Effect of Lower Extremity Exercise on Muscle Strength and Physical Capacity in COPD Patients

Anoma Santiworakul MSc*,
Suwannee Jarungjitaree MSc**, Wattana Jalayondeja PhD**,
Somchai Chantarothorn MD***, Supoj Supaibulpipat MD****

** School of Allied Health Sciences and Public Health, Walailak University, Nakhon Si Thammarat, Thailand*
*** Faculty of Physical Therapy and Applied Movement Science, Mahidol University, Nakhon Pathom, Thailand*
**** Department of Pulmonary Medicine, Somdej Phrapinklao Hospital, Bangkok, Thailand*
***** Department of Medicine, Nopparatrajathanee Hospital, Bangkok, Thailand*

Objective: *Investigate the effect of lower extremity exercise on maximum lower extremity muscle strength and physical capacity in COPD patients.*
Material and Method: *Twenty moderate to very severe COPD patients were allocated into trained and control groups. The trained group received eight weeks of lower extremity functional exercise including forward step up, lateral step up, heel raise, and lunge at home. Maximum muscle strength and Six Minute Walk Distance (6MWD) assessments were performed at pre-training, week 4, and week 8 in hospital settings.*
Results: *There was no significant difference between trained and control groups in maximum muscle strength and 6MWD at the beginning of the program. However, there was a significant improvement in 6MWD after eight weeks of training, whereas there were no significant differences in the control group.*
Conclusion: *Functional exercise may improve physical capacity in moderate to very severe COPD patients. It is beneficial and easy to perform at home.*

Keywords: *Exercise test, Exercise tolerance, Lower extremity, Muscle strength, Pulmonary disease, Chronic obstructive, Walking*

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Exercise intolerance is a characteristic and greatly troubling indication of COPD. Patients with COPD are limited commonly in their abilities to perform usual tasks, such as work activities, recreational exercise, and hobbies(1-3). The physiologic mechanisms of exercise intolerance are increasing airways resistance, ineffective ventilation, hyperinflation and increased elastic load to breathing, gas exchange abnormalities, and mechanical disadvantage of the respiratory muscles(4,5). Skeletal muscle dysfunction is another important factor that can contribute to exercise intolerance(6-9). Peripheral muscle dysfunction arises from muscle weakness, decondition, malnutrition, corticosteroids, inadequate levels of growth hormone and testosterone as well as chronic hypoxemia or hypercapnia(6,10). Characteristics of muscle dysfunction in COPD are muscle strength and endurance decreasing whereas muscle fatigability is increasing. There are reduced proportions of type I fibers and the increase in type II fibers. Muscle atrophy occurs with a reduction in fiber cross-sectional area. Oxidative enzyme activity and aerobic capacity during exercise are reduced(6,8,10-13). The impaired muscle strength and endurance are associated with reduced exercise capacity contributing to impaired quality of life and cause to increase use of health care resources in COPD patients(6,8,10,14).

An exercise program for improving the skeletal muscle dysfunction in COPD, especially muscle training will be helpful in the mechanism of deconditioning from disuse that is believed to be a major contributing factor of the skeletal muscle dysfunction(6,10). Functional exercise is an exercise program for improving muscle

Correspondence to: Jarungjitaree S, Faculty of Physical Therapy and Applied Movement Science, 999 Phuttamonthon 4 Road Salaya, Phuttamonthon, Kakhon Pathom 73170, Thailand. Phone: 0-2441-5450, E-mail: ptsjr@mahidol.ac.th

