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SHORT COMMUNICATION

A pilot study of an Internet walking program and pedometer in COPD☆

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Summary
Background: Higher levels of physical activity are associated with better functional status, fewer hospital admissions, and lower mortality. In this pilot study, we examined the feasibility and safety of a novel program that combines a pedometer with a website to increase walking.
Methods: 27 persons with stable COPD wore the Omron HJ-720ITC pedometer and used the website for 90 days. They uploaded step-count data to the study server using their home computer and received an email each week with their individualized step-count goal. The website provided step-count feedback, education, and motivational content. Subjects participated in a monthly semi-structured interview by telephone. Subjects reported changes in medical condition by telephone or on the website. Paired *T*-tests assessed change in daily step counts.
Results: Subjects were males, mean age 72 ± 8 years, with moderate COPD, FEV_1 1.57 ± 0.48 L (55 ± 16% predicted). 87% and 65% reported no problems using the pedometer and website,

Abbreviations: COPD, chronic obstructive pulmonary disease; ESC, every step counts; Ex-SRES, exercise self-regulatory efficacy scale; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; MMRC, Modified Medical Research Council; PDA, personal digital assistant; SF-36, Short Form-36; SUH, stepping up to health.

☆ The work was performed at VA Boston Healthcare System and the University of Michigan Medical School.

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respectively. At month 3, 96% reported it was true that they knew their step count goal every day, and 52% reported that they were able to reach their goal. 95% of participants said they would recommend the walking program to another person with COPD. Eight subjects experienced breathing problems unrelated to the intervention. In 24 subjects with step counts at baseline and month 3, there was a significant increase of 1263 steps per day (approximately 1.0 km), $p = 0.0054$.

Conclusions: The use of a website and pedometer was feasible and safe, and persons increased their daily walking.

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Introduction

A growing body of knowledge has identified physical activity as a modifiable factor that may impact morbidity and mortality in persons with COPD. Higher levels of physical activity are associated with better functional status, fewer hospital admissions, and lower mortality,[1–4] resulting in the recommendation that "it should be considered a high priority for future COPD therapies to ameliorate inactivity.[5,6]"

Current therapies to increase physical activity in COPD have significant limitations. Pulmonary rehabilitation programs clearly improve exercise capacity in persons with COPD.[6] However, they are based at large medical centers or outpatient medical offices, require specialized resources, and require patients to travel 2–3 times each week for 9–12 weeks.[6] It is also unclear whether the improvements in exercise capacity, measured by episodic in-clinic tests, translate into increases in daily physical activities such as walking.[7] Current home-based exercise programs are limited by inability to accurately monitor exercise, depending on self-report and need for phone calls or home visits.[8–14] Furthermore, they have lacked mechanisms for iterative feedback and dynamic, individualized goal setting.

Walking is a form of physical activity that most people can do; it is generally a safe, convenient, and inexpensive way to increase physical activity. Steps per day is a simple metric of physical activity that is meaningful to persons trying to increase their activity.[15] In COPD, a higher daily step count is associated with lower mortality, independent of pulmonary function.[4] Although many pedometer-based programs have been studied to increase walking in healthy adults,[16,17] only a few studies have used pedometers to report changes in daily step counts in COPD.[15,18–20]

We previously described a novel exercise program called Stepping Up to Health (SUH) that combined the use of the Omron HJ-720ITC pedometer with a website to promote walking in persons with cardiovascular disease risk factors.[21,22] The program accurately monitors walking with a pedometer, provides iterative feedback and goals in steps per day, and delivers education and motivation online. We have extended SUH to include website content specific for persons with COPD. This adapted walking program is called Every Step Counts (ESC) for Lung Health. In this pilot study, we examined the use of ESC in persons with COPD. Our specific aims were to (1) obtain feedback from participants, (2) assess safety and feasibility, and (3) assess change in daily step counts.

