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Original Article

Effects of low-intensity exercise training (Chronic Obstructive Pulmonary Disease Sitting Calisthenics) in patients with stable Chronic Obstructive Pulmonary Disease

Hitomi Takahashi, RPT,[1] Keiyu Sugawara, RPT, MS,[1] Masahiro Satake, RPT, PhD,[2] Takanobu Shioya, MD, PhD,[2] Hitoshi Kagaya, MD, DMSc,[3] Masahito Kawatani, MD, PhD[4]

[1]Department of Rehabilitation, Akita City Hospital, Akita City, Akita, Japan
[2]Department of Physical Therapy, Akita University Graduate School of Health Sciences, Akita City, Akita, Japan
[3]Department of Rehabilitation Medicine, Fujita Health University, Toyoake, Aichi, Japan
[4]Department of Neurophysiology, Akita University Graduate School of Medicine and Faculty of Medicine, Akita City, Akita, Japan

ABSTRACT
Takahashi H, Sugawara K, Satake M, Shioya T, Kagaya H, Kawatani M. Effects of low-intensity exercise training (Chronic Obstructive Pulmonary Disease Sitting Calisthenics) in patients with stable Chronic Obstructive Pulmonary Disease. Jpn J Compr Rehabil Sci 2011; 2: 5-12.
Objective: The purpose of this study was to investigate the effectiveness of pulmonary rehabilitation (PR), consisting of chronic obstructive pulmonary disease (COPD) sitting calisthenics (CSC), which are performed in a seated position by outpatients with stable COPD.
Methods: Sixty-seven males with stable COPD undergoing outpatient treatment were recruited. They were randomly assigned to either a calisthenics group (n = 35), which underwent PR consisting of CSC performed at home for 3 months and an educational program at the outpatient department, or a control group (n = 32) that underwent only a monthly outpatient educational program.
Results: The peak oxygen uptake ($\dot{V}O_2$) values for the aerobic CSC performed at target dyspnea ratings of 2 were 39.4-52.1% of the peak $\dot{V}O_2$ values obtained from the 6-min walking test; these findings indicated that the calisthenics were low-intensity exercises. The actual home implementation rates of CSC were as follows: stretching, 92.0%; arm strength training, 40.4%; leg strength training, 44.2%; and aerobic exercise, 76.2%. A significant improvement was noted in VC, %VC, FVC, FRC, RV, RV/TLC, 6MWD and CRQ after 3 months of PR in the calisthenics group, whereas no significant change was observed in any parameter in the control group.
Conclusion: CSC is an effective treatment strategy in patients with stable COPD.
Key words: COPD, pulmonary rehabilitation, low-intensity calisthenics

Correspondence: Hitomi Takahashi, RPT
Department of Rehabilitation, Akita City Hospital, 4-30 Kawamoto-Matsuokacho, Akita City, Akita 010-0933, Japan
E-mail: ac830887@med.city.akita.akita.jp
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Introduction

The core of pulmonary rehabilitation (PR) in patients with chronic obstructive pulmonary disease (COPD) is exercise training [1, 2], which can be broadly divided into 3 types: aerobic exercise, strength training, and stretching. Walking is generally used as an effective and easily performed type of aerobic exercise, and weighted bands, elastic rubber bands, and dumbbells are generally used as tools for strength training [3, 4]. However, as walking is an aerobic exercise, outdoor walking cannot be performed in rainy, snowy, or extremely hot weather conditions. Since strength training using tools in severe COPD patients is also difficult to implement at higher resistance loads, implementation of ongoing exercise training is rare [5-7]. Since the load of stretch is low and it is easily performed at home, stretch is often used as warm-up training for major exercise in Japan. However, evidence of the effectiveness of stretching has not been shown to date. Therefore, we advocated a program of COPD sitting calisthenics (CSC) that could be performed while being seated in an ordinary chair. The CSC is a program of low-intensity calisthenics that consists of stretches, strength training, and aerobic exercises. The purpose of this study was to investigate the effectiveness of PR consisting of CSC in patients with stable COPD undergoing outpatient treatment.

Methods

Sixty-seven stable COPD patients (all males) undergoing treatment in the outpatient department at Akita City Hospital were enrolled in the study between April 2008 and March 2010 (Table 1). Patients with forced expiratory volume in 1 s (FEV_1) of less than 70% of the reference value and increase in FEV_1 after inhalation of a β_2-agonist of less than 10% of the reference value were diagnosed with COPD in accordance with the diagnostic criteria of COPD established by the American Thoracic Society (ATS) [8]. COPD patients were randomly assigned to either a calisthenics group (n = 35), which underwent PR consisting of home CSC and a monthly educational program in the outpatient department for 3 months or to a control group (n = 32), which underwent only a monthly outpatient educational program.

