ERJ Express. Published on May 28, 2008 as doi: 10.1183/09031936.00104407

Efficacy of a cell-phone-based exercise program for chronic obstructive pulmonary disease

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Running title: Cell-phone-based home exercise for COPD

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Abstract

Application of a supervised endurance exercise training program in a home setting that offers convenience and prolonged effects is a challenge.

Forty eight patients were assessed by incremental shuttle walk test (ISWT), spirometry, and quality of life questionnaire (SF-12®) initially, every four weeks for three months and one year later. During the first three months, twenty four 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 in a cell phone. The level of endurance walking at home was re-adjusted monthly according to the result of ISWT. Twenty four patients in the control group 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 eight weeks. The improvements in ISWT distance, inspiratory capacity, and SF-12® scoring at 12 weeks persisted till the end of the study with less acute exacerbations and hospitalizations.

In this pilot study, the cell phone-based system provides an efficient home endurance exercise training program with good compliance and clinical outcomes in patients with moderate-to-severe COPD.

Key words: pulmonary rehabilitation, chronic obstructive pulmonary disease, shuttle walking tests, cell phone

Introduction

Pulmonary rehabilitation is becoming an essential part of the management of patients with chronic obstructive pulmonary disease (COPD) [1, 2]. Most pulmonary rehabilitation programs contain a comprehensive intervention that improves respiratory symptoms, and exercise capacity as well as quality of life [3]. An increasing number of reports show that pulmonary rehabilitation programs with supervised exercise training improves exercise tolerance, quality of life, activities of daily life, respiratory symptoms, exertional and overall dyspnea. It also decreases the need for hospitalization in COPD patients [4]. Most pulmonary rehabilitation programs 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 stumble blocks to the success of these programs [5]. Therefore, an alternative approach has been to consider home-based and self-managed rehabilitation programs which should also be supervised or at least closely monitored [6-8].

Exercise training is the cornerstone of pulmonary rehabilitation and is 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 work load with less dyspnea on exercise [13]. The lower limbs play an important role in exercise training programs because the quadriceps are the major muscles for patients' mobilization [14-16]. Even with light exercise, a weak lower limb will increase ventilatory demands to aggravate dynamic hyperinflation in COPD patients who may then discourage them from further exercise [17, 18]. A pulmonary rehabilitation program must contain an exercise training program 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 program in the home setting for prolonged effects remains a challenge[21-24].

We have developed a home-based exercise training program for stable COPD patients by asking them to walk at a speed controlled by the tempo of music from a program installed in a cell phone. The tempo of music is 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 web-site for storage and monitoring. This pilot study is the document for the first time the clinical efficacy, compliance and applicability of this home-based exercise training program supervised through a cell phone in patients with COPD.

Material and Methods

Study subjects

Forty-eight patients with moderate to severe COPD were recruited into this study. The diagnosis of COPD was compliant with the criteria of the GOLD guidelines as published in 2000 [25]. No subject had an acute exacerbation or received therapy with oral corticosteroids at least three months prior to the study, and all the subjects continued with a stable regimen of medications throughout the study. According to the GOLD guidelines that suggests the diagnosis of COPD in patients over age 40, in our study the patients below age 40 were excluded. Besides, the difficulty in operating the cell phone could be a problem in patients over age 80, they were excluded in this study as well. 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 program. Initially, we enrolled 60 patients and divided 30 of them into the cell-phone group according to the table of random numbers. Four patients in the cell-phone group withdrew from this study within 3 weeks due to the difficulty in operating the cell-phone. Another two patients in this group withdrew due to transport problems. In the control group, 2 patients dropped out due to COPD exacerbation within the first two weeks. Two patients in this group were lost to follow up after 3 months and another 2 patients suffered from other illness affecting exercise performance and transport problem, respectively. Finally, 48 patients were recruited into this 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. 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 Computing and High Performance Center. It is compatible with most commercially J2ME-enabled cell phones with General Packer Radio Service (GPRS). This study adopted the Sony Ericsson K600i® cell phone to execute the J2ME application for the endurance walking exercise by music pacing and data uploading through GPRS to the website.