Methods

Study population

From February to November 2011, we enrolled participants with COPD, defined as age over 40 years, forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC) <0.70 or emphysema on chest computed tomography, and a smoking history of >10 pack-years. Subjects were excluded if they did not have Internet access, were unable to ambulate, or were currently enrolled in a pulmonary rehabilitation program. All subjects participated in stable health status, with no COPD exacerbation within the previous 4 weeks. The protocol was approved by the VA Boston Healthcare System Committee on Human Research. Subjects provided written informed consent and obtained medical clearance from their healthcare provider.

Study protocol

At baseline study visit, participants completed a survey on the website that assessed demographics, medical history, and study outcomes. Values for FEV_1 were obtained from medical chart review. We used the waist-mounted Omron HJ-720ITC pedometer which has been shown to be accurate in persons with COPD.[22] Subjects were instructed to upload step counts to the study server at least weekly, using their home computer and the USB cable. Subjects collected baseline step counts by wearing the pedometer, with a sticker on its face to prevent feedback, for 7 days and engaging in their usual physical activities. After participants uploaded their baseline step counts, they received an email with their first step-count goal and instructions to remove the sticker. At that time, participants could access all contents on the website.

Subjects wore the pedometer during waking hours for the 90-day monitoring period, excluding periods of bathing or water activities. Subjects participated in monthly semi-structured telephone interviews that assessed feedback. Subjects reported changes in their medical condition by telephone or on the website. If they experienced medical problems that prevented walking, they were temporarily suspended from the study and resumed when they were at

baseline clinical status. Subjects completed an end-of-study survey on the website which assessed study outcomes.

Components of Every Step Counts (ESC) walking program

ESC is based on the behavioral theory of self-regulation which emphasizes an iterative process of behavior change.[23,24] Feedback, goal setting, and motivation are critical components of the cycle of self-regulation.[22,25,26]

(1) *Feedback*. The pedometer, with on-instrument data presentation, provided subjects with continuous step-count feedback. On their personal webpage, subjects could view graphical displays of daily step counts from the current and previous weeks (Fig. 1).
(2) *Goal setting*. An individualized step-count goal was calculated with an automated algorithm. Each week's goal was the lowest of three possible numbers: (1) the average of the most recent 7 days of step counts + 400 steps, (2) the previous goal + 400 steps, or (3) 10,000 steps per day. An 800 step increment was used in SUH for persons with cardiovascular disease risk factors,[21,22] and 400 steps were selected as an attainable increase for a COPD cohort. Each Sunday, subjects received an email with the week's step-count goal, which was also displayed on their webpage (Fig. 1).
(3) *Motivational messages* (Figs. 2 and 3). Presented on their webpage, motivational messages provided strategies to overcome general barriers (bad weather, lack of time) and COPD-specific barriers to walking (fear of becoming short of breath, embarrassment with using breathing medications and/or oxygen during walking). Educational tips were short paragraphs with links to other publicly available websites, such as those of the American College of Chest Physicians and Living Well with COPD. They provided general and COPD-specific education, such as the benefits of walking and use of bronchodilators prior to walking.

Outcome measures

The primary outcome was daily step counts. Step counts for any 24-h period were considered valid if the total counts were >100 and the pedometer had been worn for at least 8 h.[21,22] Average baseline step count was calculated if valid data were available for at least 5 of the 7 days. Daily step counts for month 1 were averaged from days 1 to 30, for month 2 from days 31 to 60, and for month 3 from days 61 to 90 (end of study).

Baseline and end-of-study surveys assessed secondary outcomes. Health status was assessed with the Medical Outcome Study Short Form-36 (SF-36) question, "In general, how would you rate your health?".[27,28] Dyspnea was assessed using the modified Medical Research Council

Figure 1 Example of study webpage.