Table 1. Characteristics of COPD patients

	PR (n = 35)	Control (n = 32)
Age (yr)	72.5 ± 7.04	72.4 ± 7.01
Height (cm)	161 ± 6.78	161 ± 6.95
Weight (kg)	53.3 ± 11.3	50.4 ± 9.09
VC (L)	2.98 ± 0.79	2.98 ± 0.74
%VC	94.8 ± 23.1	93.1 ± 24.8
FVC (L)	2.81 ± 0.78	2.84 ± 0.67
FEV_1 (L)	1.32 ± 0.61	1.30 ± 0.55
FEV_1% (%)	45.9 ± 13.8	45.6 ± 11.3
%FEV_1 (%)	53.5 ± 22.4	51.2 ± 22.8
TLC (L)	6.25 ± 0.79	6.42 ± 0.93
FRC (L)	4.35 ± 0.69	4.55 ± 0.88
RV (L)	3.22 ± 0.66	3.42 ± 0.89
RV/TLC (%)	51.8 ± 10.5	51.1 ± 11.7

Mean ± SD

The study protocol was approved by the Ethics Committees of Akita City Hospital and Akita University Graduate School of Medicine and was performed in adherence with the principles of the Declaration of Helsinki [9]. The objectives and content of the study were explained to the participants verbally and in writing. Written consent was obtained after the subjects were informed that participation was voluntary and that their privacy would be sufficiently protected.

1. COPD sitting calisthenics

CSC are calisthenics that are performed while being seated in an ordinary chair, and involve neck, shoulder girdle, and chest stretches (Fig. 1), strength training of the arms and legs using isometric contractions (Fig. 2), and aerobic exercises (Fig. 3). The methods of the CSC are summarized in Table 2.

The exercise intensity of the aerobic exercises was set using target dyspnea ratings (TDR) [10], and the exercises were performed at low intensity, rated as 2 (weak level) on the 10-level Borg scale [11].

2. Implementation of pulmonary rehabilitation

In the calisthenics group, home CSC were continued for 3 months, with a target frequency of at least 3 days per week with no interval between exercise events exceeding 3 days. During biweekly outpatient visits, respiratory assistance and guidance for activities of daily living (ADL) were provided, and once a month, an educational program was offered in the respiratory classroom. The control group was offered only the monthly educational program. The educational program consisted of various lectures (duration, 45 min) given by medical doctors, nurses, physical therapists, pharmacists, and nationally registered dietitians.

