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Efficacy of a cell phone-based exercise programme for COPD

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ABSTRACT: The application of a supervised endurance exercise training programme in a home setting offering convenience and prolonged effects is a challenge.

In total, 48 patients were initially assessed by the incremental shuttle walk test (ISWT), spirometry and the Short Form-12 (SF-12) quality-of-life questionnaire, and then every 4 weeks for 3 months thereafter and again after 1 yr. During the first 3 months, 24 patients in the cell phone group were asked to perform daily endurance walking at 80% of their maximal capacity by following the tempo of music from a program installed on a cell phone. The level of endurance walking at home was readjusted monthly according to the result of ISWT. In the control group, 24 patients received the same protocol and were verbally asked to take daily walking exercise at home.

Patients in the cell phone group significantly improved their ISWT distance and duration of endurance walking after 8 weeks. The improvements in ISWT distance, inspiratory capacity and SF-12 scoring at 12 weeks persisted until the end of the study, with less acute exacerbations and hospitalisations.

In the present pilot study, the cell phone-based system provides an efficient, home endurance exercise training programme with good compliance and clinical outcomes in patients with moderate-to-severe chronic obstructive pulmonary disease.

KEYWORDS: Cell phone, chronic obstructive pulmonary disease, pulmonary rehabilitation, shuttle walking tests

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Pulmonary rehabilitation is becoming an essential part of the management of patients with chronic obstructive pulmonary disease (COPD) [1, 2]. Most pulmonary rehabilitation programmes contain a comprehensive intervention that improve respiratory symptoms and exercise capacity, as well as quality of life [3]. An increasing number of reports show that pulmonary rehabilitation programmes with supervised exercise training improves exercise tolerance, quality of life, activities of daily life, respiratory symptoms, and exertional and overall dyspnoea. They also decrease the need for hospitalisation in COPD patients [4]. Most pulmonary rehabilitation programmes are hospital based and patients are expected to perform exercise sessions with regular supervision and monitoring in order to achieve persistent and optimal physiological benefits. However, compliance and the acceptance of regular visits to the hospital or clinics are major stumbling blocks to the success of these programmes [5]. Therefore, an alternative approach has been to consider home-based and self-managed rehabilitation programmes, which should also be supervised, or at least closely monitored [6–8].

Exercise training is the cornerstone of pulmonary rehabilitation and the best available means of improving muscle function and chronic respiratory symptoms in COPD patients [9, 10]. Exercise training improves skeletal muscle oxidative capacity and efficiency that leads to less alveolar ventilation for a given work rate [11, 12]. Patients will tolerate a heavier workload with less dyspnoea on exercise [13]. The lower limbs play an important role in exercise training programmes because the quadriceps are the major muscles for patients' mobilisation [14–16]. Even with light exercise, a weak lower limb will increase ventilatory demands, thus aggravating dynamic hyperinflation in COPD patients, who may then be discouraged from undertaking further exercise [17, 18]. A pulmonary rehabilitation programme must contain an exercise training programme that is easy to perform with good compliance and good clinical efficacy. Endurance exercise training has been reported to have consistently high clinical efficacy [19, 20], but how to apply a supervised endurance exercise training programme in the home setting for prolonged effects remains a challenge [21–24].

The current authors have developed a home-based exercise training programme for stable COPD patients. The patients were asked to walk at a speed controlled by the tempo of music from a program installed on a cell phone. The tempo of music was exactly the same as the walking speed at the intended level for endurance exercise training. The duration of endurance walking and symptom scores were recorded daily and sent by the cell phone to a website for storage and monitoring. This pilot study is the first study in COPD patients to document the clinical efficacy, compliance and applicability of a home-based exercise training programme supervised *via* a cell phone.