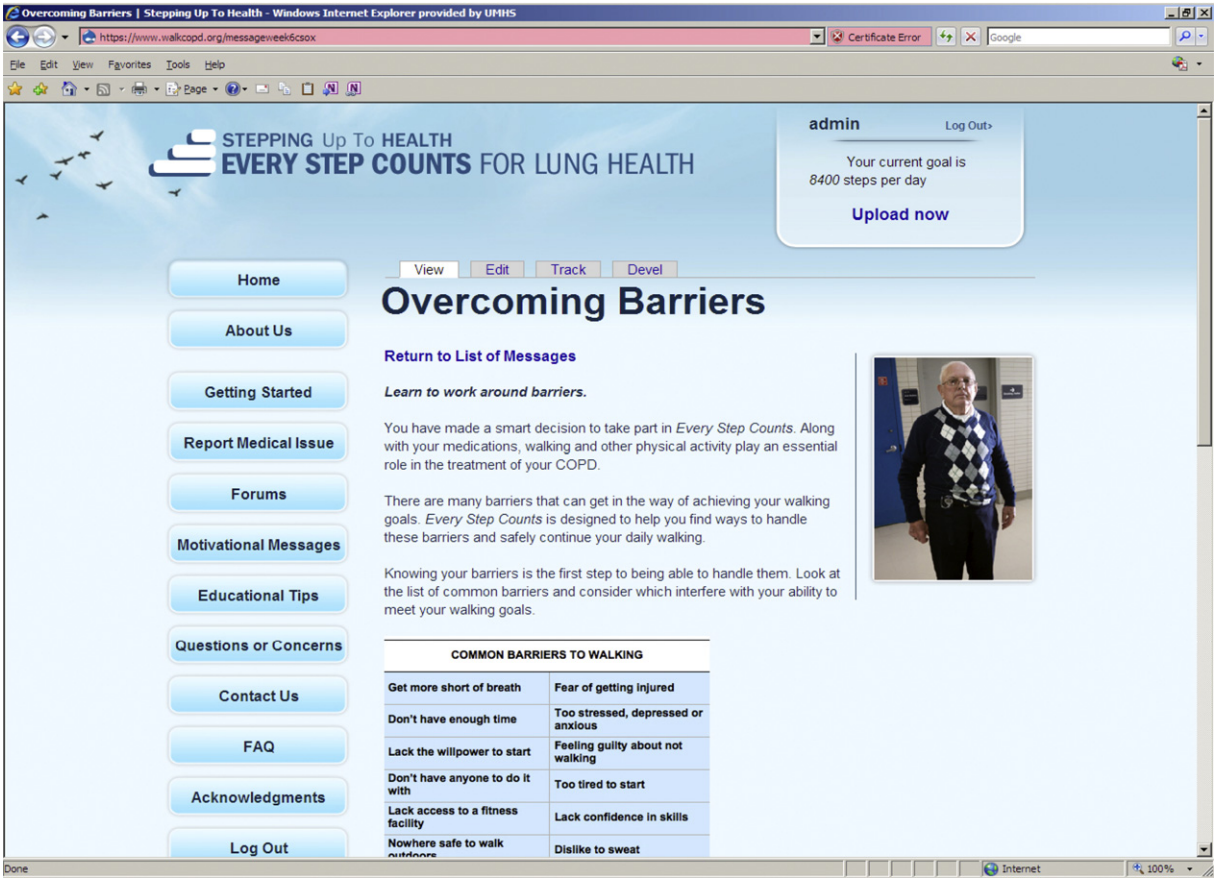

Figure 2 Example of motivational message.

(MMRC) dyspnea scale (responses 0—4, with 4 being the most dyspneic).[29] We administered the 5 questions from the exercise domain of the Bristol COPD Knowledge Questionnaire and scored the percentage of questions answered correctly.[30] We also administered the 16-item Exercise Self-Regulatory Efficacy Scale (Ex-SRES) for persons with COPD, which asks subjects to rate how confident they are to exercise 3 times a week for 20 min under different scenarios.[31] Scores range from 1 to 100 with higher scores reflecting greater self-regulatory efficacy.

