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Effects of low-intensity exercise and home-based pulmonary rehabilitation with pedometer feedback on physical activity in elderly patients with chronic obstructive pulmonary disease

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KEYWORDS
Home-based pulmonary rehabilitation;
Physical activity;
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The feedback from using pedometer;
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Summary
Purpose: We evaluated the effects of low-intensity and home-based pulmonary rehabilitation (PR) on physical activity (PA) and the feedback provided by a pedometer in stable elderly patients with chronic obstructive pulmonary disease (COPD).
Methods: We assessed PA using a newly developed triaxial accelerometer (A-MES™, Kumamoto, Japan), which measures the time spent walking, standing, sitting and lying down. Twenty-seven elderly patients with COPD (age 74 ± 8 yrs; %FEV_1 56.6 ± 18.7%) participated. They were randomly selected to undergo PR (pulmonary rehabilitation only) or PR + P (PR plus the feedback from using a pedometer). Their PA and pulmonary function, exercise capacity (6-min walking distance; 6MWD), quadriceps femoris muscle force (QF) were evaluated before the PR began (baseline) and at 1 year later. We compared the patients' changes in PA and other factors between the baseline values and those obtained 1 year later and analyzed the

Abbreviations: COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation; PA, physical activity; A-MES™, Activity Monitoring and Evaluation System™; GOLD, global initiative for chronic obstructive lung disease; 6MWD, 6 min walking distance; FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; QF, quadriceps femoris muscle force; ERS, European Respiratory Society; ATS, American Thoracic Society; MRC, Medical Research Council; QOL, quality of life; CRQ, chronic respiratory disease questionnaire; BODE, body-mass index, airflow obstruction, dyspnea, and exercise capacity.

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relationships between the changes in PA and other factors in the both groups.
Results: The increase in the time spent walking in the PR + P group (51.3 ± 63.7 min/day) was significantly greater than that of PR group (12.3 ± 25.5 min/day) after the PR. The improvement rate of daily walking time after PR was significantly correlated with that of the 6MWD and QF in all subjects.
Conclusions: These data suggest that low-intensity and home-based PR with the feedback from using pedometer was effective in improving PA, and the improvements of physiological factors were correlated with increased walking time in stable elderly patients with COPD.

Introduction

The progress of chronic obstructive pulmonary disease (COPD) causes breathlessness, disability, and frequent hospitalization, and is associated with a reduction in physical activity (PA). It is known that the level of PA is an independent prognostic factor for mortality and hospitalization due to the severe exacerbation of COPD [1]. The primary goal of pulmonary rehabilitation (PR) has been to break the downward spiral of breathlessness, disability and inactivity that leads to deconditioning. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) guideline states that PA is recommended for all patients with COPD to improve their exercise capacity and decrease their dyspnea and fatigue [2].

The previous studies and guideline note that PR is beneficial for COPD patients as it improves exercise capacity, muscle force, symptoms, and health-related quality of life [2,3]. However, it has been reported that various types of PR had little or no effect on PA in COPD patients [4]. The evidence that increased PA is achieved through participation in PR is inconclusive. Some studies reported that PR had the immediate effect of increasing PA, but no long-term effects that could maintain the subjects' PA [5,6]. Agarwal et al. proposed that a longitudinal exercise program in addition to PR may be required for COPD patients [7].

These studies also suggested that alternative methods that affect behavior to increase daily physical activity are needed [8,9]. For example, bimonthly phone calls to subjects to provide motivational support for improving their activity were tested [8]. The effect of a counseling program with feedback from a pedometer during PR was shown to improve the patients' outcome and maintenance of rehabilitation [9]. A PR program we devised consists of home-based exercise at low intensity, nutrition counseling and weekly education sessions; we found that this program improves the participants' exercise capacity and other health status factors [10,11]. This program has been used for COPD patients who can come to our hospital. It may be effective for maintaining their conditioning, including physical activity.

Pedometers are easy to use and have been found to enhance PA and contribute to the maintenance of PA as a feedback tool [9,12]. Thus, the objective of the present study was to evaluate the effect of our PR program over a long term with or without the feedback of daily pedometer use by patients with COPD.