function as the activity of muscle is the same as in functional use in daily activity. It is easy to do and can be trained at the patients' home. Home program exercise can eliminate the difficulty of patients in their traveling and leads to decreased cost of treatment[15]. Functional exercise such as stair climbing is integrated strength of the quadriceps, hamstrings, hip flexors and extensors and plantar flexors[16,17]. In daily life, it is common to utilize large muscle groups of lower extremity in any activity such as walking, stairs climbing, standing from the chair, standing from the floor, and heel raise to picking up the object on a high shelf. Functional exercise for lower extremity is important to generate muscle function and improves functional performance in COPD patients. In COPD patients, Clark et al, 1996 studied the effect of lower intensity of peripheral muscle exercise of both upper and lower extremities on pulmonary function, muscle performance, whole body endurance, and maximal exercise capacity. They found that functional exercise improved peripheral muscle endurance and whole body endurance[18]. O'Donnell et al, 1998 studied the effect of general exercise at the highest attainable work rate for the longest tolerable duration. The results showed significant improvement in quadriceps strength and endurance, exercise endurance, and maximum inspiratory pressure (MIP) & maximum expiratory pressure (MEP)[19]. In addition, several studies found that functional exercise improved muscle strength, endurance, and functional performance in older and healthy adults[16,20-22].

Functional exercise is a countermeasure to muscle dysfunction but the study of the effect of functional exercise in COPD patients, especially in low loading strengthening exercise is still lacking. The present study, aimed to investigate the effect of exercise for muscle dysfunction improvement by lower extremity training on muscle performance and physical capacity in patients with COPD.

Material and Method

Subjects

COPD patients with moderate to very severe obstruction (FEV_1/FVC < 70% and FEV1< 80% predicted) ranged from 61 to 74 years old, were included in the present study[23]. All COPD patients received optimal bronchodilator therapy and were medically stable. Patients with a symptomatic heart disease, uncontrolled hypertension, diabetic mellitus, musculo-skeletal problems, which limits test and exercise, and on prednisolone more than 10 mg/day were excluded.

Twenty-six male patients with COPD were divided into two groups; training and control groups. Both groups were interviewed about age, weight, height, medication, smoking years, quit smoking years, and were assessed by pulmonary function test to classify state of COPD. Ethical approval for the present study was granted by the Ethical Committee on Research Involving Human Subject, Faculty of Medicine, Siriraj Hospital, Mahidol University.

Procedure

The patients who met the inclusion criteria signed an approved informed consent prior to participation. All patients were interviewed about history and performed pulmonary function test. The maximum lower extremity muscle strength and six-minute walk measurements were repeated at the end of week 4 and week 8.

Pulmonary function

Determinations of forced expiratory spirometry including force vital capacity (FVC) and force expiratory volume in one second (FEV_1) were achieved by using a spirometer (SCHILLER Spirovit SP-1, USA), according to standard procedures of American Thoracic Society for measurement spirometry[24]. Each spirometric parameter was determined 3-8 times and accepted when the variation between each trial was less than 0.2 L[24].

Measurement of maximum lower extremity muscle strength

Maximum lower extremity muscle strength value was evaluated by using back and leg dynamometer. The patient stood on a platform with trunk erected and the knees flexed to an angle of 135°. The patient's hands held the hand bar using a pronated grip and position across the thighs by adjusting the length of the chain. The patient slowly extended their legs with a maximal contraction of lower extremity muscle without using the back muscle. The subject received encouragement until there were no further changes of the scale. The test was performed three times with 1-min rest interval or rest until the patient did not show sign of dyspnea between trials; the highest value was selected (kg).

Measurement of six minute walk test

Distance was measured after the patients had to walk at their own pace in the period of 6 minutes. This test performed along 15-meter walkways, which had a chair placed at each end. The patients were instructed to walk from end to end as far as they could in six minutes and allowed slowing down or stopping as necessary. If the patient had to stop for resting, the duration of the resting period was recorded. The patient received instruction and standardized encouragement according to standard procedures of American Thoracic Society for measurement six-minute walk test[25]. Parameters including heart rate, respiratory rate, oxygen saturation, rating of perceived exertion, and fatigue scale were recorded at before and after the walking test.