MATERIALS AND METHODS

Study subjects

In total, 48 patients with moderate-to-severe COPD were recruited into the study. The diagnosis of COPD was compliant with the criteria of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines published in 2000 [25]. No subject had an acute exacerbation or received therapy with oral corticosteroids for $\geqslant$3 months prior to the study, and all the subjects continued with a stable regimen of medications throughout the study. According to the GOLD guidelines, the diagnosis of COPD is suggested to be made in patients $>$40 yrs of age; therefore, patients aged $<$40y yrs were excluded. In addition, patients aged $>$80 yrs were excluded, as they may experience difficulty in operating the cell phone. Subjects were also excluded if any of the following criteria applied: requirement for oxygen therapy; presence of symptomatic cardiovascular diseases or severe systemic diseases limiting exercise capacity; use of medications affecting exercise responses; musculoskeletal conditions likely to influence exercise performance; and impaired hearing or vision affecting a subject's ability to follow the exercise training programme. Initially, 60 patients were enrolled and 30 were assigned to the cell phone group according to a table of random numbers. Four patients in the cell phone group withdrew from the study within 3 weeks owing to difficulty in operating the cell phone. Another two patients in this group withdrew owing to transport problems. In the control group, two patients dropped out owing to COPD exacerbation within the first 2 weeks. Two patients in this group were lost to follow-up after 3 months and another two patients suffered from another illness affecting exercise performance and transport problems, respectively. Finally, 48 patients were recruited into the present study and 24 of them were in the cell phone group. The study was approved by the Human Research Ethics Committees of Chang Gung Memorial Hospital (Taipei, Tiawan). Informed consent was obtained from all subjects.

Cell phones and software

The software used was a Java application (Java 2 Micro Edition (J2ME)) designed by the National Center for High-Performance Computing (Hsinchu, Taiwan). It is compatible with most commercial J2ME-enabled cell phones with General Packer Radio Service (GPRS). The present study adopted the Sony Ericsson K600i® cell phone (Sony, Tokyo, Japan) to execute the J2ME application for the endurance walking exercise by music pacing and data uploading through GPRS to a website.

Study design

At the start of the study, all the subjects were assessed by an incremental shuttle walking test (ISWT) [26], spirometry and the Short Form-12 (SF-12) quality-of-life questionnaire. Patients in the cell phone group were asked to take daily endurance exercise training with cell phone assistance. The level of endurance walking was reassessed and readjusted at return clinical visits every 4 weeks during the first 3 months (the exercise training period). During this period, the adherence to protocol was reinforced by telephone when patients missed 1 day of walking training. Patients were then asked to continue their exercise programme at home at a fixed walking speed and to return to the clinic every 3 months for the following 9 months (the self-management period). However, no telephone reinforcement was made during this period. The adherence and compliance of the home-based exercise training programme was assessed on the website by monitoring the frequency of performance and the duration of the endurance walking programme every week. An exacerbation of COPD was defined as a change in the patient's baseline dyspnoea, cough and/or sputum beyond normal day-to-day variations, which warranted an earlier return to the clinic for a change in regular medication, or hospitalisation [27]. Therefore, the clinical outcomes were assessed for the episodes of acute exacerbation by recording the number of unscheduled visits and hospitalisations during the period of study. Patients in the control group received the same protocol and telephone reinforcement every 2 weeks during the first 3 months of the study period. The adherence to the walking exercise at home was reported by the patients themselves at the return visits to the clinic. All the patients performed ISWT, SF-12 and spirometry measurements every month for the first 3 months and at the end of the self-management period. In both groups, each patient was provided with a home rehabilitation programme booklet and a DVD, including written instructions for home walking exercise training.

Endurance walking exercise with constant intensity

The walking speed of the endurance exercise training at home was set at 80% of the individual's maximal capacity, which could be predicted from the distance walked during the ISWT [28]. Using the following equation (1), the peak oxygen uptake ($V'_{O_2,peak}$) of ISWT could be determined. The level closest to the speed derived from 80% of the predicted $V'_{O_2,peak}$ value was then determined, representing 80% of the maximal capacity for endurance walking training at home [29].

$$\text{Predicted } V'_{O_2,peak}\ (\text{mL}\cdot\text{min}\cdot\text{kg}^{-1}) = 4.19 + (0.025 \times \text{ISWT distance}) \quad (1)$$

During the period of ISWT, the entire test was recorded by a camcorder in order to count the number of steps per shuttle at the appropriate level. Using the walking speed and the number of steps per shuttle, the tempo of music for the appropriate walking speed was calculated using the following equation (2). The patients were then asked to follow this individualised music tempo and to walk at a fixed pace to maintain a constant speed.