Methods

Subjects and study design

Forty-two patients who were diagnosed with stable COPD from mild to very severe stage (GOLD) [13] were enrolled in the present study. The patients were all retired. The inclusion criteria for this study were: (1) the patient was in stable condition with no infection or exacerbation of COPD for at least the prior 3 months; (2) the patient was able to walk unassisted and operate the device to measure their PA; (3) the patient had no severe and/or unstable cardiac disease, orthopedic disease, or mental disorder that could impair physical activities in daily life. The objective and content of the study were orally explained to the participants, with additional documents. Written consent was obtained after all patients were informed that they could decide whether or not to participate based on their own free will and that their privacy would be sufficiently considered.

The trial design was a prospective, randomized, controlled trial (Fig. 1). The patients were randomly assigned to one of two groups: the PR (pulmonary rehabilitation only) or PR + P (Pulmonary rehabilitation and feedback from using a pedometer) group. Patients were not blinded to the randomization. This study followed the COPD patients from baseline before the PR to 1 year later. The assessments of physical activity in daily life, pulmonary function, submaximal exercise capacity (6MWD; six-minute walk distance), respiratory and quadriceps muscle force, functional status, and health-related quality of life were done at baseline before the PR and 1 year from the baseline.

This study was reviewed and approved by the Ethics Committees of our hospital and the Akita University Graduate School of Medicine, and carried out in conformity with the Declaration of Helsinki, 2008 [14].

Intervention

PR group (pulmonary rehabilitation only)

Our PR program is a multidisciplinary home-based program. Breathing retraining consisted of pursed-lip breathing, diaphragmatic breathing, and slow-deep breathing, in both the supine and sitting positions. Exercise training included upper and lower limb exercises including COPD sitting calisthenics [10], respiratory muscle stretching calisthenics [15], level walking for at least 15 min, and inspiratory

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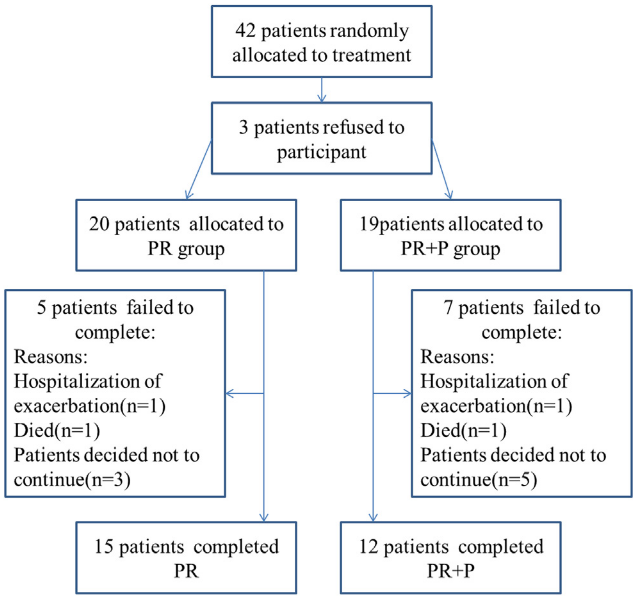

Figure 1 Study design.

muscle exercises using an inspiratory muscle trainer, the Threshold™ (HealthScan Products, Cedar Grove, NJ) set at a training intensity of 30%–40% of the maximal inspiratory (PImax) muscle forces. The patients also underwent a monthly 45-min education program including lectures about equipment use, nutrition, stress management, relaxation techniques, home exercises and the benefits of PR. Patients were instructed to practice this program daily at home and were supervised by a respiratory therapist every 2 wks in our hospital, and then we reset the intensity of exercise as their conditions allowed.

The achievements of this home program have been reported [10,16]. Indeed, the participants in the present study were able to perform our daily program at home for 239 ± 25 days of a year (65.4 ± 6.8%). A nurse periodically visited each patient at home and provided information on the role of the PR program. The overall training intensity was set at a dyspnea rating scale of 3, which corresponds to approx. 50% of the maximum oxygen consumption [17].

PR + P group (pulmonary rehabilitation and feedback from pedometer use)

The subjects in the PR + P group completed the monitoring using a pedometer (Kens Lifecorder EX, Nagoya, Japan; Fig. 2) and received monthly feedback about their pedometer use by PR staff for 1 year in addition to the other aspects of the program described above for the PR group. They attached the pedometer (which is small and lightweight) to their belt at the waist for a period of 12 h (from waking time until going to bed) each day for 1 year.