Intervention

The trained group received the functional training, home program, including heel raise, forward step up, lateral step up and lunge exercises for eight weeks. Each exercise position was divided by the intensity into 5 steps as shown in Fig. 1. The intensity of step 1 to 3 was progressively increased by the body position and gravity, whereas the intensity of step 4 and 5 was increased by the elastic band (one-band and double-band for step 4 and 5, respectively). Prior to training, all patients were tested for the appropriate exercise level of each exercise position. The individual's appropriate exercise level in each position was defined as the number of steps that the patient could not perform the exercise more than 15 repetitions by leg fatigue. The final step and the number of the repetitions that the patient could perform were recorded and used to be the first exercise level of each patient. As a result, most of the trained group started exercise level from step 2 to 3 in heel raise, forward step up and lateral step up, whereas they started exercise level from step 1 to 3 in lunge exercise. The patients were trained for the functional exercise three times/day (morning, afternoon, and evening), three days/week, for eight weeks. Before and after completing each training session, the patients were asked to stretch their lower extremities muscles, which are glutral, quadriceps, hamstring, and gastrosoleus muscles for 3-5 repetitions/muscle group. Every week, each patient was contacted by phone to check and discuss about their exercise. The exercise intensity was adjusted every month. The result of the present study revealed that the level of exercise intensity increased 1-2 steps after completing four weeks of the exercise program. After completing the 4th week of exercise training, the patients increased the exercise intensity by testing the appropriate exercise level in each exercise position, the same as prior to participating in the training program. The patients were trained with this exercise intensity for four weeks.

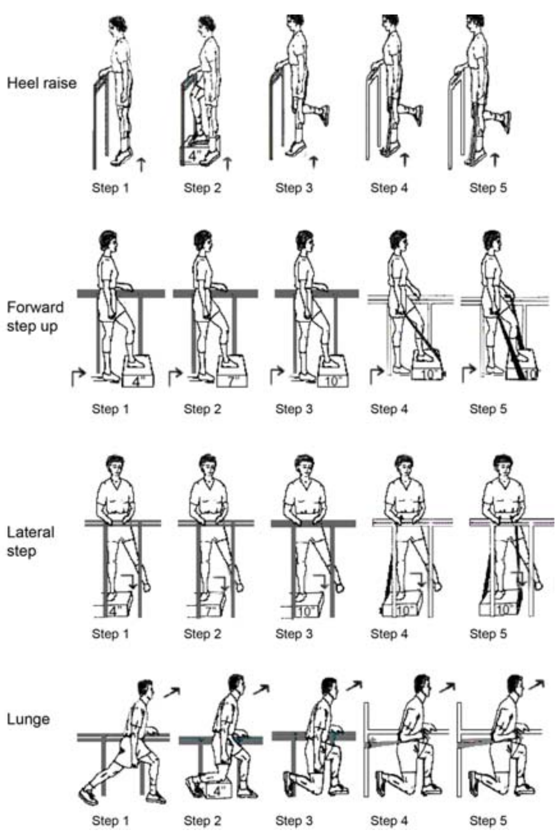


Fig. 1 Functional training including heel raise, forward step up, lateral step up, and lunge

Data analysis

The results were reported as means $\pm$ SD. Distribution of data was tested by one sample Kolmogorov-Smirnov Goodness of fit test. Two-way ANOVA was used to test for the differences of maximum lower extremity muscle strength test and six minutes walk distance. If there was a significant difference, Bonferroni correction was used as a post-hoc test. Statistical significance was defined as p less than 0.05.

Results

Twenty-six male outpatients with COPD volunteered to participate in the present study. Six patients (four in the trained group and two in the control group) did not complete the program. Two subjects were excluded because of acute exacerbations of COPD and one subject had severe upper respiratory infection during week 4-6 of the exercise program and one subject had an ankle injury while working which limited the exercise training. Two of the subjects refused to continue the program because they could not continuously follow the exercise program. Thus, ten patients were in the trained group who received eight weeks of home program of functional exercise and the other ten patients were in the control group.