TABLE 1 Characteristics of study subjects

	Cell phone group	Control group	p-value
Subjects n	24	24	
Age yrs	71.4±1.7	72.8±1.3	0.741
Males	24 (100)	24 (100)	1.000
Body mass index	22.9±0.7	23.5±0.7	0.773
SF-12 PCS	38.7±1.8	40.1±1.3	0.959
ISWT m	255.8±20.6	262.9±16.5	0.464
FVC L	1.87±0.07	2.00±0.13	0.718
FEV_1 L	0.97±0.06	0.99±0.06	0.951
FEV_1 % pred	45.2±3.2	46.0±2.8	0.918
FEV_1/FVC%	51.8±2.8	50.8±2.4	0.650
IC pre-ISWT L	1.59±0.06	1.69±0.12	0.789
IC post-ISWT L	1.30±0.06	1.37±0.11	0.934
Change in IC	0.29±0.02	0.32±0.03	0.322

Data are presented as mean±SEM or n (%), unless otherwise stated. SF-12: Short Form-12 Health Survey; PCS: physical component summary scores; ISWT: incremental shuttle walk test; FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; % pred: % predicted; IC: inspiratory capacity.

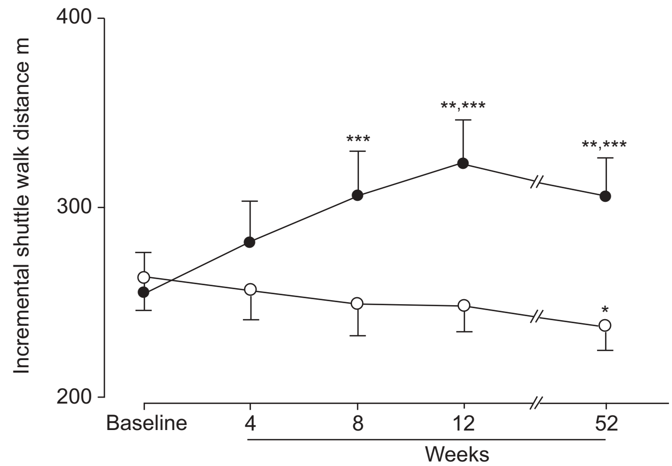

FIGURE 1. Distance covered during the incremental shuttle walk test at baseline and then every 4 weeks for 3 months and after 1 yr. In the cell phone group (●), the distance increased significantly at 8 weeks, 12 weeks and 1 yr compared with baseline. This was greater than that of the control group (○) after 12 weeks and 1 yr. Data presented as mean±SEM. *: $p<0.05$; **$p<0.01$; ***: $p<0.001$; compared with the baseline of the control group.

$$\text{Tempo (beats}\cdot\text{min}^{-1}) = \text{speed (km}\cdot\text{h}^{-1}) \times 100 \times \text{steps per shuttle} / 60 \quad (2)$$

Home-based endurance exercise training

In the cell phone group, the music software with an individualised tempo and short questionnaires for recording respiratory symptoms were installed onto the patients' cell phones after being downloaded. Patients were asked to perform endurance exercise training everyday by switching on the program on the cell phones, completing the questionnaires and walking at a speed following the tempo of the music. Patients were allowed to use earphones if the music was not loud enough for them to hear. The patients were required to keep the walking speed until they could not keep up. They then stopped walking and turned off the program. The cell phone recorded the duration of music played (equal to the duration of walking) which was then automatically sent to the website for storage by GPRS, accompanied by the data of respiratory symptom scores. On the website, the data was updated and displayed immediately.

Measurements

In the cell phone group, patients were asked to complete questionnaires on the cell phone covering respiratory symptoms, including breathlessness, cough and sputum, before they started daily endurance walking training [30]. Pulmonary function tests were performed at the beginning of the study, at the return clinical visits every 4 weeks in the first 3 months and at the end of the self-management period. The forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC, inspiratory capacity (IC) and breathlessness (rated by the Borg scale) were measured before and immediately after the ISWT. The walking distance of the ISWT, body mass index (BMI) and SF-12 were also recorded in both groups at each visit.

Analysis

The primary end-point of exercise training was change in distance in ISWT from baseline value. The sample size calculation was performed by estimating the standard deviation for increased distance in ISWT. It was calculated that 20 subjects would provide 99% statistical power for detecting a 50-m absolute difference, with a two-sided 0.05 significance level test [31, 32]. The repeated measures test of ANOVA was used to compare data within groups. The two-tailed unpaired t-test or nonparametric Mann–Whitney U-test was applied to compare results between the two groups. Statistical significance was defined as $p<0.05$. All data are presented as the mean±SEM.

RESULTS

Patient characteristics

The characteristics of the study subjects are shown in table 1. There were no significant differences between the two groups in terms of age, sex, BMI, initial exercise capacity, severity of COPD, pulmonary function or the extent of dynamic hyperinflation. There were no significant differences in either the maintenance medications or in the baseline SF-12 scores.