Study design

At the start of this study, all the subjects were assessed by an incremental shuttle walking test (ISWT) [26], spirometry and quality of life questionnaire (SF-12®). Patients in the cell phone group were asked to take daily endurance exercise training with cell phone assistance. The level of endurance walking was re-assessed and re-adjusted initially at return clinical visits every four weeks in the first three months (the exercise training period). During this period of time, the adherence to protocol was reinforced by telephone whenever patients missed one day of their walking training. Patients were then asked to continue their exercise program at home at a fixed walking speed and to return to the clinic every three months for nine months (the self-management period). However, no telephone reinforcement was made during the self-management period. The adherence and compliance of the home-based exercise training program was assessed on the website by monitoring the frequency of performance and the duration of the endurance walking program every week. An exacerbation of COPD is defined as a change in the patient's baseline dyspnea, cough, and/or sputum, beyond normal day-to-day variations, that may warrant earlier return to clinic for a change in regular medication or hospitalization [27]. The clinical outcomes were therefore assessed for the episodes of acute exacerbation by recording the number of unscheduled visits and hospitalizations 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 clinic visits. All the patients performed ISWT, SF-12 and spirometry measurements every month in the first three months and at the end of the self-management period. In both groups, each patient was provided with a home rehabilitation program booklet and 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 Equation 1 below, we could estimate the peak oxygen uptake (VO_2peak) of ISWT. Then we determined the level closest to the speed derived from 80% of the predicted VO2peak value, representing 80% of the maximal capacity for endurance walking training at home [29].

Equation 1: $\text{Predicted VO2peak (ml/min/kg)} = 4.19 + (0.025 \times \text{ISWT distance})$

During the period of ISWT, we recorded the entire course by a camcorder to count the number of steps per shuttle at the according level. Using the walking speed and the number of steps per shuttle, we calculated the tempo of music for the appropriate walking speed (Equation 2). We then asked our patients to follow this individualized music tempo and to walk at a fixed pace to maintain a constant speed.

Equation 2: $\text{Tempo (beats per minute)} = \text{speed (km/h)} \times 100 \times \text{steps per shuttle} \div 60$

Home-based endurance exercise training

In the cell phone group, the music software with an individualized tempo and short questionnaires for recording respiratory symptoms was installed onto the patients' cell phones after being downloaded from our website. Patients were asked to perform an endurance exercise training everyday by turning on the program on the cell phones, filling out the questionnaires and walking at a speed following the tempo of music. Earphones were allowed to use if the music not loud enough for the patient to hear it. They were required to keep the walking speed until they could not catch up. Patients 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 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 covering respiratory symptoms including breathlessness, cough and sputum on the cell phone before they started endurance walking training everyday [30]. Pulmonary function tests were performed at the beginning of the study, at each return clinical visit every four weeks in the first three months and at the end of the self-management period. The forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, inspiratory capacity (IC) and breathlessness (rated by Borg's scale) were measured before and immediately after the ISWT. The walking distance of the ISWT, body mass index (BMI) and quality of life questionnaire (SF-12®) were also recorded in both groups at each visit.

Analysis

The primary endpoint of exercise training in this study was change of distance in ISWT from baseline value. The sample size calculation was performed by estimating the standard deviation for increased distance in ISWT. We calculated that 20 subjects would provide 99% statistical power for detecting a 50-meter 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 non-parametric Mann-Whitney test was applied to compare results between the two groups. Statistical significance was defined at $p < 0.05$. All data are presented as the mean ± SE.

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, gender, body mass index, 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 (Table 1).

Clinical efficacy of cell-phone-based endurance walking exercise program

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 eight weeks (307.1±23.5 M, $p<0.001$, $n=24$) and at 12 weeks (324.2±22.5 M, $p<0.001$, $n=24$) compared to the baseline (255.8±20.6 M, $n=24$) (Figure 1). The improvement persisted for nine months until the end of the self-management period (306.7±21.2 M, $p<0.001$, $n=24$) (Figure 1). The distance walked in the ISWT by patients of the cell phone group was significantly greater than that of the control group after twelve and 52 weeks of home exercise training (Figure 1).

There was no significant change in the resting breathlessness in either group throughout the course of the study (Figure 2). However, breathlessness measured by the Borg scale after the ISWT in the cell phone group was significantly decreased compared to that of the control group after 12 weeks of the endurance walking exercise at home (3.0±0.1 vs. 4.3±0.1, $p<0.01$, n=24) and at the end of the self-management period (3.2±0.2 vs. 3.9±0.2, $p<0.05$, n=24) (Figure 2).