Statistical analysis

Analyses were performed with SAS (version 9.1, SAS Institute; Cary, NC). Data were analyzed for 27 subjects who had baseline step counts, wore the pedometer for at least one month, and participated in at least one of the following: the baseline survey, feedback telephone calls, or the end-of-study survey. 507 of the 2430 study days (21%) had missing or invalid step counts. Three participants (2 with medical problems who did not complete study and 1 who dropped out) had no step-count data in month 3 and were excluded from the end-of-study to baseline paired *T*-test. Subjects with valid step counts for any number of days in month 3 were included. We also performed a sensitivity analysis with subjects who had valid step count data for at least 20 of 30 days in month 3. An additional 2 participants (1 with medical problems who resumed study and 1 who did not upload step counts) had no step-count data in month 1 or 2. Therefore, in 22 participants, analysis of variance assessed the trend in daily step counts by month of study. p Value <0.05 was considered statistically significant.

Results

Subject characteristics

The 27 subjects were males, with mean age 72 $\pm$ 8 years and moderate COPD, FEV_1 1.57 $\pm$ 0.48 L (55 $\pm$ 16% predicted)[32] (Table 1). All were former smokers, 9 subjects used supplemental oxygen, and 7 had previously participated in a pulmonary rehabilitation program. For worsening of breathing over the past year, 5 subjects had been hospitalized, 5 had required an antibiotic, and 6 required an oral corticosteroid. Eighteen subjects reported using the Internet almost every day.

Participant feedback

At month 3, 87% and 65% of subjects reported no problems using the pedometer and website, respectively, compared to 78% and 52% at month 1. The most common problems were the pedometer easily detaching from the waist and difficulty with the first upload of step counts. Subjects used the step count graphs most frequently, with 91% using them

Figure 3 Example of educational tip.

in month 3 (Table 2). At month 3, 96% of subjects reported they knew their step count goal every day, compared to 81% at month 1. The percentage of subjects who reported they were able to reach their goal each week decreased from 67% at month 1 to 52% at month 3. 95% of participants said they would recommend the walking program to another person with COPD.

Safety

Two subjects had mild leg pain that was associated with the walking intervention. Five subjects experienced a serious adverse event requiring hospitalization. Three subjects were hospitalized for a COPD exacerbation, 1 subject was hospitalized for chest pain, and 1 hospitalized for gallstones. All serious adverse events were judged by the study physician to be unrelated to the exercise intervention. During the study, an additional 5 subjects experienced worsening of breathing requiring treatment with prednisone and/or antibiotics.

Daily step counts

In 24 subjects, daily step counts were 2908 at baseline and 4171 at month 3, with a significant increase of 1263 steps per day, $p = 0.0054$ (Table 3). The average weekly goal increased from 3217 steps per day at week 1 to 3979 steps per day at week 12. For these 24 subjects, the median number of days in month 3 with valid step counts was 29 (range 11—30 days, mean 26 $\pm$ 6 days). In a sensitivity analysis with 20 subjects who had valid step count data for at least 20 of 30 days in month 3, daily step counts were 3307 at baseline and 4837 at month 3, with an increase of 1530 steps per day. In 22 subjects with step-count data at baseline, months 1, 2, and 3, there was a significant trend of increasing step counts by month of study, with average daily steps of 2978 (baseline), 3517 (month 1), 4030 (month 2), and 4409 (month 3), $p = 0.024$.

Secondary outcomes

At baseline, 82% of participants reported overall health to be good, fair, or poor (Table 1) and 44% had an MMRC dyspnea score of $\geq$2. On baseline assessment of COPD knowledge of exercise, 59% of the questions were answered correctly. 78% of subjects answered incorrectly that it is true that exercise should be stopped if it makes you breathless. The Ex-SRES showed that subjects were least confident that they could continue exercise if they felt sick (55%), tired (69%), or short of breath (69%). At end of study, there was no significant change in secondary outcomes (Table 3).

Table 1 Baseline subject characteristics, $n = 27$.