The pedometer contains a uniaxial accelerometer to measure the wearer's energy expenditure and the number of steps every 4 s throughout each day. A proprietary algorithm determines daily step counts with an intramodel reliability of 0.998 and accuracy within ±3% of the actual number of steps taken [18]. The memory of this instrument has a 36-day date storage capacity. When a patient comes to our hospital for a consultation each 2 wks or monthly, we

Figure 2 LifecorderEX®.

can retrieve the date and replace the battery within a few minutes. The patients received the feedback monthly with their average daily PA of the previous month from the PR staff. The patients received this feedback 11 times in the year.

The Nakanojo study reported that 8000 steps per a day was correlated with lower limb function [18], and thus the COPD patients in that study were given the goal of taking 8000 steps per a day. The PR staff also gave verbal reinforcement to the patients to increase their PA when they received their PA feedback. Compliance was good, as the patients wore their pedometers for 293 ± 49 days of a year (80.4 ± 13.3%).

Outcome measures

Assessment of physical activity in daily living

The assessment of physical activity in daily life was done using a new tri-axial accelerometer system (Activity Monitoring and Evaluation System [A-MES™], Solid Brains, Kumamoto, Japan) [19]. The A-MES consists of two sensors (69 H × 44 W × 11.5 D mm each, weight: 28 g each), a station, and analytical software used with a personal computer. These sensors are so small and light that they can be attached on the thigh and the chest of the subject wearing clothing with two pockets (Fig. 3). The physical activity data recorded by the two sensors is sent to the A-MES station and analyzed by the A-MES software. The A-MES system measures the time that the wearer has spent in several positions and moving (lying down, sitting, standing,

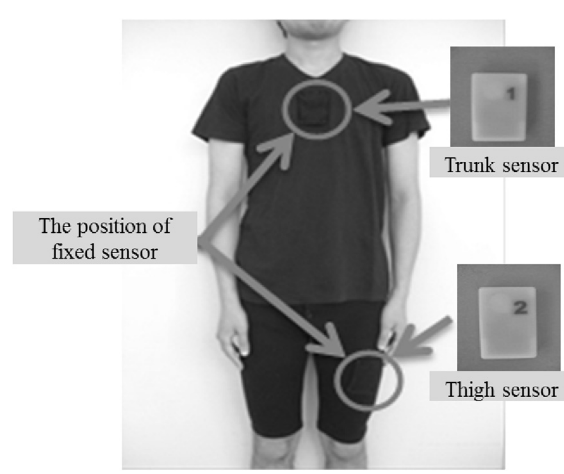

Figure 3 Activity Monitoring and Evaluation System™ (A-MES™); Size 69 (H) × 44 (W) × 11.5 (D) mm. Weight 28 g.

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and walking) by using a three-dimensional analysis of acceleration. The system can also measure the frequency of postural changes: getting-up (i.e., the bodily change from a recumbent position to an upright position) and standing-up (i.e., the bodily change from a sitting position to an upright position) (Fig. 4).

We informed our patients about how to use the A-MES and confirmed that each patient understood the device's operation. Each patient was given an A-MES, an instruction book, and the appropriate clothing, and we instructed the patients to measure their physical activity themselves. Since physical activity varies according to the cycle of the seasons [20], we measured all patient's physical activities before and after PR for 1 year from June 2012 until October 2013. The assessment was done for a maximum of 7 consecutive days including weekdays and weekends, and physical activity was measured with the A-MES from waking time until 12 h after the waking time [21]. We used the data of the patients who provided at least two valid days of assessment, which we considered the minimum number of necessary days to assess reliable physical activities in daily life [22].

Other measurements

Pulmonary function was assessed as forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC, and %FEV_1 measured by a spirometer (HI-701 Multi-Functional Spirometer, Chest M.I., Tokyo). The mouth pressure was measured as respiratory muscle strength using a respiratory dynamometer (Vitalopower KH-101, Chest M.I.) following the method reported by the American Thoracic Society/European Respiratory Society (ATS/ERS) recommendations [23].

