology	Output	Pricing
 Fitbit Ultra	3-axis accelerometer	Energy expenditure	US \$99
	Altimeter	Steps	
	Wireless synchronization to Internet database	Stairs climbed	
 PAM AM300	3-axis accelerometer wireless synchronization to Internet database	PAM points	US \$135

## Validity Study

In order to assess validity of both the FB and the PAM in daily living conditions we conducted a field validation study where we compared FB and PAM output with energy expenditure expressed as METs from the well-validated SenseWear Armband (SWA) from BodyMedia Inc. In order to assess the energy expenditure at home during 48 hours it was not an option to use indirect calorimetry as gold standard. Therefore, we used the validated SenseWear Armband as a criterion measure. In a one-hour standardized activity protocol, performed by COPD patients, the energy expenditure measured by the SWA previously showed a correlation of  $r=.76$  (95% CI .54-.91) when compared to indirect calorimetry [12]. When compared with doubly labeled water, the SWA showed an ICC of .76 (95% CI .47-.90) on total energy expenditure over a 14-day period in women with COPD [13].

After a physiotherapist at the rehabilitation center had properly attached the devices, each patient wore the two low-cost accelerometers as well as the SWA simultaneously for 2 consecutive days at home during the daytime. Patients were instructed to re-attach the devices in the exact same position they were attached at the rehabilitation centre when they had to detach the devices, for instance when changing clothes or after bathing or sleeping. After 2 days, patients returned to the rehabilitation centre where the devices were collected for analysis.

## Usability Study

For the assessment of usability of two low-cost accelerometers we used a cross-over design study where COPD patients, who had never used either device before, were asked to wear the FB and PAM each for 7 consecutive days during the daytime. Participants were instructed to attach the devices to their waistband close to the hip (PAM) or trouser pocket (FB), immediately after waking up and to continue to wear the device until going to sleep. Block-randomization determined the order in which activity monitors were worn (PAM-FB or FB-PAM). The devices' usability was measured by a self-developed 16-item usability questionnaire. After each 7-day period patients were asked to what extent they agreed with 16 statements regarding ease-of-use, usefulness, and acceptability of the corresponding accelerometer using a seven point Likert scale (1=disagree totally, 2=disagree strongly, 3=disagree slightly, 4=neutral, 5=agree slightly, 6=agree strongly, 7=agree totally). The questions were grouped in six domains which are presented in Table 3.

## Data Analysis

### Validity Study

Data, which were stored by the devices, were downloaded to a personal computer. Data from the devices included steps (FB), stairs (FB), energy expenditure (FB), and PAM-score (PAM). Metabolic equivalents (METs) are used as a means of expressing the intensity and energy expenditure of activities. By convention one MET represents an energy expenditure of one kilocalorie per kilogram of body mass per hour. The PAM-score is an index representing the ratio of energy expended through physical activity to resting metabolism. MET values from the SWA were used as a reference standard for energy expenditure and were compared with energy expenditure (FB) and PAM-score.

Using linear regression analysis with step counts and calories (FB) and PAM-score and METs/3hr from the SWA as independent variable we estimated METs for FB and PAM. PA was expressed as mean METs per three-hour periods, since these time periods were found to provide sufficient detail for feedback on PA. In an additional linear regression model we included a dummy variable for each patient in order to adjust METs for the individual patient level. This allows the analysis of the agreement of changes in METs in individual patients between FB, PAM, and SWA, respectively. The agreement of mean METs/3hr between the Internet-based accelerometers and the gold standard was analyzed by the intra-class correlation coefficient (ICC) and Bland-Altman plots. Energy expenditure from FB and PAM was derived for every patient and then plotted in an identity plot against METs from the SWA. Subsequently, correlations (Pearson Correlation Coefficient) between these parameters were calculated. In order to investigate the total variance potentially explained by the devices, their output information was inserted into linear regression models to investigate the total variance ( $R^2$ ) in METs explained by each device. Using linear regression modeling an algorithm to estimate METs was developed for FB and PAM, using the SWA as reference standard. Patient characteristics such as age, gender, FEV<sub>1</sub>(L), FEV<sub>1</sub>(% predicted), exercise capacity measured by cardiopulmonary exercise testing (Watts), and peak VO<sub>2</sub>(ml/min) were inserted into the model. The models were constructed using PAM-score from the PAM and steps and calories from the FB on a 3-hour basis. To correct for individual effects we constructed separate models which corrected for these effects.