Characteristics	Mean ± S.D. or frequency (%)
Age	72 ± 8
FEV_1 (l)	1.57 ± 0.48
FEV_1 % predicted	55 ± 16
Race (white)	26 (96)
Marital status (married)	13 (48)
Educational status (some college or higher)	19 (70)
Employment status (retired)	15 (56)
Current oxygen use[a]	9 (36)
Prior pulmonary rehabilitation[b]	7 (27)
Coronary artery disease[a]	4 (16)
Hypertension	16 (59)
Diabetes Mellitus[b]	11 (42)
Depression[b]	3 (12)
Osteoarthritis[b]	10 (38)
General health status	
2 (very good)	5 (19)
3 (good)	15 (56)
4 (fair)	6 (22)
5 (poor)	1 (4)
MMRC dyspnea score[a]	
0	4 (16)
1	10 (40)
2	6 (24)
3	4 (16)
4	1 (4)

[a] $n = 25$.
[b] $n = 26$.

Discussion

Our pilot study demonstrates that it is feasible and safe for persons with COPD to increase their daily walking using an innovative program that combines a pedometer with a website. A recent survey showed that 78% of adult Americans use the Internet[33] suggesting that it could be a platform for implementing a widely accessible exercise program. A few pilot studies have used mobile devices, such as cell phones and personal digital assistants (PDA), which interface with the Internet to promote physical activity in persons with COPD.[20,34,35] These programs required self-monitoring and entering exercise information into the devices. In contrast, our program requires minimal manipulation by the participant. We demonstrate that the technology was well-received and observed good compliance and retention, with one subject who did not upload counts on a weekly basis and one subject who dropped out.

The increase in daily step counts of 1263 steps per day (approximately 1.0 km) is in the range of that observed in two previous studies that have used pedometers in COPD. Persons in an exercise counseling program increased walking by 785 steps per day compared to a control group.[18] Persons in a regular pulmonary rehabilitation plus counseling intervention showed an increase of 1787 steps per day compared to a control group that participated only in pulmonary rehabilitation.[19] We previously reported that persons with COPD who used SUH had an increase of 988 steps per day[22] and hypothesized that adapting the content of SUH to be specific for COPD would result in further gains. The absence of significant further gains in step counts may be due to differences in disease severity or season of monitoring between the two studies.[36] It is also possible that participants had reached the maximum amount of walking they could do as suggested by the decrease in subjects who reported being able to reach their weekly goals at month 3.

Studies that have demonstrated an association between higher daily step counts and better functional status, better health-related quality of life, and lower mortality, independent of lung function, have not distinguished step counts from aerobic walking versus walking as part of activities of daily living.[3,4,37,38] These studies suggest that any increase in daily step count could confer health benefits. Therefore, our program focused on increasing all step counts both those from walking for exercise and from overall increases in activities of daily living. In addition, it is crucial to understand barriers to walking, since every step counts.[39,40] Our results provide additional evidence that overall knowledge of exercise is poor and identify shortness of breath, illness, and fatigue as barriers to exercise self-regulation. We included the secondary outcomes for exploratory purposes to assess baseline knowledge and

Table 2 Frequency of use of components of website and participant feedback.

	Month 1 $n = 27$	Month 2 $n = 23$	Month 3 $n = 23$
Do you use step-count graphs? (yes)	21 (78)	20 (87)	21 (91)
Do you use educational tips? (yes)	12 (44)	14 (61)	13 (57)
Do you use motivational messages? (yes)	13 (48)	16 (70)	15 (65)
Have you had any problems using the Omron pedometer? (no)	21 (78)	17 (74)	20 (87)
Have you had any problems using Every Step Counts for Lung Health website? (no)	14 (52)	14 (61)	15 (65)
It is easy for me to find the time to log in to the website once a week (true)	21 (78)	19 (83)	19 (83)
The Every Step Counts for Lung Health website is easy to understand (true)	23 (85)	20 (87)	20 (87)
I know what my step count goal should be every day (true)	22 (81)	20 (87)	22 (96)
I was able to comfortably reach my step count goal each week as directed by Every Step Counts	18 (67)	13 (57)	12 (52)
The daily step count goals are too high for me to walk each day (true)	8 (30)	6 (26)	7 (30)

Table 3 Change in average daily step counts and secondary outcomes.