For quadriceps femoris muscle force (QF), the maximum isometric extension and contraction of this muscle were measured at 0°/sec 80° flexion using the Hydro Musculator GT-160 (OG Giken Co., Tokyo) [24]. For the measurements of exercise performance, the patient performed a corridor walk for 6 min according to the ATS guidelines [25]. The patients were not encouraged during the walk. The patients' dyspnea was assessed using Medical Research Council (MRC) dyspnea scale [26]. The BODE index (body-mass index, airflow obstruction, dyspnea, and exercise capacity index) [27] was assessed as a prognosis factor for COPD patients. The disease-specific health-related quality of life (QOL) was measured using the Japanese version of the Chronic Respiratory Disease Questionnaire (CRQ) [28].

Statistical analysis

The data of the 27 patients were entered and analyzed using SPSS (Windows) software version 21.0J for normal distribution using parametric and non-parametric tests. P-values <0.05 were accepted as significant. The differences between the two groups were compared using independent t-tests and Mann–Whitney U-tests on parametric and nonparametric data, respectively. A Student paired t-test or a Wilcoxon signed rank test was performed (on parametric and nonparametric data, respectively) to compare these differences between pre-rehabilitation and post-rehabilitation in both groups. Pearson's product-moment correlation coefficient was used for single correlations between the changes of time spent in different activities (walking, standing, sitting and lying) between pre- and post-PR and those of other physiologic measurements, and Spearman's rank correlation coefficient was used for the ordinal scales (i.e., the MRC dyspnea scale).

Results

Forty-two patients were recruited to the present study. Three patients refused to participate and 12 dropped out. Therefore, 39 patients gave informed consent, and the 27 patients who completed our PR program were used for the analyses. Details of the reasons for drop-out can be written in Fig. 1. Twelve patients dropped out of the rehabilitation program due to an acute exacerbation requiring long-term hospitalization (n = 2), death (n = 2), and a lack of motivation or personal reasons (n = 8). The baseline characteristics of the 27 COPD patients are presented in Table 1. There were no significant differences in baseline characteristics between the PR and PR + P groups.

Comparison of these assessments between pre and post PR in each group

The PA results of both groups are shown in Fig. 5. There were no significant baseline differences between the groups. The time spent walking, standing, and lying were significantly improved from baseline to 1 year later in both groups. There were also significant improvements in the frequency of standing-up only in the PR + P group. Table 2 shows the comparison of the patients' health status and physiological function from baseline to 1 year later. There

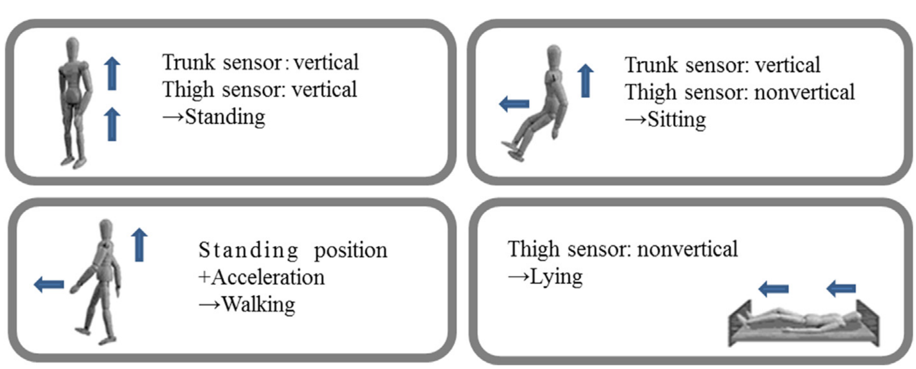

Figure 4 The measurement of a subject's position, moving, and postural changes by the A-MES™ sensors.

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Table 1 PR and PR + P subject's baseline characteristics.