Endurance walking exercise at home

Patients in the cell phone group performed the walking exercise at home at a frequency of around four to six days per week in the first three months. Their duration of endurance walking significantly increased after eight weeks of home exercise training (1887±221 sec, n=24) compared to the baseline (1382±205 sec, n=24, $p<0.001$), and they reached a plateau at 12 weeks (2083±230 sec, n=24). Their respiratory symptom scores decreased concomitantly with their improvement in exercise tolerance. One patient dropped out from the control group because of acute respiratory failure requiring intubation leading to mortality at 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 nine months (the self-management period) of the home-based exercise training program. All these patients persistently continued their endurance exercise program at the similar frequency and constant workload from the program installed on the cell phone during the self-management period. At the end of the study, 92% of the patients (n=22) in the cell phone group maintained their regular endurance walking exercise.

During the self-management period, only 38% of the patients (n=9) in the control group self-reported that they still kept up 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 scores at 8 weeks (PCS, 42.5±1.8, $p<0.05$, n=24) and at 12 weeks (45.4±1.1, $p<0.01$, n=24) compared to the baseline (38.7±1.8, n=24) (Figure 3). The improvement in SF-12 PCS (47.9±1.5 vs. 38.7±1.8, $p<0.01$, n=24) persisted for nine months throughout the self-management period (Figure 3). In addition, the SF-12 PCS (45.4±1.1 vs. 34.3±1.5, $p<0.001$, n=24) values in the cell phone group were significantly greater than in those of the control group after 12 weeks of exercise training and this difference persisted throughout the self-management period (47.9±1.5 vs. 30.9±2.2, $p<0.001$, n=24). There was significant decrease of SF12 PCS in the control ($p<0.001$) at 1 year compared with the data of baseline, 4 weeks and 8 weeks (30.9±2.2 vs. 40.1±1.3, 39.5±1.7 and 38.7±1.5, $p<0.05$).

Clinical outcomes

The patients in either group had GOLD stage 3 severity of COPD and all had previous exacerbation of COPD, at the rate of 1-2 hospitalizations per year. Among 10 out of 24 patients in the control group had 26 episodes of acute exacerbation and most of them occurred in the last half a year, resulting in total 26 unscheduled clinical visits, and 22 hospitalizations in 8 of these patients (33%, n=8). Four unscheduled visits occurred in the exercise training period and during the self-management period, 4 and 18 events leading to hospitalizations took place at the first 3 and the last 6 months, respectively. There was no hospitalization due to causes other than COPD acute exacerbation in patients of the control group during the study period (Table 2). The median length of hospital stay was 7.5 days (range, 4-20 days) and total stay was 191 days. Two of them suffered from acute respiratory failure requiring intubation leading to the death of one patient (Table 2). In contrast, only two patients in the cell phone group suffered from acute exacerbation with hospitalization, and only twice (hospital stay 5 and 12 days) during the study period of one year (Table 2).

Pulmonary function

There was no significant change in forced expiratory volume in one second (FEV1) in either group. The inspiratory capacity (IC) in the cell phone group significantly increased after 12 weeks of endurance walking exercise at home (1.75±0.07L before ISWT, $p<0.001$ and 1.53±0.06L after ISWT, $p<0.001$, n=24) compared with the baseline (1.59±0.06L before ISWT and 1.30±0.06L after ISWT, respectively) (Figure 4A). For patients in the control group, there was no significant change in the IC either before or after the ISWT throughout the period of exercise training (Figure 4A). Besides, the change in IC on exercise, representing dynamic hyperinflation, was significantly decreased in the cell phone group (0.21±0.03 L, $p<0.001$, n=24) when compared with the control group (0.33±0.02 L, n=24) after 12 weeks of endurance exercise training at home (Figure 4B). The clinical benefits of the cell phone based exercise training program in improving IC (1.69±0.07 L before ISWT, $p=0.004$ and 1.48±0.06 L after ISWT, $p<0.001$, $n=24$), and dynamic hyperinflation (0.21±0.03 L, $p<0.05$, $n=24$) persisted for nine months till the end of the self-management period (Figures 4).