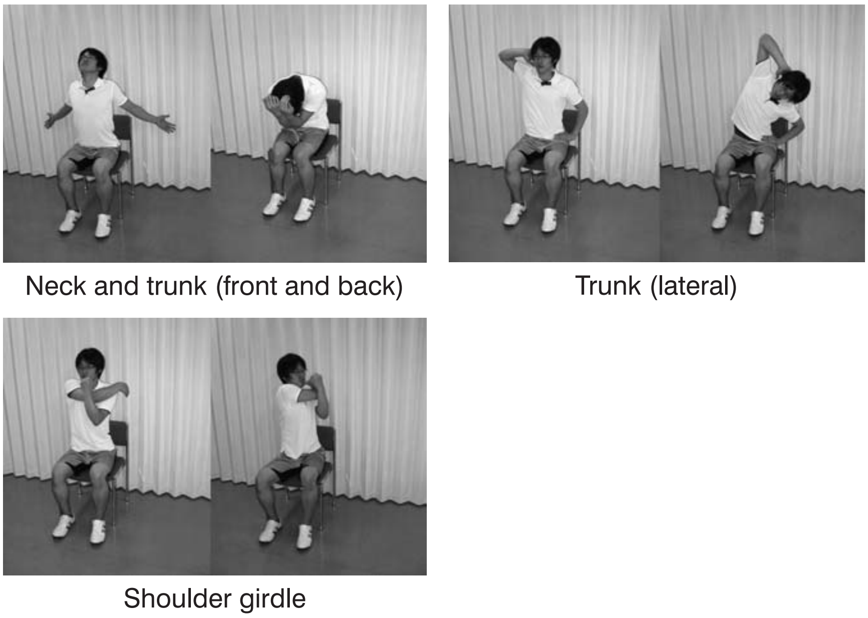

Figure 1. Stretching exercises

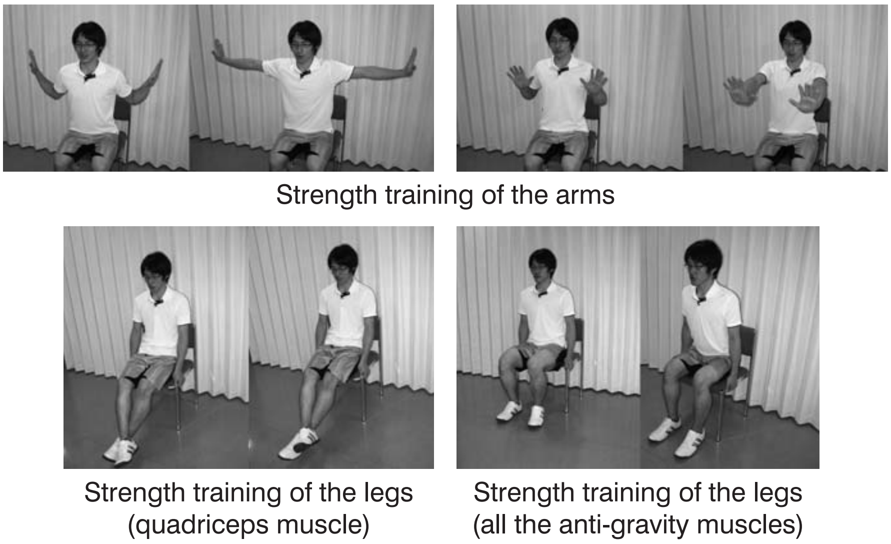

Figure 2. Strength training of the arms and legs

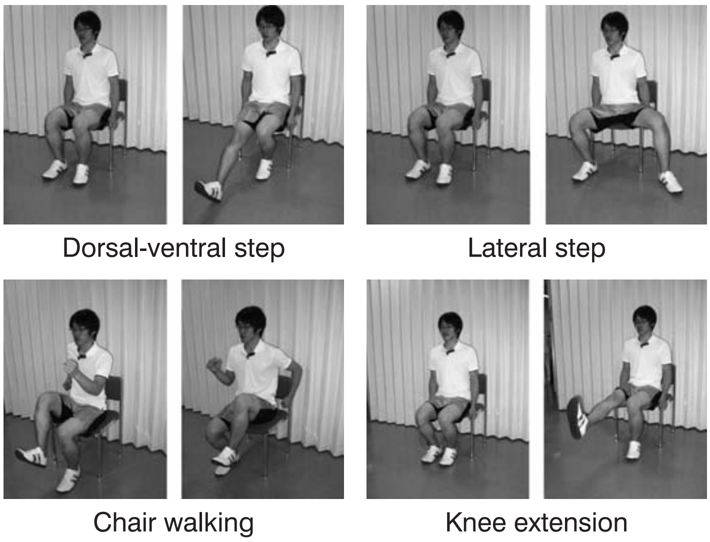

Figure 3. Aerobic exercises

The intensity of aerobic exercises performed at a TDR of 2 and the actual home CSC implementation rate were investigated in the calisthenics group, and the change in each of the parameters listed in Table 3 before and after introduction of PR was comparatively investigated within the calisthenics group and between groups.

The intensity of aerobic exercise performed at a TDR of 2 was determined from the peak oxygen uptake (peak $\dot{V}O_2$) during a 6-min walking test (6MWT) [12]. Analysis of exhaled gases during CSC was carried out using a portable exhaled gas analysis device (MetaMax 3B; Cortex Biophysik, Germany), and measurement and analysis was performed on a breath-by-breath basis (Fig. 4) [13, 14]. Dyspnea was measured every minute using the Borg Category Ratio Scale [15]. At baseline and after intervention, forced volume in 1 s (FEV_1), vital capacity (VC), and forced vital capacity (FVC) were measured with the use of a spirometer (CHESTAC-8800; Chest, Inc, Tokyo, Japan), and functional residual capacity (FRC) was measured as thoracic gas volume (VTG) with the use of a body box (CHESTAC-8800 BDN type; Chest, Inc, Tokyo, Japan). Total lung capacity (TLC) and residual volume (RV) were calculated from VC and FRC [16].

The actual home CSC implementation rate was determined using a questionnaire survey conducted 3 months after PR was implemented; the questionnaire recorded the rate at which stretching, aerobic exercise, and strength training of the arms and legs was performed at least 3 times per week.