	Mean ± SD	
	PR	PR + P
Gender, male/female	14/1	10/2
Age, yr	75 ± 9	74 ± 8
BMI, kg/m^2	22.0 ± 3.1	21.7 ± 3.1
FVC, L	3.2 ± 0.7	2.8 ± 0.7
FEV_1, L	1.5 ± 0.5	1.4 ± 0.7
FEV_1/FVC, %	46.8 ± 14.4	49.9 ± 16.5
FEV_1 %pred	60.6 ± 20.8	58.0 ± 23.2
GOLD stage	2.2 ± 0.9	2.5 ± 1.2
Smoking history (Yes/No)	15/0	10/2
Brinkman index	1196 ± 583	1637 ± 1125
Comorbidities (=n)		
Osteoporosis	3	3
Diabetes	2	3
Chronic heart failure	1	0
Hyper tension	2	1
Low back pain	1	2
Athritis	1	1
Charlson's score	0.5 ± 0.6	0.6 ± 0.9

SD; standard deviation, BMI; body mass index, FVC; forced tidal capacity, FEV_1; forced expiratory volume in one second, GOLD; global initiative for chronic obstructive lung disease.

were significant improvements in PImax values, 6MWD, and CRQ scores in both groups. MRC and QF were significantly improved only in the PR + P group.

Comparison of changes in physical activity from baseline to 1 year later between the PR and PR + P groups

The changes of the time spent walking from baseline to 1 year later in the PR + P group were higher than those in the PR group (PR: 12.3 ± 25.5 vs. PR + P: 51.36 ± 3.7, $p = 0.036$). There were no significant differences in the changes of other parameters (Table 3).

The correlation between the degrees of improvement in physical activity and physiologic function in all patients

Changes in walking time after 1 year of pulmonary rehabilitation in both groups were significantly correlated with changes in PImax ($r = 0.576$, $p = 0.002$), 6MWD ($r = 0.477$, $p = 0.012$), WBI ($r = 0.512$, $p = 0.006$) and BODE index ($r = -0.481$, $p = 0.011$). Changes in the time spent standing were significantly correlated with 6MWD ($r = 0.401$, $p = 0.038$), WBI ($r = 0.552$, $p = 0.005$), and the CRQ score ($r = 0.540$, $p = 0.004$), and the changes in

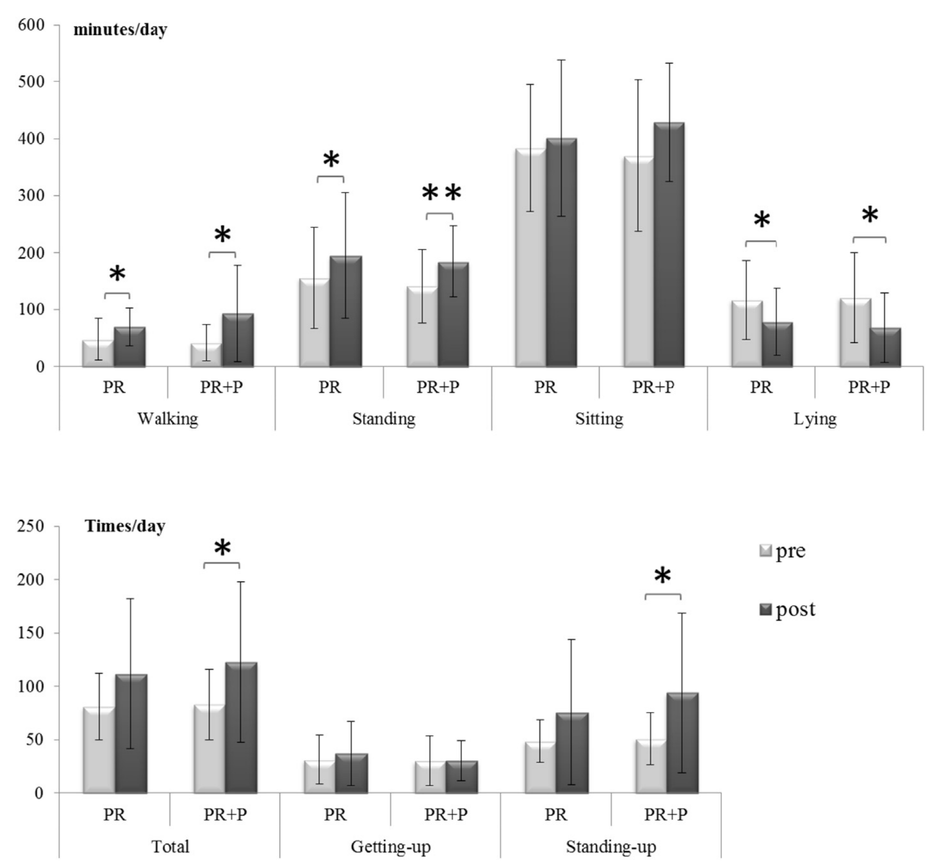

Figure 5 Comparison of time spent in body position and moving, the frequency of postural changes between pre and post PR in PR and PR + P groups.