Compliance with home-based exercise

All the patients in the cell phone group were adherent to the protocol during the exercise training period and 12 of them (50%) were still adherent to the protocol taking regular endurance exercise walking assisted by cell phones and sent data to the website by GPRS throughout the self-management period. Ten patients (42%) also kept the endurance exercise with cell phone assistance, but stopped sending data by GPRS during the self-management period. Two patients (8%) refused to continue using cell phones during the self-management period. In contrast, during the self-management period, only 38% of patients (n=9) in the control group self-reported regular walking exercise at home (Table 2).

Discussion

This study has demonstrated that COPD patients with the assistance of cell phones are able to perform a home-based endurance exercise training program at an intended walking speed controlled by a pre-set 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 program was reinforced by telephone when patients missed one day of performing their walking training during the first three months of the exercise training period. The following three months of home based exercise training, exercise capacity, respiratory symptoms, quality of life, inspiratory capacity before or after exercise and the change in inspiratory capacity on exercise, representing dynamic hyperinflation, were significantly improved in the group using the cell phones, but not in the control group. Without telephone reinforcement or frequent return visits to the clinic during the nine months of the self-management period, most of the patients (92%, n=22) in the cell phone group were observed to maintain their regular exercise training program 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 COPD exacerbation throughout the course, while there were eight in the control group who experienced 26 episodes of acute exacerbation resulting in 22 hospitalizations and 2 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 program [35, 36]. In this study, our 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 three months to achieve maximum physiological benefits. Thereafter, patients walked at a constant workload in the self-management period to assess the clinical outcomes, persistence of physiological benefits and compliance to the home-based exercise training program [37, 38].

Most exercise training and other pulmonary rehabilitation programs are executed and supervised in the hospital. Those programs usually last for four to twelve weeks. Prolongation of a supervised pulmonary rehabilitation program for three to six 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 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 programs are preferred by patients, since they are able to spend more time with their families and, in addition, can adjust their training to their daily life. Currently, several home-based rehabilitation programs have been developed with proven clinical benefits in quality of life and exercise tolerance [42-44]. However, some of those programs entail an extreme degree of complexity. In many cases, in those programs for which walking freely for a period of time are recommended, it is more difficult to even 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 standardize the intensity of home training programs. There was a significant improvement with this program in exercise tolerance, distance walked and dyspnea at twelve 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 programs.

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. Second, the duration of daily endurance exercise may be a good index for overall control in the status of COPD. Through 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. Third, the long-term adherence to the exercise training is the critical factor to sustain the clinical benefit in the home setting program, it declines when regular monitoring removed [46, 47]. Through the internet or cell phone technology, it provides a feasible and acceptable method for the monitoring of adherence even in the elderly COPD patients [48, 49]. In this study, the good compliance and adherence to the exercise program are additional factors contributing to the maintenance of those 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 the review article and new studies suggest the clinically significant difference for ISWT is about 48 to 60 meters [51]. In this study, the difference of distance (mean±SD) in the ISWT after exercise training at 8 weeks, 12 weeks and one year were 51.3±38.5, 68.3±46.6 and 50.8±49.4 m, respectively. All of them had 99% powers to detect these differences with a significance level (alpha) of 0.05 (two-tailed). It was suspected that the changes of distance could be larger if we used endurance shuttle walk test rather than the ISWT [52]. However, we performed the ISWT to evaluate these patients' maximal exercise capacity and determine the intensity of endurance walking at home.

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

There was a trend for worsening of life quality in the control group with significant decrease of SF12 PCS at 1 year compared with the data of baseline, 4 weeks and 8 weeks. This could be due to the increased number of exacerbations leading to hospitalization and most of them occurred in the last half a year. Another possibility is because that rehabilitation exercise was undertaken only infrequently during the self-management period.

Patients with COPD are heavy users of health care and social service resources [53, 54]. Although the benefits of pulmonary rehabilitation in decreasing hospitalization, emergency department visits and reducing number of unscheduled physician visits are well known [55], most training programs are costly in terms of time, manpower and resources. On top of this, the patient-centered outcomes of health status and training adherence should be recorded to ensure quality control of the rehabilitation program [56]. Our cell-phone assisted system may provide an efficient home-based exercise training program with its controlled exercise workload and web-based supervision of exercise performance and daily respiratory symptoms. Even though they were in a home-based setting, we found that patients in the cell phone group could achieve significant clinical benefits after eight to twelve weeks of exercise training. This clinical efficacy is similar to that of most hospital-based supervised programs [4, 10, 57]. We can attribute the good adherence in the cell phone group to the user-friendly software and accurate walking speed for patients to follow [58]. Since the software is compatible with most commercialized cell phones and the data are transmitted through GPRS, the monthly cost for each patient is less than USD 10 in Taiwan to use such a service.