Furthermore, to investigate the effects of calisthenics, we investigated changes in 6-min walking distance (6MWD) and changes in the score on the Chronic Respiratory Disease Questionnaire (CRQ) [17], which is an index of pulmonary function, and for health-related quality of life (HRQOL), from before to 3

Table 2. Methods of COPD sitting calisthenics

1) Muscle stretching
- Neck and trunk (front and back)
  1. While inhaling through the nose, the neck is bent backwards, and both hands are pulled backwards.
  2. While exhaling through the mouth, the neck is bent forwards, and the back is rounded. (These are repeated 5 times.)
- Trunk (lateral)
  While exhaling through the mouth, the elbow on the arm that was touching the head is brought upwards. (3 times on each side)
- Shoulder Girdle
  While exhaling through the mouth, the neck and upper torso are twisted in the opposite direction. (3 times on each side)

2) Strength training of the arms and legs
- Strength training of the arms
  1. Both arms are extended dorsally until they are oriented straight to the sides.
  2. While exhaling with pursed lips, the extensor muscles of the arms are isometrically contracted for 6 s.
  3. Then, the arms are brought in front of the body. Repeat the same steps as above. (5 times in each position)
- Strength training of the legs (quadriceps muscle)
  1. The legs are crossed at the ankles, and the upper leg restrains the lower leg.
  2. While breathing out through pursed lips, the quadriceps muscle is isometrically contracted for 6 s.
  3. Then, the legs are switched, and the same steps are repeated on the other side. (5 times for each side)
- Strength training of the legs (all the anti-gravity muscles)
  1. The sides of the chair are grasped with both hands, and force is applied by the legs as if to brace them against the floor.
  2. While breathing out through pursed lips, the anti-gravity muscles of the lower extremities are isometrically contracted for 6 s. (5 times)

3) Aerobic exercise
- Dorsal-ventral step
  1. One foot is extended forward, with the heel touching the ground, and then, the foot is returned to its original position.
  2. The same movements are performed with the opposite foot, and these movements are repeated.
- Lateral step
  Take a step in the right and left directions.
- Chair walking
  One arm is swung to the front and the other is swung to the back, and the walking motion is repeated.
- Knee extension
  1. One foot is raised, and after extending the knee, the foot is returned to its original position.
  2. The opposite foot is moved in the same manner, and these movements are repeated.

  The 4 aerobic exercises mentioned above are performed in 2 sets at intervals of 2.5 min (total of 20 min) with TDR 2.
  The patients are asked to exhale in such a manner that the respiratory pattern of exhalation:inhalation is 2:1.

Table 3. Effect of PR consisting of COPD calisthenics

	PR (n = 35)		Control (n = 32)	
	baseline	after 3 months	baseline	after 3 months
VC (L)	2.98 ± 0.79	3.25 ± 0.75**	2.98 ± 0.74	3.00 ± 0.68
%VC	94.8 ± 23.1	103.9 ± 21.0**	93.1 ± 24.8	96.0 ± 23.0
FVC (L)	2.81 ± 0.78	3.07 ± 0.75**	2.84 ± 0.67	2.89 ± 0.64
FEV_1 (L)	1.32 ± 0.61	1.37 ± 0.58	1.30 ± 0.55	1.34 ± 0.57
FEV_1% (%)	45.9 ± 13.8	45.4 ± 13.7	45.6 ± 11.3	45.9 ± 12.8
%FEV_1 (%)	53.5 ± 22.4	55.7 ± 21.5	51.2 ± 22.8	52.0 ± 24.4
TLC (L)	6.25 ± 0.79	6.18 ± 0.87	6.42 ± 0.93	6.42 ± 0.94
FRC (L)	4.35 ± 0.69	4.13 ± 074**	4.55 ± 0.88	4.47 ± 0.89
RV (L)	3.22 ± 0.66	2.90 ± 0.67**	3.42 ± 0.89	3.34 ± 0.98
RV/TLC (%)	51.8 ± 10.5	47.8 ± 10.5**	51.1 ± 11.7	51.3 ± 10.1
6MWD (m)	367 ± 123	429 ± 97.0**	364 ± 107	367 ± 100
CRQ total	97.0 ± 23.1	111.8 ± 18.2**	98.9 ± 23.3	99.1 ± 21.3
Dyspnea	21.5 ± 7.7	25.8 ± 6.2**	23.3 ± 5.7	24.5 ± 4.4
Fatigue	19.3 ± 6.7	21.5 ± 4.9*	20.4 ± 6.6	20.2 ± 5.7
Emotion	36.0 ± 10.1	42.1 ± 5.4**	38.5 ± 9.9	36.7 ± 10.5
Mastery	20.7 ± 4.5	23.0 ± 5.3*	21.9 ± 6.3	21.8 ± 5.6