Clinical efficacy of a cell phone-based endurance walking exercise programme

Exercise tolerance

Repeated measures ANOVA revealed a significant difference in the walking distance of the ISWT in the study group ($p<0.001$) but not in the control group ($p=0.078$). In the cell phone group there was a statistically significant increase in the walking distance of the ISWT at 8 weeks (307.1±23.5 m; $p<0.001$) and at 12 weeks (324.2±22.5 m; $p<0.001$) compared with baseline (255.8±20.6 m; fig. 1). The improvement lasted for 9 months until the end of the self-management period (306.7±21.2 m, $p<0.001$; fig. 1). The distance walked in the ISWT by patients in the cell phone group was significantly

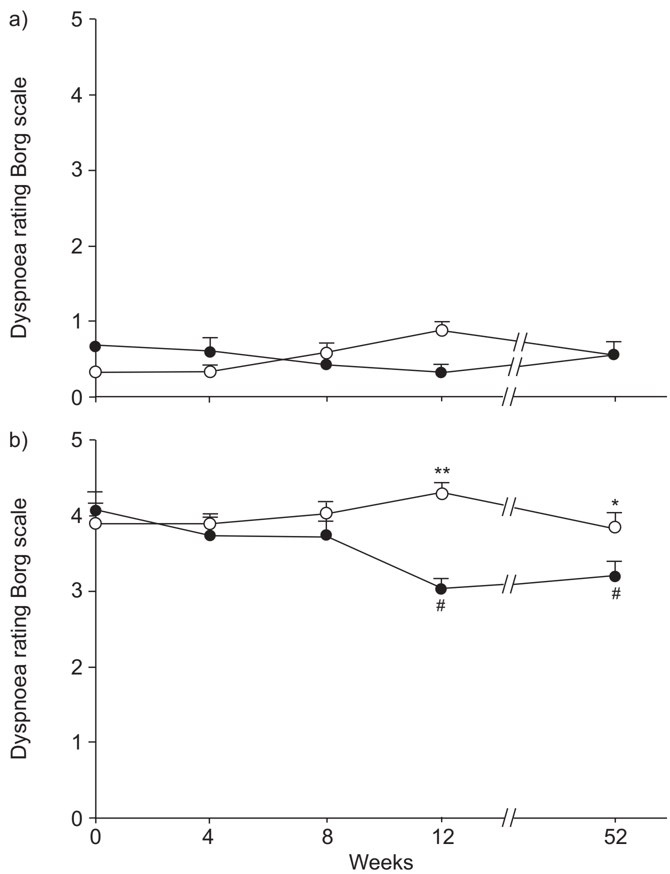

FIGURE 2. Dyspnoea rating (Borg scale) a) before and b) after incremental shuttle walk test (ISWT) at baseline and then every 4 weeks for 3 months and after 1 yr. In the control group (○), the Borg scale after ISWT was significantly greater than that of the cell phone group (●) at 12 weeks (3.0±0.1 *versus* 4.3±0.1, n=24) and after 1 yr (3.2±0.2 *versus* 3.9±0.2). Data presented as mean±SEM. #: p<0.01 compared with the baseline of the cell phone-group. *: p<0.05; **: p<0.01 *versus* cell phone group.

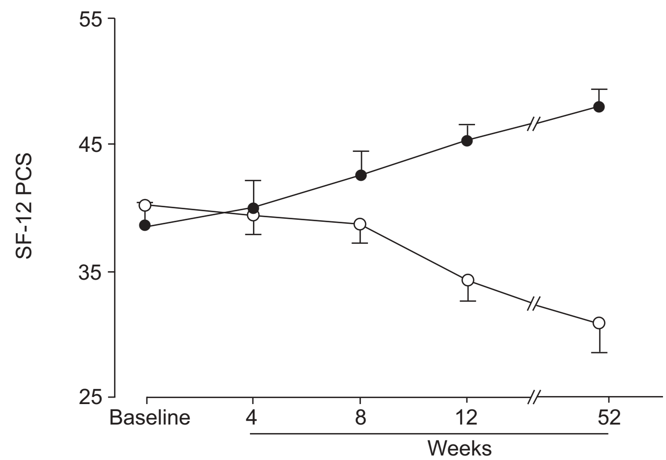

FIGURE 3. Quality of life questionnaire by Short Form-12 (SF-12) physical component summary scores (PCS) at baseline and then every 4 weeks for 3 months and after 1 yr. The SF-12 PCS values in the cell phone group (●) were significantly improved after 8 weeks (p<0.05; n=24), 12 weeks (p<0.01; n=24) and 1 yr (p<0.01; n=24) compared with the baseline, and were significantly greater than those of the control group (○) at 12 weeks (p<0.001; n=24) and 1 yr (p<0.001; n=24).

greater than that of the control group after 12 and 52 weeks of home exercise training (fig. 1).