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 used to or not able to operate cell phones are not suitable for this system. We also could not guarantee that the patient was actually walking during the whole duration of music played. However, music paced walking is easy to perform that the fixed speed could supervise the intensity of home-based exercise training.

In summary, our cell-phone-based system provides an efficient home endurance exercise training program 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 COPD. 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, which will need to be confirmed in a larger study. Good compliance may encourage establishing a more comprehensive telemedicine model for long term home-based rehabilitation programs and monitoring systems.

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Legends to Figures

Figure 1 Distance covered during the incremental shuttle walk test at baseline, every four weeks for 3 months and one year later in both groups. In the cell phone group, the distance increased significantly at eight weeks, twelve weeks and one year later compared to the baseline (**$p<0.001$). This was greater than that of the control group after twelve weeks and one year later ($^{\alpha}p<0.01$). $^{\#}p<0.05$ compared to the baseline of the control group. Data presented as mean±SE.

Fig. 1.

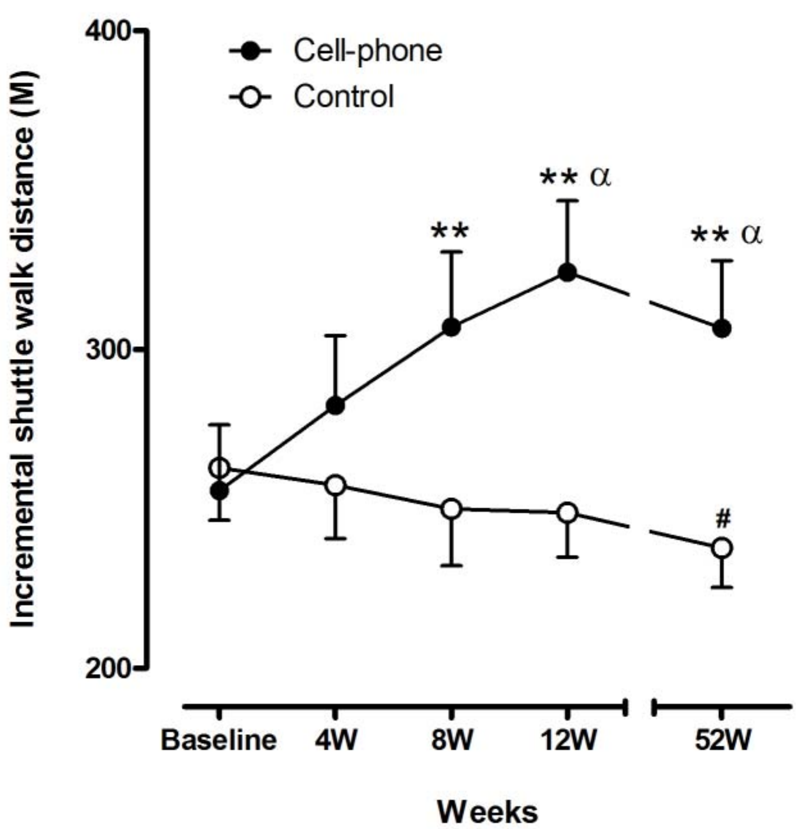


Figure 2 Dyspnea rating (Borg scale) before and after incremental shuttle walk test (ISWT) at baseline, every four weeks for 3 months and one year later in both groups. In the control group, the Borg scale after ISWT was significantly greater than that of the cell phone group at twelve weeks (3.0±0.1 vs. 4.3±0.1, $^{\varphi}$p<0.01, n=24) and one year later (3.2±0.2 vs. 3.9±0.2, #p<0.05). **p<0.01 compared to the baseline of cell-phone group. Data presented as mean±SE.

Fig. 2.