	Baseline	Month 3
Daily step counts* $n = 24$	2908 ± 2416	4171 ± 2970
General health status $n = 23$	3.13 ± 0.757	3.22 ± 0.736
MMRC dyspnea score $n = 21$	2.48 ± 1.12	2.24 ± 1.04
Bristol knowledge, % correct $n = 23$	60.0 ± 28.3	64.3 ± 25.6
Exercise self-efficacy total score $n = 10$	77.8 ± 23.1	78.5 ± 21.2

*$p = 0.0054$.

exercise self-regulation, and to see how feasible it is for questions to be answered online. The study was not powered to see differences in these outcomes and we are not surprised by the lack of change observed.

Our study has several limitations. It is a pilot study mainly to determine feasibility and safety. It was performed in a convenience sample of male subjects at a single site, limiting the generalizability of the results. There is no control arm, so future studies are needed to distinguish the effects of the pedometer from the effects of the website. Longer follow-up in future studies are also needed to assess the duration of benefit beyond the 90-day intervention period, and longer periods of the intervention are needed to assess long-term changes and adherence. Over half of the participants in the current study had little dyspnea and reported good or very good general health status, and future studies including subjects representing the entire range of COPD severity and symptoms are needed to assess the role of this intervention in COPD.

We chose 7 days as our baseline monitoring period since 7-day monitoring periods have been routinely used in physical activity monitor studies because they provide a sufficiently large number of days to achieve intraclass correlations of more than 80% in most populations, while also providing the opportunity to sample behavior on both week and week-end days.[41] We believe that the absolute baseline daily step count is less important than the continued increase in daily step counts by month of study seen in the cohort. For example, it is possible that week 2 or 3 more accurately represented a subject's baseline, but the goals would be calculated based on iterative, updated values and continue to promote increases in daily step counts. Persons who did not fully adhere to the 3-month walking program were included in the analysis to minimize missing data. However, this may have resulted in conservative estimates of change in step counts because persons who participated in the entire intervention may be expected to walk more. In the sensitivity analysis with subjects who had valid step count data for at least 20 of 30 days in month 3, baseline and end-of-study step counts were higher compared to results for the subjects with any valid step counts in month 3. We chose not to perform simple imputation or carry forward step-count values as the data were not missing completely at random, and these methods would result in biased estimates. The omitted answers on the survey questions appeared to be missing completely at random and unrelated to level of walking. We acknowledge that response behavior to questions administered by a computer may differ from administration by paper and pencil.

In summary, this walking program is safe and feasible. Persons with COPD can increase their daily walking with the use of a pedometer and website. Our preliminary results need to be confirmed in future studies but our results suggest that this intervention has the potential to provide a widely accessible, ongoing home-based exercise program.

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Contributorship

Marilyn Moy has contributed substantially to the study design, data analysis and interpretation, and the writing of this manuscript. Dr. Moy has full access to the data and will vouch to the integrity of the work as a whole, from inception to published article.

Nicole Weston has contributed substantially to the study design, acquisition of data, and the writing of this manuscript.

Elizabeth Wilson has contributed substantially to the study design, acquisition of data and the writing of this manuscript.

Michael Hess has contributed substantially to the study design and acquisition of data.

Caroline Richardson has contributed substantially to the study design, data interpretation, and the writing of this manuscript.

This study was initiated by the investigators. The results of the present study do not constitute endorsement of the Omron pedometer by the authors. Omron Healthcare had no involvement in the study design, the collection, analysis, and interpretation of data, in the writing of the report, or in the decision to submit the paper for publication.

Conflict of interest

Dr. Moy's funding comes entirely from federal sources. Dr. Richardson's funding comes from federal, state or nonprofit foundations. She works with companies (Omron, Blue Care Network and Walkingspree) on research projects but has no financial interest in these companies and receives no funding from them. She is a regular speaker at national meetings on this topic. None of the other authors have any disclosures.

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