There was no significant change in the resting breathlessness in either group throughout the course of the study (fig. 2). However, breathlessness measured by the Borg scale after the ISWT in the cell phone group was significantly decreased compared with that of the control group after 12 weeks of endurance walking exercise at home (3.0±0.1 *versus* 4.3±0.1; p<0.01), and at the end of the self-management period (3.2±0.2 *versus* 3.9±0.2; p<0.05; fig. 2).

Endurance walking exercise at home

Patients in the cell phone group performed the walking exercise at home at a frequency of ~4–6 days·week^{-1} in the first 3 months. The duration of endurance walking significantly increased after 8 weeks of home exercise training (1,887±221 s) compared with baseline (1,382±205 s; p<0.001), and a plateau was reached at 12 weeks (2,083±230 s). The patients' respiratory symptom scores decreased concomitantly with improvement in exercise tolerance. One patient dropped out of the control group because of acute respiratory failure requiring intubation, leading to death in the 10th month of the study. Patients in the cell phone group were asked to keep the same pace of walking without further adjustment in the following 9 months (the self-management period) of the home-based exercise training programme. During the self-management period, all these patients persistently continued their endurance exercise programme at a similar frequency and constant workload as the program installed on the cell phone. At the end of the study, 22 (92%) of the patients in the cell phone group maintained their regular endurance walking exercise. During the self-management period, only nine (38%) of the patients in the control group self-reported that they had maintained the regular walking.

Quality of life

Patients in the cell phone group showed improved quality of life with significant increases in their SF-12 physical component summary (PCS) scores at 8 weeks (42.5±1.8; p<0.05) and at 12 weeks (45.4±1.1; p<0.01) compared with baseline (38.7±1.8; fig. 3). The improvement in SF-12 PCS (47.9±1.5 *versus* 38.7±1.8; p<0.01) persisted for 9 months throughout the self-management period (fig. 3). In addition, the SF-12 PCS (45.4±1.1 *versus* 34.3±1.5; p<0.001) values in the cell phone group were significantly greater than in those of the control group after 12 weeks of exercise training. This difference persisted throughout the self-management period (47.9±1.5 *versus* 30.9±2.2; p<0.001). There was significant decrease of SF-12 PCS in the controls (p<0.001) at 1 yr compared with the data at baseline, 4 weeks and 8 weeks (30.9±2.2 *versus* 40.1±1.3, 39.5±1.7 and 38.7±1.5, respectively, p<0.05).

Clinical outcomes

The patients in both groups had GOLD stage III severity of COPD and all had previously experienced exacerbations of COPD, at the rate of one to two hospitalisations per year. Out of the 24 patients in the control group, 10 patients had 26

TABLE 2 Clinical outcomes during the 1-yr study period

	Cell phone group	Control group
Subjects	24	24
Daily regular walking	22 (92)	9 (38)**
Unscheduled visit		
Number of patients	2 (8)	10 (42)**
Number of visits	3	26**
Number of visits·patient^{-1}·yr^{-1}	0.13	1.08**
Hospitalisation		
Number of patients	2 (8)	8 (33)*
Number of hospitalisations	2	22**
Number of hospitalisations·patient^{-1}·yr^{-1}	0.08	0.92**
Length of hospital stay	8.5 (5–12)	7.5 (4–20)
Respiratory failures	0	2
Deaths	0	1

Data are presented as n, n (%) or median (range). *: p<0.05; **: p<0.01; compared with corresponding cell phone group.

episodes of acute exacerbation, most of which had occurred in the second half of the year, resulting in 26 unscheduled clinical visits and 22 hospitalisations in eight (33%) of these patients. Four unscheduled visits occurred in the exercise training period and during the self-management period, four and 18 events leading to hospitalisation took place during the initial 3 months and final 6 months, respectively. There was no hospitalisation due to causes other than acute exacerbation of COPD in the control group during the study period (table 2). The median (range) length of hospital stay was 7.5 (4–20) days and the total length of hospitalisation was 191 days. In the control group, two patients suffered from acute respiratory failure requiring intubation, which lead to the death of one patient (table 2). In contrast, only two patients in the cell phone-group suffered from acute exacerbation with hospitalisation, and there were only two hospitalisations (during hospital stay of 5 and 12 days) during the 1-yr study period (table 2).