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Table 2 The changes of characteristics from Baseline to 1 year later in both groups.

	Mean ± SD					
	PR		p-value	PR + P		p-value
	Pre	Post		Pre	Post	
BMI (kg/m^2)	22.1 ± 2.9	22.2 ± 2.9	0.832	21.9 ± 2.6	21.9 ± 2.6	0.888
PImax (cmH$_2$O)	59.5 ± 24.8	77.6 ± 27.8	<0.01	61.9 ± 27.7	75.4 ± 33.9	0.025
PEmax (cmH$_2$O)	107.3 ± 44.5	101.8 ± 38.7	0.523	102.9 ± 49.7	110.1 ± 32.1	0.406
6MWD (m)	404 ± 148	467 ± 151	<0.01	369 ± 119	445 ± 138	<0.01
MRC	1.9 ± 0.7	1.4 ± 0.9	0.106	1.9 ± 0.8	1.2 ± 0.9	0.039
QF (kg)	34.9 ± 13.0	37.1 ± 12.2	0.056	35.5 ± 13.4	40.6 ± 13.7	<0.01
BODE index	2.5 ± 2.1	2.3 ± 1.6	0.364	2.8 ± 2.3	2.3 ± 1.6	0.089
CRQ (total score)	99 ± 19	110 ± 19	<0.01	98 ± 20	108 ± 19	0.027
Dyspnea	20 ± 9	23 ± 8	0.229	18 ± 8	23 ± 9	0.046
Fatigue	22 ± 4	21 ± 5	0.735	21 ± 5	22 ± 4	0.713
Emotional function	39 ± 7	41 ± 7	0.277	41 ± 6	40 ± 7	0.474
Mastery	22 ± 6	23 ± 6	0.730	20 ± 5	21 ± 6	0.967

BMI; Body mass index, PImax; maximum inspiratory mouth pressure, PEmax; maximum expiratory mouth pressure, 6MWD; six-minute walking distance, MRC; Medical Research Council, QF; quadriceps femoris muscle force, BODE index; The body-mass index, airflow obstruction, dyspnea, and exercise capacity index, CRQ; chronic respiratory disease questionnaire.

the time spent lying down were significantly correlated with only the BODE index (r = 0.656, p = 0.001) (Table 4).

Discussion

The GOLD guideline [1] states that physical activity is recommended for all patients with COPD, who are apt to reduce their physical activity in the downward spiral of disability with COPD. Several prior studies found that the effect of pulmonary rehabilitation for PA was obscure [4–6,29–31], but most of these studies used high-intensity exercise for a relatively short term; i.e., from 8 wks to 6 months [4,5,29–31]. In Japan, there are many elderly COPD patients, and high-intensity exercise is not generally used for them due to the risk and low patient adherence [10]. The results of the present study show that home-based pulmonary rehabilitation with low-intensity exercise for 1 year improved domestic physical activity, and that the PR + P patients who received the additional pedometer feedback, were more improved than the PR-alone patients.

Our home-based PR program with low-intensity exercise for 1 year also resulted in significant improvements of PImax, 6MWD, and CRQ scores. Pitta et al. reported that the improvements in exercise performance, functional status, and QOL following an increased amount of daily physical activity are limited and that a long-lasting rehabilitation program was major contributing factor to the changes in physical activity habits in everyday life [30]. Egan et al. studied the short- and long-term effects of a 7-wk PR program on activity levels. They reported that the program increased physical capacity, but these benefits were not sustained after 1 year, and there was no increase in free-living activity [5]. The present study showed that the patients' compliance in a home exercise program was relatively good; the patients were able to perform our daily program at home for 239 ± 25 days of a year (4 days a week, in other words). We suspect that our program's patient

Table 3 Comparison of changes in physical activity from Baseline to 1 year later between PR and PR + P group.