Characteristics of subjects

Twenty male patients with moderate to very severe obstruction (FEV_1 of 1.23 $\pm$ 0.43 liters, 41 $\pm$ 14% of predicted value) ranged from 61 to 74 years old, were included in the present study[23]. The physical characteristics and lung function of patients in trained and control groups are presented in Table 1. Age, weight, height, BMI, FEV_1, % FEV_1 predicted, smoking years, quit smoking years were compared. No significant differences were detected between the groups ($p > 0.05$). Thus, the two groups had similar significant characteristics.

Effect of functional exercise on maximum lower extremity muscle strength

Maximum lower extremity muscle strength was determined by leg dynamometer test value. The effects of functional exercise on maximum lower extremity strength are shown in Fig. 2. After 4 and 8 weeks of training, maximum lower extremity muscle strength in both trained and control groups showed no significant difference from pre-training. There were no significant differences between control and trained groups at pre-training ($p = 0.770$), week 4 ($p = 0.919$), and week 8 ($p = 0.676$).

Effect of functional exercise on physical capacity

Physical capacity was determined by the six-minute walk distance. The effects of functional exercise on the six-minute walk distance are shown in Fig. 3. The trained group was significantly increased in six minute walk distance after four weeks (≤ 0.001) and eight weeks (≤ 0.001) of training (Fig. 3), whereas this was not found in the control group. However, the comparison between groups significant was not difference at pre-training ($p = 0.730$), week 4 ($p = 0.443$) and week 8 ($p = 0.289$).

Table. 1 Characteristics of control and trained groups at pre-training

Variable	Control group (n = 10) (mean $\pm$ SD)	Trained group (n = 10) (mean $\pm$ SD)	p-value
Age (years)	68.30 $\pm$ 4.57	70.80 $\pm$ 2.66	0.182[a]
Weight (kg)	69.30 $\pm$ 11.05	60.80 $\pm$ 11.13	0.104
Height (cm)	166.80 $\pm$ 3.85	164.40 $\pm$ 4.93	0.241
BMI	24.84 $\pm$ 3.38	22.52 $\pm$ 4.31	0.198
FEV_1 (liter)	1.34 $\pm$ 0.42	1.11 $\pm$ 0.42	0.233
% FEV_1 predicted	44.00 $\pm$ 14.00	39.00 $\pm$ 15.00	0.417
Smoking years	44.70 $\pm$ 9.30	46.60 $\pm$ 10.35	0.671
Quit smoking years	3.50 $\pm$ 4.43	3.40 $\pm$ 4.22	0.959

Test by independent t-test, except[a] test by Mann-Whitney test

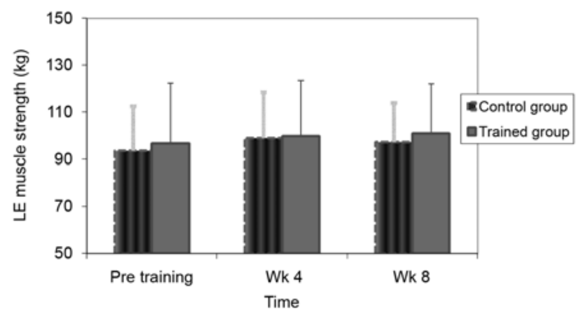
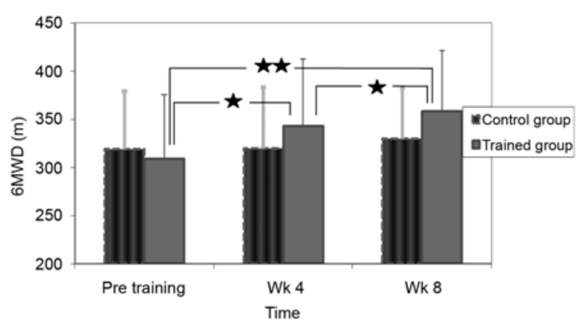


Fig. 2 Effect of functional exercise on maximum lower extremity muscle strength



★ Significant difference at $p \leq 0.001$

★★ Significant difference at $p = 0.05$

Fig. 3 Effect of functional exercise on six minute walk distance

Discussion

Twenty male COPD patients participated in the present study. The patients received the standard treatment and were followed up by specialists in pulmonary medicine. All patients received oral bronchodilator (xanthine group) and inhale bronchodilator.