Pulmonary function

There was no significant change in FEV1 in either group. The IC in the cell phone group significantly increased after 12 weeks of endurance walking exercise at home (1.75±0.07 and 1.53±0.06 L pre- and post-ISWT, respectively; $p<0.001$ for both comparisons) compared with baseline (1.59±0.06 and 1.30±0.06 L pre- and post-ISWT, respectively; fig. 4a and b). In the control group, there was no significant change in the IC either pre- or post-ISWT throughout the period of exercise training (fig. 4a and b). In addition, the change in IC on exercise, representing dynamic hyperinflation, was significantly decreased in the cell phone group (0.21±0.03 L; $p<0.001$) when compared with the control group (0.33±0.02 L) after 12 weeks of endurance exercise training at home (fig. 4c). The clinical benefits of the cell phone-based exercise training programme in improving IC (1.69±0.07 L pre-ISWT; $p=0.004$, 1.48±0.06 L post-ISWT; $p<0.001$) and dynamic hyperinflation (0.21±0.03 L; $p<0.05$) continued for 9 months until the end of the self-management period (fig. 4).

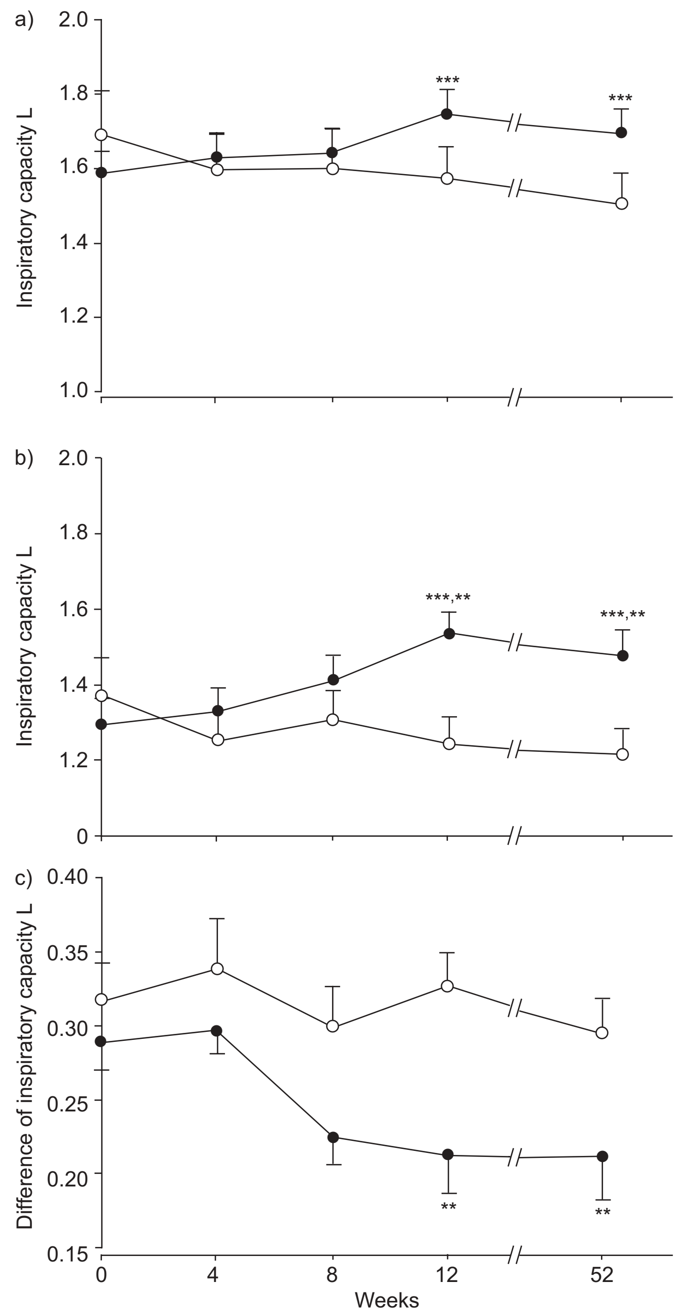

FIGURE 4. Inspiratory capacity a) before and b) after incremental shuttle walk test (ISWT) at baseline and then every 4 weeks for 3 months and after 1 yrs. a and b) In the cell phone group (●), the inspiratory capacity increased after 12 weeks ($p<0.001$; n=24) of endurance walking and after 1 yr ($p<0.001$, n=24) both pre- and post-ISWT compared with baseline. c) Change in inspiratory capacity on ISWT, representing dynamic hyperinflation, was significantly decreased in the cell phone group when compared with the control group after 12 weeks ($p<0.01$) and after 1 yr ($p<0.01$). ***: $p<0.001$ compared with baseline; **: $p<0.01$ compared with control group.