### Usability Study

For each domain of questions an average score was calculated, and differences between average domain scores for FB and



PAM were compared using a paired  $t$  test. Furthermore, differences between males and females were investigated by calculating mean scores for women and men for each domain. Existing between-group differences were tested with an unpaired  $t$  test.

## Results

### Validity Study

Patient characteristics are shown in Table 1. Of the patients, 1 was excluded from the analysis due to technical problems, leaving 9 patients in the final analysis.

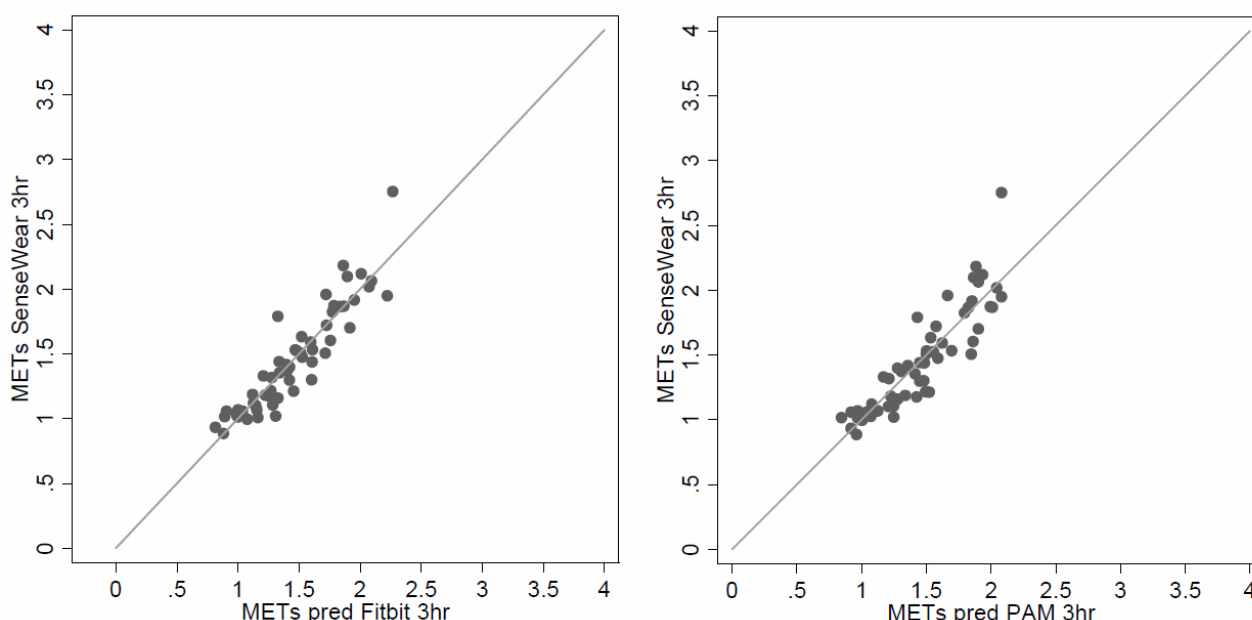
Analysis showed that correlations per individual between METs (SWA) and energy expenditure (FB) ranged from 0.47 to 0.88 with a mean of 0.77 (95% CI 0.66-0.87) and correlations between METs (SWA) and PAM score from 0.18 and 0.61 with a mean of 0.41 (95% CI 0.30-0.53). Figure 1 shows the identity plots of the agreement in estimated mean METs/3hr between