Level of airflow obstruction in a COPD patient indicated functional ability of each patient. At moderate obstructive level and below, patients limited their activities and got worse when obstructive level was increased[23]. In the present study, COPD patients with moderate to very severe were included.

Effect of functional exercise on maximum lower extremity strength

The result showed that the maximum lower extremity muscle strength at pre-training were 93.65 $\pm$ 18.92 kg and 96.65 $\pm$ 25.83 kg in the control group and the trained group, respectively. The value was lower than normal subjects of Corbin et al's study. They studied the norms of healthy subjects. They found that the static leg strength at below 123 kg in persons over 50 years old presented very poor strength level[26]. Agreement with several studies revealed COPD patients had lower muscle strength in lower extremity than healthy people of the same age because of muscle dysfunction[7,8,27].

In the present study, maximum lower extremity muscle strength in both groups showed no difference at week 8 compared to pre-training. Several researches showed the positive effect of functional exercise on muscle strength in healthy subjects, older adults and COPD patients[16,19-22]. In contrast, some researches did not show improvement of muscle performance in their subjects[18,28,29]. Each study had a different pattern, detail in exercise program and specific measurements. These differences are explained in the following section.

1) Low load exercise: Training and adapting response for resistance exercise appeared to have a specific relationship. Delorme, 1945 suggested that a resistance-training program using low repetition/high resistance led to adaptation for strength/power, whereas training with high repetition/low resistance induced muscle endurance[30]. ACSM guidelines, 2006 suggested that resistance exercise program at 8-12 repetitions maximum (RM) could improve maximum muscle strength[31]. Heyward, 1998 recommended that dynamic resistance exercise program should be 4-8 RM for strength, 10-12 RM for hypertrophy, 15-20 RM or higher for endurance[32]. As mentioned above, it seemed that 10-15 RM specified in lower extremity muscle exercise might not be enough to improve maximum muscle strength in the present study. However, safety and psychological effect in the patients would be considered. Patients with COPD commonly assumed sedentary lifestyle to avoid the dyspnea[10]. They had ventilatory limitation and muscle dysfunction[6,10]. High load exercise also produced risk to injury from exercise and affected psychological condition[33,34].

2) Specificity of the measurement: Back and leg dynamometer test was safe for patients because isometric test had a low risk of muscle fiber tear, high reliability, and easy to test[35,36]. However, isometric test could not completely determine the effect of dynamic exercise. The neuronal and mechanical factors had different influence on the dynamic and isometric test. In mechanical factor, isometric test was specific to velocity of zero and angle at measurement angle. Dynamic exercise required dynamic activation of musculature through a movement range[37,38]. Another factor was neural activation of muscle. Isometric and dynamic activation might be different in the specific recruitment patterns[39]. However, Hortobagyi et al, 1996 showed that isometric test could determine the improvement of muscle strength in dynamic exercise but the measurement value was lower than dynamic strength test[40]. Possibly, the exercise program in the present study might not improve maximum muscle strength resulting from specific measurement.

Effect of functional exercise on physical capacity

The six-minute walk distance (6MWD) represented physical capacity of the subject. The test values were 318.88 $\pm$ 60.61 meters in the control group and 308.96 $\pm$ 66.62 meters in the trained group at pre-training. The comparison of test value between the patient in the present study and healthy adults from other studies at similar age demonstrated that the patient had lower 6MWD[41,42]. Thus, the COPD patients had lower physical capacity than healthy subjects.