Compliance with home-based exercise

All patients in the cell phone group were adherent to the protocol during the exercise-training period. Of these, 12 (50%) patients were still adherent to the protocol throughout the self-management period and undertook regular endurance exercise walking assisted by cell phones and sent data to the website by GPRS. In addition, 10 (42%) patients also maintained endurance exercise with cell phone assistance, but stopped sending data by GPRS during the self-management period. Two (8%) patients refused to continue using cell phones during the self-management period. In contrast, during the self-management period, only nine (38%) patients in the control group self-reported regular walking exercise at home (table 2).

DISCUSSION

The present study has demonstrated that COPD patients, with the assistance of cell phones, are able to perform a home-based endurance exercise training programme at an intended walking speed controlled by a preset tempo of music. The duration of the endurance walking and daily respiratory symptoms can be monitored in real-time on the website. The adherence to an exercise programme was reinforced by telephone when patients missed a day of performing their walking training during the initial 3 months of the exercise-training period. The following 3 months of home-based exercise training, exercise capacity, respiratory symptoms, quality of life, IC before or after exercise and the change in IC on exercise, representing dynamic hyperinflation, were significantly improved in the cell phone group, but not in the control group. Without telephone reinforcement or frequent return visits to the clinic during the 9 months of the self-management period, 22 (92%) of the patients in the cell phone group were observed to maintain their regular exercise training programme at home. The clinical benefits of the endurance walking-exercise training in the cell phone-group persisted throughout the self-management period. Although the small number of patients studied precluded any definite statement about overall outcomes, it is of interest that only two patients in the cell phone group suffered from an exacerbation of COPD throughout the study, while eight patients in the control group experienced 26 episodes of acute exacerbation resulting in 22 hospitalisations and two respiratory failures.

Exercise training is the cornerstone of pulmonary rehabilitation. There are several reports showing that endurance exercise provides consistently high clinical efficacy [15, 19, 20, 33]. Training at low intensity, as well as at high intensity, achieves benefits, providing there is an equal amount of work per session [34]. However, several studies have demonstrated that patients obtain more benefit when they have a high-intensity training programme [35, 36]. In the present study, patients in both groups received home-based endurance walking exercise training at 80% of their maximal exercise capacity. The level of their endurance exercise was adjusted in the first 3 months in order to achieve maximum physiological benefits. Thereafter, patients walked at a constant work load in the self-management period to assess the clinical outcomes, persistence of physiological benefits and compliance to the home-based exercise training programme [37, 38].

Most exercise training, and other pulmonary rehabilitation programmes, are executed and supervised in the hospital. These programmes usually last for 4–12 weeks. Prolonging of a supervised pulmonary rehabilitation programme for 3–6 months may yield larger and more endurable training effects on the functional capacity and quality of life of patients [4, 7, 39]. However, patients should exercise at least three times per week with regular supervision in order to achieve optimal physiological benefits [40]. Owing to the necessity of regular returns to the hospital or clinics, patients' motivation and compliance are always the limiting factors [41]. Home-based rehabilitation programmes are preferred by patients, as they are able to spend more time with their families and, in addition, can adjust their training to suit their daily life. Currently, several home-based rehabilitation programmes have been developed with proven clinical benefits in quality of life and exercise tolerance [42–44]. However, some of these programmes entail an extreme degree of complexity. In many cases, in those programmes for which walking freely for a period of time is recommended, it is more difficult to establish the walking speed necessary to achieve a training effect at home [45]. A study of home-based rehabilitation has recently been conducted by HERNÁNDEZ *et al.* [41], using the shuttle walking test (SWT) to standardise the intensity of home-training programmes. There was a significant improvement observed with this programme in exercise tolerance, distance walked and dyspnoea at 12 weeks of rehabilitation, but not in the pulmonary function or effort parameters (SWT or cycle ergometer) [41]. However, the frequency and duration of exercise training at home are not well controlled in most established home-based exercise training programmes.