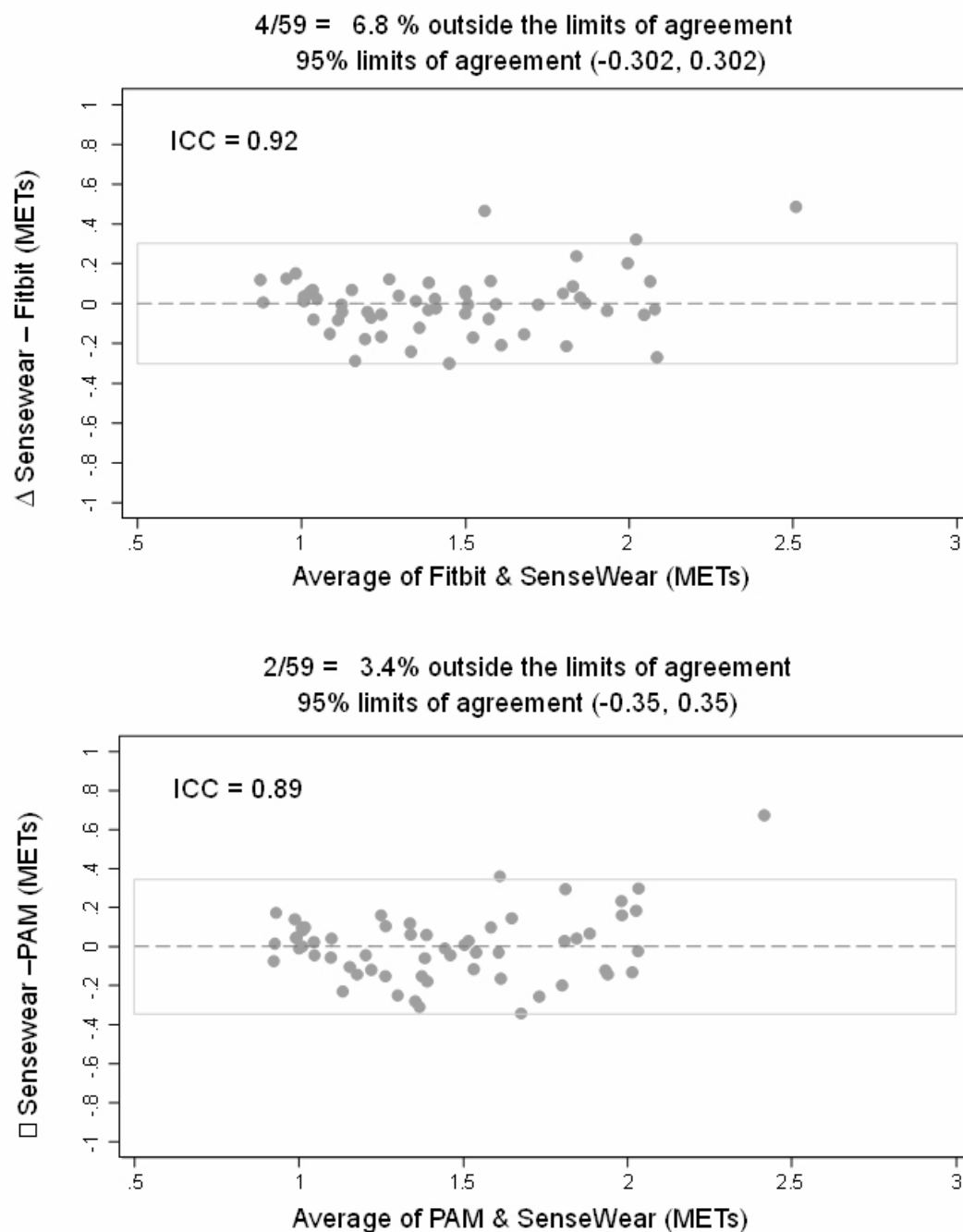
FB and PAM Internet accelerometers and SenseWear SWA, respectively. The regression model that was constructed to predict METs from FB output was able to explain 65% of total variance. After adding significant patient characteristics (length and sex) the explained variance improved to 67% and after correcting for patient effects to 85% (ICC= 0.92).

The model that was constructed to predict METs from PAM output was initially able to explain 53% of total variance which improved, after adding significant patient characteristics (length), to 70% and after correcting for patient effects to 81% (ICC= 0.89). The line of identity, indicating perfect agreement, has been drawn.

Figure 2 shows the Bland-Altman plots of the agreement in estimated mean METs/3hr between Fitbit and PAM Internet accelerometers and SenseWear Armband, respectively. There was good correlation between METs from SenseWear Armband, METs estimated by Fitbit (ICC=0.92), and PAM Internet accelerometers (ICC=0.89), respectively.

**Figure 1.** Identity plots of mean energy expenditure in METs/3 hours assessed by Fitbit and PAM compared to SenseWear.



**Figure 2.** Bland Altman Plots for agreement in mean energy expenditure in METs/3 hours.

### Usability Study

Patient characteristics are listed in [Table 1](#). Of the 19 patients who initially agreed to participate, 3 withdrew from the study. One patient found it psychologically too stressing to participate and two patients experienced problems installing the required software onto their computer, leaving 16 patients in the final analysis.

The different domains of usability and the results of the study are presented in [Table 3](#). Overall, we found no statistically significant difference between the devices in any domain ( $P > .10$ ) and overall usability score ( $P = .28$ ). Additional between-group analyses revealed no significant differences between men and women for the different domains.