	Mean ± SD		
	PR	PR + P	p-value
The time spent in position and moving (min/day)			
Walking	12.3 ± 25.5	51.3 ± 63.7	0.036
Standing	31.3 ± 46.8	43.0 ± 28.1	0.694
Sitting	6.1 ± 90.1	59.3 ± 103.3	0.198
Lying down	−28.6 ± 55.1	−52.9 ± 68.4	0.303
The frequency of potural changes (times/day)			
Total	19 ± 44	40 ± 66	0.303
Getting-up	6 ± 31	0.1 ± 25	0.857
Standing-up	14 ± 34	43 ± 60	0.181

Table 4 The correlation between the degrees of improvement in physical activity and physiologic function in all subjects (=r).

	Walking	Standing	Lying
PImax (cmH$_2$O)	0.576**	0.339	−0.006
PEmax (cmH$_2$O)	−0.330	0.203	0.081
6MWD (m)	0.477*	0.401*	−0.115
MRC[a]	−0.156	−0.239	0.333
QF	0.512**	0.552**	−0.371
BODE index	−0.481*	−0.103	0.656**
CRQ score	−0.171	0.540**	0.357

[a] Spearman's rank correlation coefficient, *p < 0.05, **p < 0.01, PImax; maximum inspiratory mouth pressure, PEmax; maximum expiratory mouth pressure, 6MWD; six-minute walking distance, MRC; Medical Research Council, QF; quadriceps femoris muscle force, BODE index; The body-mass index, airflow obstruction, dyspnea, and exercise capacity index, CRQ; chronic respiratory disease questionnaire.

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education and use of low-intensity exercise contributed to the high compliance. A long-term PR program maintaining such continuity may lead to improvements in physical capacity and to increased physical activity at home.

In the PR + P group, the walking time was more improved than in the PR group after 1 year of the PR program with the feedback from a pedometer. With a pedometer, people become aware of their current level of PA and have a tool to gain information and enhance their behavior modification efforts [12]. Blok et al. noted that the use of a pedometer with exercise and stimulation of lifestyle physical activity is a feasible addition to a PR program that can improve outcomes and the maintenance of rehabilitation results [9]. In the present study, the long-term feedback from a pedometer as an intervention may have enhanced the participants' motivation to increase their PA, resulting in the improvement of the walking time, MRC and QF in the PR + P group.

The reason why the PA was improved by the PR program with the pedometer feedback can be explained by the correlation between the degrees of improvement in PA and physiological function in all patients (Table 4). According to these findings, the patients' PA was not only affected by the improvements of physiological factors; the patients' physiological factors were also affected by the improvement of (i.e., increase in) PA. This indicates a reciprocal influence between the physiological factors and PA, which may lead to the improvement of psychological factors such as health-related QOL. It is important that aging COPD patients maintain their physiological function for daily activity. Moreover, it may be possible to break the downward spiral of inactivity using the additional enhancement with the pedometer in PR.

Factors other than PR affect an individual's PA. For example, Swell et al. demonstrated that PA varies according to the cycle of the seasons [20]. In the present study, this seasonal gap was minimized to measure the patients' PA before their PR and 1 year later. However, the patient's self-efficacy has been reported to be a predictor as PA [31]. A limitation of the present study is that the self-efficacy of our patients was not evaluated. In addition, the design of this present study was not blinded, which might have concern in the result that the PA in PR + P group were more improved than that in PR group. As the number of the patients enrolled is very low and they were from an individual facility, the effect of low-intensity exercise and home-based pulmonary rehabilitation with pedometer feedback on physical activity in elderly COPD may be worth closely investigating through a multi-institutional joint research involving a large number of cases in future. Further research is needed to test the effects of increasing PA on the prognosis of COPD patients.

Conclusions

In summary, our present findings demonstrated improvements of PA in elderly patients with COPD who followed our home-based PR program with low-intensity exercise and feedback from a pedometer. The beneficial changes in the amount of time spent walking in the PR + P group were significantly greater than that of the PR group. The improved rate of activity after PR was significantly correlated with the improvements in physiological factors. These data suggest that home-based PR with low-intensity exercise is effective for increasing PA, and the feedback from using a pedometer adds to this effectiveness.

Conflicts of interest

The authors state that they have no conflicts of interest.

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