The study revealed that the six-minute walk distance in COPD patients had significant difference in week 4 and week 8 of training in the trained group whereas no change in the control group. This result agreed with previous studies that studied the effect of functional exercise on physical capacity in older subjects and COPD patients[19,22]. O'Donnell et al, 1998 studied the effect of general exercise on muscle performance and 6MWD. They found a significant difference in 6MWD between the control and trained group[19], while Bean et al, 2002 studied the effect of weighted stair climbing exercise on muscle performance and 6MWD in older subjects. They also found significant increase in 6MWD after the training program[22]. According ATS, 2002, the six-minute walk distance was higher than 17% from baseline of the present study showing the improvement in clinic[25]. This confirmed that functional exercise has an impact on physical capacity.

The six-minute walk distance was a sub-maximal exercise test. It could determine over all involved systems during exercise. As activity of daily living was performed at sub maximal level, 6MWD possible reflected the functional exercise level for daily activity in COPD patients[25]. The present study revealed that COPD patients had improvement of functional activity after functional exercise training. However, increasing in 6MWD did not specify the improvement system. Improvements in 6MWD may also come from respiratory and neuromuscular systems. Ventilatory requirement decreasing during exercise desensitized dyspnea, which may be the mechanism for improving respiratory system[43]. Repeat test measurement induced coordination, walking adjustment and reduced anxiety during test, those produced improvement in the neuromuscular system[25]. Further investigations in this matter are needed.

Clinical implication and future study

Functional exercise can improve physical capacity in COPD patients. Functional exercise, including forward step up, lateral step up, heel raise and lunge, are the lower extremity muscle exercise which are close to activities in daily living. The present study proved that they were effective and did not produce injury.

The further study should emphasize on the progressive loading of functional exercise program for strengthening lower extremity muscles. The longer duration than eight weeks of exercise program should be considered in pulmonary rehabilitation prescription for significant effect. The specific test will be required to measure exercise effect, dynamic strength test. The direct physiological measurement should be performed for observing physiological changes in muscle, respiratory and others. Additionally, quality of life is another interesting parameter.

Conclusion

Functional exercise of lower extremity muscles improved physical capacity in COPD patients after eight weeks of training. It is a simple and easy exercise program to perform at home. It can be applied to a training program for COPD patients and may be modified for other groups of patients who have muscle dysfunction of lower extremities.

References

1. Ries AL, Bauldoff GS, Carlin BW, Casaburi R, Emery CF, Mahler DA, et al. Pulmonary rehabilitation: Joint ACCP/AACVPR evidence-based clinical practice guidelines. Chest 2007; 131: 4S-42S.
2. Bourjeily G, Rochester CL. Exercise training in chronic obstructive pulmonary disease. Clin Chest Med 2000; 21: 763-81.
3. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005; 171: 972-7.
4. Gallagher CG. Exercise limitation and clinical exercise testing in chronic obstructive pulmonary disease. Clin Chest Med 1994; 15: 305-26.
5. Richardson RS, Sheldon J, Poole DC, Hopkins SR, Ries AL, Wagner PD. Evidence of skeletal muscle metabolic reserve during whole body exercise in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med 1999; 159: 881-5.
6. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. A statement of the American Thoracic Society and European Respiratory Society Am J Respir Crit Care Med 1999; 159: S1-40.
7. Bernard S, LeBlanc P, Whittom F, Carrier G, Jobin J, Belleau R, et al. Peripheral muscle weakness in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med 1998; 158: 629-34.
8. Hamilton AL, Killian KJ, Summers E, Jones NL. Muscle strength, symptom intensity, and exercise capacity in patients with cardiorespiratory disorders. Am J Respir Crit Care Med 1995; 152: 2021-31.
9. Gosselink R, Troosters T, Decramer M. Peripheral muscle weakness contributes to exercise limitation in COPD. Am J Respir Crit Care Med 1996; 153: 976-80.
10. Mador MJ, Bozkanat E. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. Respir Res 2001; 2: 216-24.
11. Allaire J, Maltais F, Doyon JF, Noel M, LeBlanc P, Carrier G, et al. Peripheral muscle endurance and the oxidative profile of the quadriceps in patients with COPD. Thorax 2004; 59: 673-8.
12. Mador MJ, Deniz O, Aggarwal A, Kufel TJ. Quadriceps fatigability after single muscle exercise in patients with chronic obstructive