**Table 3.** Domains and findings from the usability questionnaire.

Domain	Number of questions	Mean score (score range 1-7)		Difference ( <i>P</i> value)
		Fitbit	PAM	
Comfort in attaching and wearing the device (eg, easy to attach, comfortable to wear, wearing every day)	5	6.60	6.07	0.53 ( <i>P</i> =.15)
Opinions towards wearing the device (eg, pleasant to wear, frightening to wear, frustrating to wear)	4	5.95	5.34	0.61 ( <i>P</i> =.11)
Usefulness of activity monitoring (eg, useful to monitor activity, disadvantage to wear an activity monitor)	2	6.11	5.93	0.18 ( <i>P</i> =.46)
Intention/willingness to monitor activity (eg, willingness to use an activity monitor/recommend to others)	3	5.53	5.17	0.36 ( <i>P</i> =.23)
Technical aspects of the device (ie, it was easy to install the software)	1	4.85	4.95	0.10 ( <i>P</i> =.82)
General appearance of the device (ie, device has an attractive appearance)	1	5.62	5.08	0.54 ( <i>P</i> =.24)
Total usability score All questions	16	6.04	5.70	0.34 ( <i>P</i> =.28)

## Discussion

### Principal Results

The present study shows that the Fitbit and PAM low-cost Internet-connected accelerometers have good validity and usability properties in order to monitor physical activity in patients with COPD. The Fitbit and PAM were both found to be valid when compared to the SenseWear Armband. Usability of the devices was well-rated with little difference between the Fitbit and the PAM. No negative or unpleasant feelings (frightening, frustrating) towards wearing the devices were reported during the usability study. In fact, the devices were found pleasant to wear and patients showed willingness to wear such a device for extended periods of time (>12 weeks), implying that they can be used outside the formal care settings. For instance, for supporting self-management of physical activity.

Our work shows that monitoring of physical activity using valid, user-friendly, and affordable devices is possible. Furthermore, patients with COPD show willingness to use these kinds of devices and are interested in monitoring their own physical activity.

### Limitations

Our studies inevitably have limitations. Firstly, patients included in the studies were participating or had already recently participated in a respiratory rehabilitation program, composing a convenience sample of patients that may have been (more) motivated to be physically active. This might indicate that our results do not necessarily apply to patients who were not involved in respiratory rehabilitation. However, as rehabilitation should be considered for all patients with chronic respiratory

disease who have persistent symptoms, limited activity, and/or are unable to adjust to illness despite otherwise optimal medical management [15], our results might apply for COPD patients that have not yet been involved in rehabilitation, but are good candidates for doing so.

Secondly, the sample sizes for both studies are small and might not reflect COPD in general. However, we tried to use a representative sample of patients with COPD throughout both studies and as we took the frequency distribution of severity stages among patients with COPD in the Dutch population into account, it shows that in the usability study the frequency distribution of severity stages well represents the Dutch population: Gold I (13% vs 28%); Gold II (56% vs 54%); Gold III (25% vs 15%); and Gold IV (6% vs 3%). In the validity study the patients with very severe limitation are even a bit overrepresented (11% vs 3%) in the Dutch population.

Furthermore, we did not compare estimation of energy expenditure by the Fitbit and PAM with doubly-labeled water, as is recommended by the literature. Nevertheless, as the SenseWear was previously validated for estimating energy expenditure in patients with COPD [12,13,16-18], we found it justifiable to use it as a reference standard for comparison with new activity monitoring devices.

As we wanted to assess validity of the devices in real life conditions we did not control or directly influence the activities that were conducted by the patients. Variation in activity intensity was small in our sample, possibly limiting generalizability to activities with higher intensities. However, as our sample comprised patients from all four GOLD stages, the limited variation in exercise intensity might just reflect the actual activity patterns of this particular group.

The questionnaire used to measure usability has not been validated. However, it was based on the Unified Theory of Acceptance and Use of Technology (UTAUT) which was described in MIS Quarterly by Venkatesh et al [19], and the Post-Study System Usability Questionnaire (PSSUQ) by Lewis [20], where a seven-point Likert scale was used to assess acceptance and ease of use.

### Comparison to Related Work

Our studies focused on low-cost accelerometers for long-term self-management with regard to physical activity in persons with COPD. To our knowledge, the validity and usability of such devices have never been investigated in the targeted population. Previous studies have demonstrated validity of sophisticated activity monitoring devices [12,13,16-18], which, however, are not intended for long-term monitoring of PA and are fairly expensive. Low-cost pedometers have been successfully used in persons with COPD in the short-term (3 months) [21], and in children and adolescents [22]. The devices used in our studies provide information on both intensity and duration of activities rather than just reporting on step counts, thereby broadening the range of activities that can be conducted to increase physical activity.