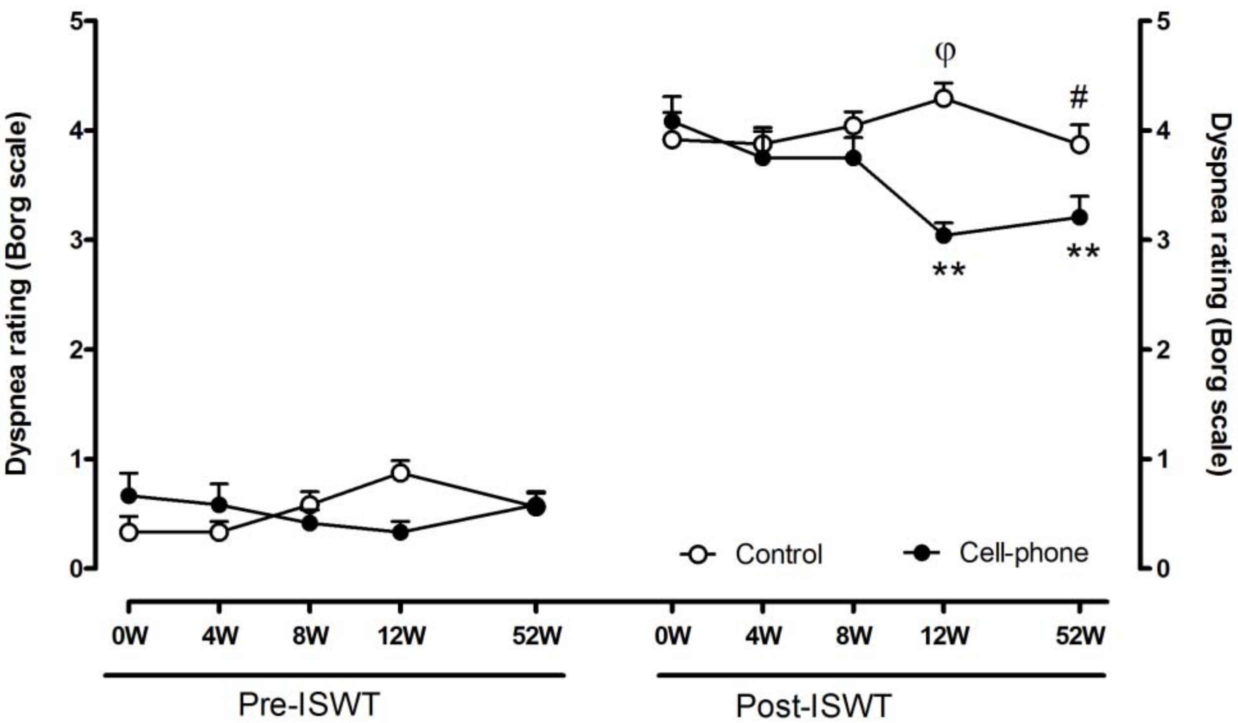


Figure 3 Quality of life questionnaire by SF-12 physical component summary scores (PCS) at baseline, every four weeks for 3 months and one year later in both groups. The SF-12 PCS values in the cell phone group were significantly improved after eight weeks (*p<0.05, n=24), twelve weeks (**p<0.01, n=24) and one year later (**p<0.01, n=24) compared to the baseline and were

significantly greater than that of the control group at twelve weeks ($^{\varphi}p<0.001$, n=24) and one year later ($^{\varphi}p<0.001$, n=24).

Fig. 3.