pulmonary disease. Am J Respir Crit Care Med 2003; 168: 102-8.
13. Couillard A, Maltais F, Saey D, Debigare R, Michaud A, Koechlin C, et al. Exercise-induced quadriceps oxidative stress and peripheral muscle dysfunction in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2003; 167: 1664-9.
14. Decramer M, Gosselink R, Troosters T, Verschueren M, Evers G. Muscle weakness is related to utilization of health care resources in COPD patients. Eur Respir J 1997; 10: 417-23.
15. Hernandez MT, Rubio TM, Ruiz FO, Riera HS, Gil RS, Gomez JC. Results of a home-based training program for patients with COPD. Chest 2000; 118: 106-14.
16. Cress ME, Conley KE, Balding SL, Hansen-Smith F, Konczak J. Functional training: muscle structure, function, and performance in older women. J Orthop Sports Phys Ther 1996; 24: 4-10.
17. Wang MY, Flanagan S, Song JE, Greendale GA, Salem GJ. Lower-extremity biomechanics during forward and lateral stepping activities in older adults. Clin Biomech (Bristol , Avon) 2003; 18: 214-21.
18. Clark CJ, Cochrane L, Mackay E. Low intensity peripheral muscle conditioning improves exercise tolerance and breathlessness in COPD. Eur Respir J 1996; 9: 2590-6.
19. O'Donnell DE, McGuire M, Samis L, Webb KA. General exercise training improves ventilatory and peripheral muscle strength and endurance in chronic airflow limitation. Am J Respir Crit Care Med 1998; 157: 1489-97.
20. Worrell TW, Borchert B, Erner K, Fritz J, Leerar P. Effect of a lateral step-up exercise protocol on quadriceps and lower extremity performance. J Orthop Sports Phys Ther 1993; 18: 646-53.
21. Loy SF, Conley LM, Sacco ER, Vincent WJ, Holland GJ, Sletten EG, et al. Effects of stairclimbing on VO2max and quadriceps strength in middle-aged females. Med Sci Sports Exerc 1994; 26: 241-7.
22. Bean J, Herman S, Kiely DK, Callahan D, Mizer K, Frontera WR, et al. Weighted stair climbing in mobility-limited older people: a pilot study. J Am Geriatr Soc 2002; 50: 663-70.
23. Global Initiative for Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. NHLBI/WHO Workshop, Bethesda: National Heart, Lung and Blood Institute; 2003.
24. American Thoracic Society. Standardization of spirometry, 1994 update. Am J Respir Crit Care Med 1995; 152: 1107-36.
25. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002; 166: 111-7.
26. Corbin CB, Dowell LJ, Lindsey R, Tolson H. Concepts in physical education with laboratories and experiments. Dubuque, Iowa: Wm C Brown; 1978.
27. Clark CJ, Cochrane LM, Mackay E, Paton B. Skeletal muscle strength and endurance in patients with mild COPD and the effects of weight training. Eur Respir J 2000; 15: 92-7.
28. Jette AM, Harris BA, Sleeper L, Lachman ME, Heislein D, Giorgetti M, et al. A home-based exercise program for nondisabled older adults. J Am Geriatr Soc 1996; 44: 644-9.
29. Engels HJ, Currie JS, Lueck CC, Wirth JC. Bench/step training with and without extremity loading. Effects on muscular fitness, body composition profile, and psychological affect. J Sports Med Phys Fitness 2002; 42: 71-8.
30. DeLorme TL. Restoration of muscle power by heavy-resistance exercise. J Bone Joint Surg 1945; 27: 645-67.
31. American College of Sports Medicine. Rate of progression. In: ACSM's guidelines for exercise testing and prescription. Baltimore: Williams & Wilkins; 2006: 154-8.
32. Heyward VH. Designing resistance training programs. In. Heyward VH, editor. Advanced fitness assessment & exercise prescription. 3rd ed. Champaign, IL: Human Kinetics; 1998: 121-44.
33. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. JAMA 1994; 272: 1909-14.
34. Di Fabio RP. One repetition maximum for older person: Is it safe? J Orthop Sports Phys Ther 2001; 31: 2-3.
35. Coldwells A, Atkinson G, Reilly T. Sources of variation in back and leg dynamometry. Ergonomics 1994; 37: 79-86.
36. Deones VL, Wiley SC, Worrell T. Assessment of quadriceps muscle performance by a hand-held dynamometer and an isokinetic dynamometer. J Orthop Sports Phys Ther 1994; 20: 296-301.
37. Kraemer WJ, Fry AC. Strength testing:

development and evaluation of methodology. In: Maud P, Foster C, editors. Physiological assessment of human fitness. Champaign, IL: Human Kinetics; 1995: 115-38.
38. Bosco C. Isometric test. In: Methods of functional testing during rehabilitation exercises. Vergata, Italy: University of Rome Tor - Vergata, Italy - School of Specialisation in Physical Medicine and Rehabilitation; 1999: 5-6.
39. Babault N, Pousson M, Ballay Y, Van Hoecke J. Activation of human quadriceps femoris during isometric, concentric, and eccentric contractions. J Appl Physiol 2001; 91: 2628-34.
40. Hortobagyi T, Barrier J, Beard D, Braspennincx J, Koens P, Devita P, et al. Greater initial adaptations to submaximal muscle lengthening than maximal shortening. J Appl Physiol 1996; 81: 1677-82.
41. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. Am J Respir Crit Care Med 1998; 158: 1384-7.
42. Troosters T, Gosselink R, Decramer M. Six minute walking distance in healthy elderly subjects. Eur Respir J 1999; 14: 270-4.
43. Casaburi R, Patessio A, Ioli F, Zanaboni S, Donner CF, Wasserman K. Reductions in exercise lactic acidosis and ventilation as a result of exercise training in patients with obstructive lung disease. Am Rev Respir Dis 1991; 143: 9-18.

ผลของการฝึกกล้ามเนื้อขาต่อความแข็งแรงของกล้ามเนื้อและการออกกำลังกายในผู้ป่วยโรคปอดอุดกั้นเรื้อรัง

อโนมา สันติวรกุล, สุวรรณี จรูงจิตรอารี, วรรธนะ ชลายนเดชะ, สมชาย จันทโรธร, สุพจน์ สุไพบูลย์พิพัฒน์

การศึกษาผลการออกกำลังกล้ามเนื้อขาต่อความแข็งแรงของกล้ามเนื้อ และความสามารถในการออกกำลังกายในผู้ป่วยโรคปอดอุดกั้นเรื้อรังความรุนแรงปานกลางถึงมาก จำนวน 20 คน กลุ่มออกกำลังกายได้รับโปรแกรมการออกกำลังกล้ามเนื้อขาที่บ้าน 8 สัปดาห์ เปรียบเทียบความแข็งแรงของกล้ามเนื้อขาและระยะทางการเดิน 6 นาที ก่อนออกกำลังกาย หลังสัปดาห์ที่ 4 และ 8 ผลการวิจัยพบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างกลุ่มออกกำลังกายและกลุ่มควบคุม แต่กลุ่มออกกำลังกายมีการเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติของระยะทางการเดิน 6 นาทีหลัง 8 สัปดาห์ สรุปได้ว่าการออกกำลังกล้ามเนื้อขาเพิ่มความสามารถในการออกกำลังกายของผู้ป่วยโรคปอดอุดกั้นเรื้อรังความรุนแรงปานกลางถึงมากได้ และสามารถปฏิบัติที่บ้านได้ง่าย