Patients were positive regarding the usability of both devices. Both devices are quite small and discrete and were found comfortable to wear. Furthermore, patients showed interest in and willingness to monitor their PA. Finally, as there was no skin contact involved in wearing these devices, hygienic issues or skin reactions, which were found to be important issues in patients' acceptance of wearable sensors [23], were not present.

As mentioned before, Internet-based activity monitoring is incorporated in PatientCoach, an interactive web-application to support COPD patients' self-management. The evaluation of effectiveness of support by this system following a pulmonary rehabilitation program in COPD is currently ongoing in the PRACTISS trial (NTR 4009). In order to explore patients'

preferences with regards to the use of an activity monitor we organized a focus group at the Rijnlands Rehabilitation Centre with 5 COPD patients. Issues such as visual presentation of physical activity, feedback, and whether or not it was rewarding were addressed. Consistent with findings from van der Weegen et al [24], patients preferred simple and meaningful visualizations of activity data (active minutes per day). They also found it important to have an overview of activity results over several weeks or even months, and provided feedback should not be paternalistic.

### Implications

People with COPD can monitor their physical activity by using low cost Internet-based accelerometers. In the context of rehabilitation, this provides possibilities for COPD patients to monitor their PA between consultations, especially for gaining insight into any change and fluctuation. These can then be discussed with health care professionals (e.g. physician, physical therapist or specialized nurse) during a face-to-face consultation. These low-cost devices are also relevant to help patients monitor their PA after a rehabilitation treatment, knowing that PA tends to decrease during the post-rehabilitation period.

The results from our studies add knowledge that can be used for enhancing self-management of COPD patients, specifically regarding physical activity.

### Conclusions

Low cost Internet-based accelerometers can provide valid and useful estimates of within-person differences in metabolic equivalent level over three-hour periods in patients with COPD. These devices could provide information and feedback on longer-term PA in free-living conditions, and they are both user-friendly according to these mostly older patients. In the future, these devices may be useful in interventions aiming to increase physical activity levels by providing information and feedback on physical activity in patients with COPD.

### Acknowledgments

The authors would like to thank all the COPD patients who participated in the studies, Ad Kaptein, Julia Koopmans and Niels Chavannes for their helpful comments and our TNO colleague Yvonne Janssen who conducted the focus group. Furthermore we would like to thank Erik Damen (PAM BV, the Netherlands) for providing us with the PAM AM300 devices.

### Conflicts of Interest

None declared.

### Multimedia Appendix 1

Usability and ease of use questionnaire.

[PDF File (Adobe PDF File), 16KB - [ijmr\\_v3i4e14\\_app1.pdf](#)]

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## Abbreviations

**ACSM:** American College of Sports Medicine

**API:** application programming interface

**BMI:** body mass index

**COPD:** chronic obstructive pulmonary disease

**FB:** Fitbit

**FEV1:** Forced Expiration Volume in 1 second

**GOLD:** Global initiative for chronic Obstructive Lung Disease

**ICC:** intraclass correlation coefficient

**MET:** metabolic equivalent

**MRC:** Medical Research Council

**NTR:** Netherlands Trial Register

**PA:** physical activity

**PAM:** physical activity monitor

**PRACTISS:** Pulmonary RehAbilitation in COPD; Trial of sustained Self-management Support

**PSSUQ:** post-study system usability questionnaire

**SWA:** Sensewear Armband

**UTAUT:** Unified Theory of Acceptance and Use of Technology

*Edited by G Eysenbach; submitted 12.11.13; peer-reviewed by M Spruit, M Moy, A Holzinger; comments to author 09.01.14; revised version received 22.03.14; accepted 04.08.14; published 27.10.14.*

*Please cite as:*

*Vooijs M, Alpay LL, Snoeck-Stroband JB, Beerthuisen T, Siemonsma PC, Abbink JJ, Sont JK, Rövekamp TA*

*Validity and Usability of Low-Cost Accelerometers for Internet-Based Self-Monitoring of Physical Activity in Patients With Chronic Obstructive Pulmonary Disease*

*Interact J Med Res* 2014;3(4):e14

URL: <http://www.i-jmr.org/2014/4/e14/>

doi: [10.2196/ijmr.3056](https://doi.org/10.2196/ijmr.3056)

PMID: [25347989](https://pubmed.ncbi.nlm.nih.gov/25347989/)

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JMIR Publications  
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