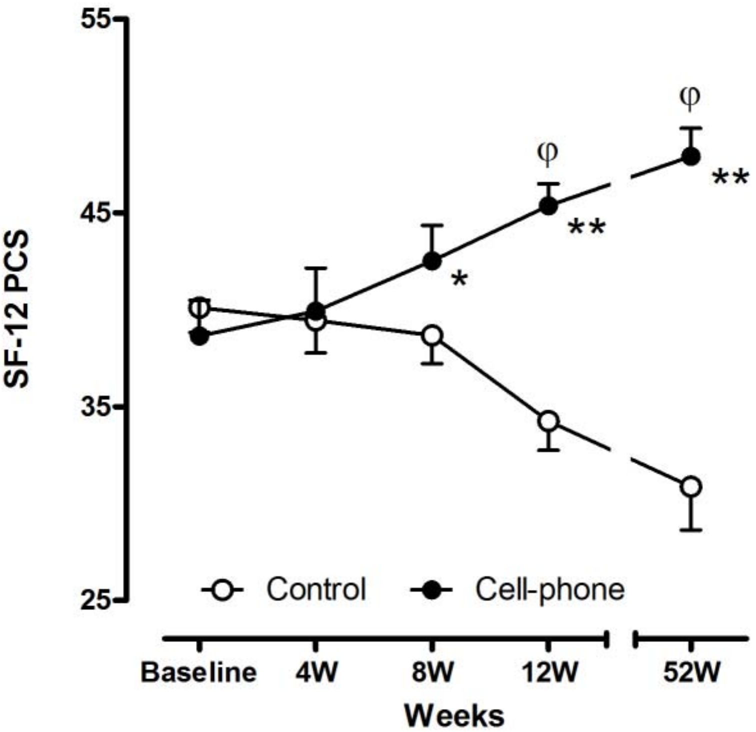
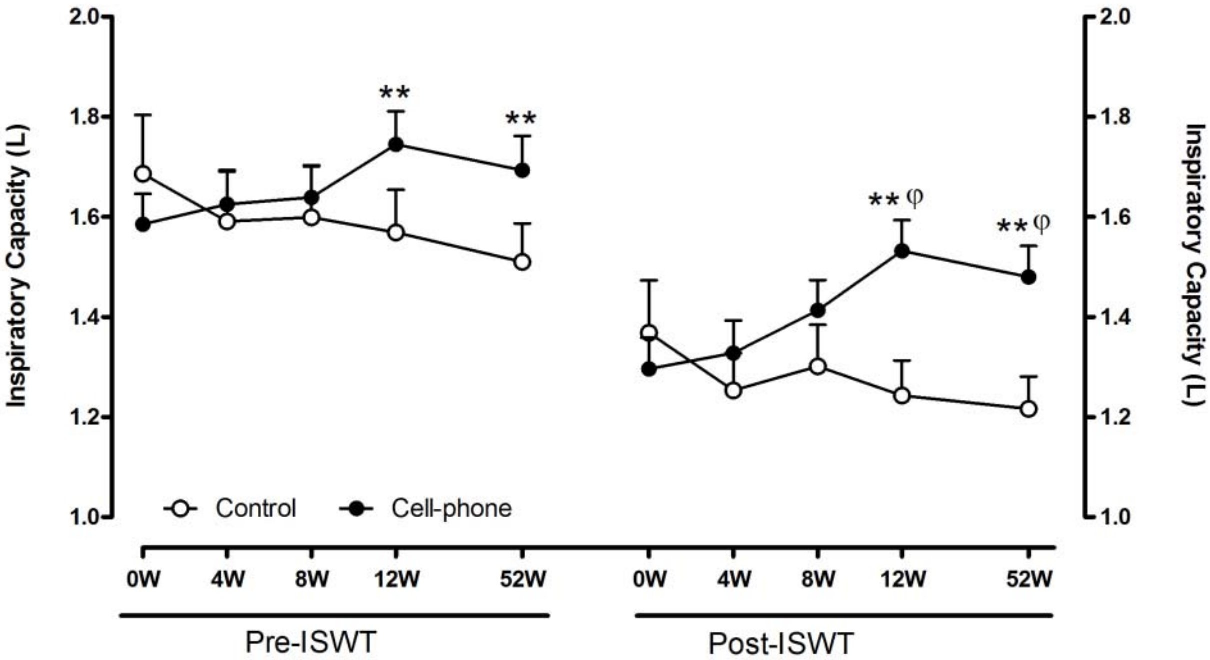


Figure 4 Inspiratory capacity before and after incremental shuttle walk test (ISWT) at baseline, every four weeks for 3 months and one year later. (A) In the cell phone group, the inspiratory capacity increased after twelve weeks (**p<0.001, n=24) of endurance walking and at the end of this study (**p<0.001, n=24) compared with the baseline. $^{\varphi}p<0.01$ compared to the control group. (B) Change in inspiratory capacity on ISWT, representing dynamic hyperinflation, was significantly decreased in