The clinical benefits obtained by the assistance of cell phones may be attributed to several factors. First, the walking speed is exactly controlled by the tempo of music to achieve the intended level of endurance training at home. Secondly, the duration of daily endurance exercise may be a good index for overall control in the status of COPD. Using cell phones, the daily record of endurance exercise duration is well monitored. The change in endurance exercise duration may draw attention to patients themselves and physicians who observe the data on the website, and early medical intervention may be implemented to prevent deterioration of COPD control. Thirdly, the long-term adherence to exercise training is the critical factor in sustaining the clinical benefit in the home setting programme; it declines when regular monitoring is removed [46, 47]. Using internet or cell phone technology, a feasible and acceptable method for the monitoring of adherence can be provided, even in elderly COPD patients [48, 49]. In the present study, good compliance and adherence to the exercise programme are additional factors that contribute to the maintenance of clinical benefits in the cell phone group during the self-management period.

The minimum clinically important difference of ISWT has not yet been published [50], but a review article and several new studies suggest the clinically significant difference for ISWT is ~48–60 m [51]. In the present study, the difference of distance (mean $\pm$ SD) in the ISWT after exercise training at 8 weeks, 12 weeks and 1 yr were 51.3 ± 38.5, 68.3 ± 46.6 and 50.8 ± 49.4 m, respectively. All of these differences had 99% power to detect these differences with a significance level (α) of 0.05 (two-tailed). It was suspected that the changes of distance could be larger if an endurance shuttle walk test was used rather than the ISWT [52]. However, the ISWT was performed to evaluate patients' maximal exercise capacity and determine the intensity of endurance walking at home.

The oxidative capacity and efficiency could be improved after exercise training, which leads to lower alveolar ventilation in the same exercise workload [11, 12]. In the current study, the change in IC on exercise, representing dynamic hyperinflation, were significantly improved in the cell phone group. The present authors speculate that the improvement of dynamic hyperinflation may be due to less breathlessness and alveolar ventilation on exercise, allowing for more expiratory time.

There was a trend for worsening of quality of life in the control group with significant decrease of SF-12 PCS at 1 yr compared with the data at baseline, 4 weeks and 8 weeks. This could be due to the increased number of exacerbations leading to hospitalisation, most of which occurred in the second half of the year. Another possibility is due to the fact that rehabilitation exercise was undertaken only infrequently during the self-management period.

Patients with COPD are heavy users of healthcare and social service resources [53, 54]. Although the benefits of pulmonary rehabilitation in decreasing hospitalisation, emergency department visits and number of unscheduled physician visits are well known [55], most training programmes are costly in terms of time, man power and resources. In addition to this, the patient-centred outcomes of health status and training adherence should be recorded in order to ensure quality control of the rehabilitation programme [56]. The current cell phone-assisted system may provide an efficient home-based exercise training programme, due to its controlled exercise workload and web-based supervision of exercise performance and daily respiratory symptoms. Even though patients were in a home-based setting, the current authors found that patients in the cell phone group could achieve significant clinical benefits after 8–12 weeks of exercise training. This clinical efficacy is similar to that of most hospital-based supervised programmes [4, 10, 57]. The good adherence in the cell phone group can be attributed to the user-friendly software and accurate walking speed for patients to follow [58]. Since the software is compatible with most commercial cell phones and the data are transmitted *via* GPRS, the monthly cost for each patient to use such a service in Taiwan is <US$10. Some of the COPD patients may find difficulty in operating this cell phone-based system. Patients who have hearing or visual impairment or those who are not familiar with or not able to operate cell phones are not suitable for this system. It also can not be guaranteed that the patient was actually walking during the whole duration of music played. However, music-paced walking is easy to perform and the fixed speed could supervise the intensity of home-based exercise training.

In summary, the present cell phone-based system provides an efficient home endurance exercise training programme with good compliance and clinical outcomes in improving exercise capacity, breathlessness, quality of life, inspiratory capacity and air-trapping in patients with moderate-to-severe chronic obstructive pulmonary disease. It is simple, reliable, easy to perform and time and cost saving. The significant clinical benefits include a reduction in acute exacerbation and early medical intervention; this will need to be confirmed in a larger study. Good compliance may encourage establishment of a more comprehensive telemedicine model for long-term home-based rehabilitation programmes and monitoring systems.

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