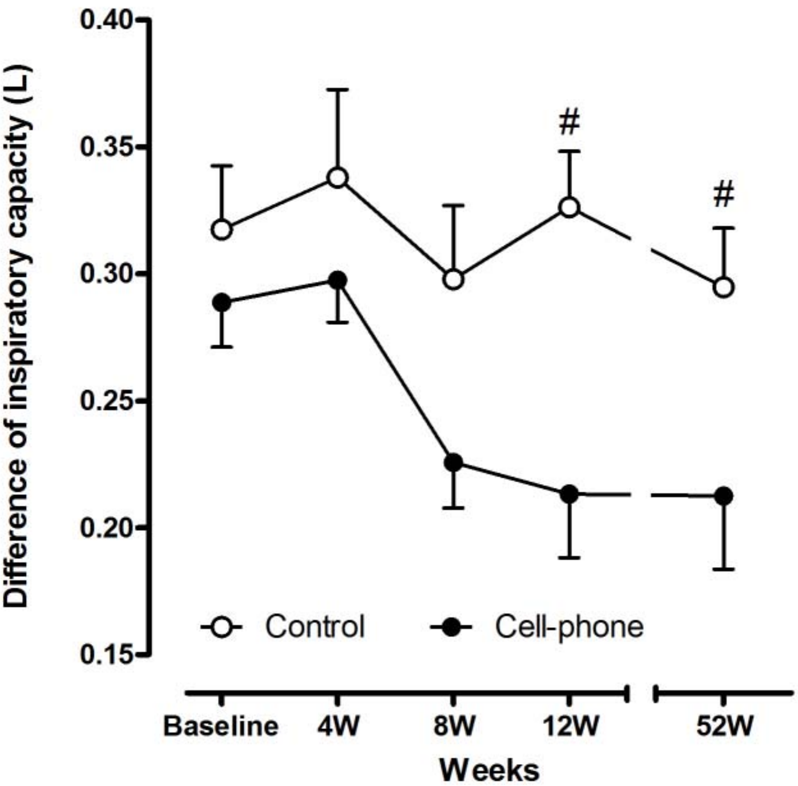
the cell phone group when compared with the control group after twelve weeks (#$p<0.01$) and at the end of the study (#$p<0.01$).

Fig. 4A.



Inspiratory Capacity (L)
2.0
1.8
1.6
1.4
1.2
1.0
**
**
** φ
** φ
Control
Cell-phone
0W
4W
8W
12W
52W
0W
4W
8W
12W
52W
Pre-ISWT
Post-ISWT
Inspiratory Capacity (L)

Fig. 4B.



Difference of inspiratory capacity (L)
0.40
0.35
0.30
0.25
0.20
0.15
#
#
Control
Cell-phone
Baseline
4W
8W
12W
52W
Weeks

Table 1 Characteristics of study subjects

	Cell phone (N= 24)	Control (N = 24)	*P*- value
Age, years	71.4 ± 1.7	72.8 ± 1.3	0.741
Male, No. (%)	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
Walking distance (ISWT), M	255.8 ± 20.6	262.9 ± 16.5	0.464
FVC, L	1.87 ± 0.07	2.00 ± 0.13	0.718
FEV1, L	0.97 ± 0.06	0.99 ± 0.06	0.951
FEV1, % predicted	45.2 ± 3.2	46.0 ± 2.8	0.918
FEV1/FVC, %	51.8 ± 2.8	50.8 ± 2.4	0.650
IC of pre-ISWT, L	1.59 ± 0.06	1.69 ± 0.12	0.789
IC of post-ISWT, L	1.30 ± 0.06	1.37 ± 0.11	0.934
∆IC*	0.29 ± 0.02	0.32 ± 0.03	0.322

Definition of abbreviations: PCS = physical component summary scores; ISWT = incremental shuttle walk test; FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity; IC = inspiratory capacity

* Change in inspiratory capacity on exercise

Table 2 Clinical outcomes during the study period of one year

	Cell phone (N=24)	Control (N = 24)
Daily regular walking, (%)	22 (92%)	9 (38%)**
Unscheduled visit,		
Number of patients (%)	2 (8%)	10 (42%)**
Number of visits	3	26**
Number of visit per patient	0.13	1.08**
Hospitalization,		
Number of patients (%)	2 (8%)	8 (33%)*
Number of hospitalization	2	22**
Number of hospitalization per patient	0.08	0.92**
Length of hospital stay, median (range)	8.5 (5-12)	7.5 (4-20)
Number of respiratory failure	0	2
Number of deaths	0	1

**p<0.01, *p<0.05 compared with corresponding cell phone group