Mean ± SD **$p < 0.01$ *$p < 0.05$

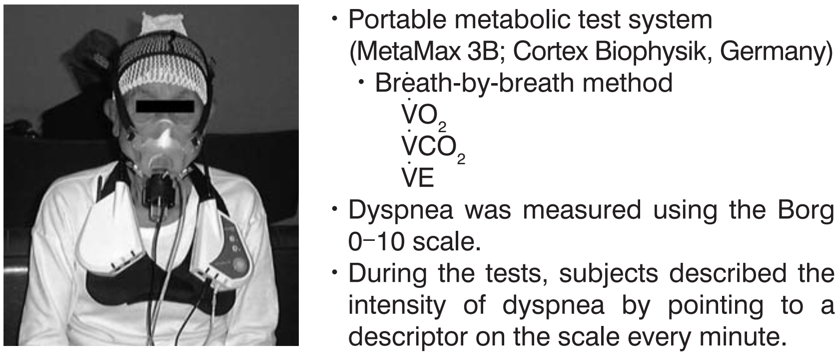

Figure 4. Measurement of exercise intensity of aerobic exercises

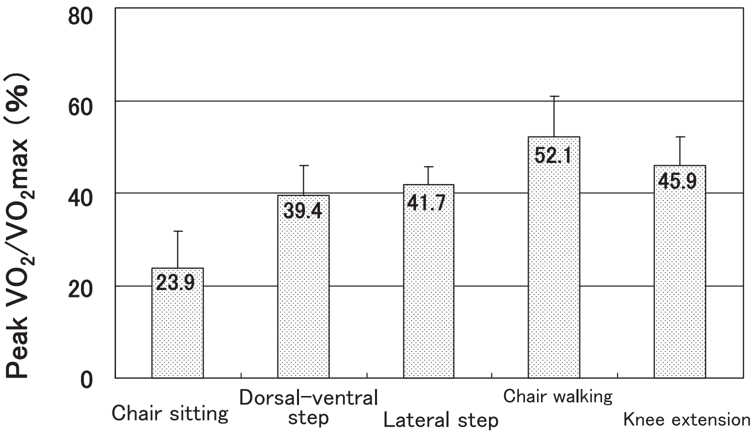

Figure 5. $\dot{V}O_2$/peak$\dot{V}O_2$ in each exercise

months after the introduction of CSC.

3. Statistical analysis

After verifying the normality of data from the calisthenics group and the control group, we performed comparisons between the groups using an unpaired *t*-test, and comparisons from before to 3 months after the introduction of PR was performed using a paired *t*-test in the calisthenics group. In both tests, significance was established at the 5% level.

Results

The peak $\dot{V}O_2$ values for the aerobic CSC performed at a TDR of 2 were as follows: dorsal-ventral step, 5.8 ± 1.3 mL/min/kg; lateral step, 6.1 ± 1.1 mL/min/kg; chair walking, 7.6 ± 1.6 mL/min/kg; and knee extension, 6.7 ± 1.4 mL/min/kg. These values were low-intensity values, being in the range of 39.4–52.1% of the peak $\dot{V}O_2$ values obtained from the 6MWT (Fig. 5).

The actual home CSC rate of implementation at least 3 days per week for stretching was 92.0%, for upper extremity strength training was 40.4%, for lower extremity strength training was 44.2%, and for aerobic exercise was 76.2% (Fig. 6).

A significant improvement was noted in some aspects of lung function, 6MWD, and CRQ in the calisthenics group 3 months after the introduction of CSC. A significant difference in lung function was seen in the following parameters (expressed as the mean ± standard deviation): VC from 2.98 ± 0.79 L to 3.25 ± 0.54 L ($P < 0.01$), %VC from 94.8 ± 23.1% to 103.9 ± 21.0% ($P < 0.01$), FVC from 2.81 ± 0.78 L to 3.07 ± 0.75 L ($P < 0.01$), FRC from 4.35 ± 0.69 L to 4.13 ± 0.74 L ($P < 0.01$), RV from 3.22 ± 0.66 L to 2.90 ± 0.67 L ($P < 0.01$), and RV/TLC from 51.8 ± 10.5 to 47.8 ± 10.5 ($P < 0.01$). Furthermore, there was a significant improvement in 6MWD from 367 ± 123 m to 429 ± 97 m ($P < 0.01$). A significant improvement was also seen in the total CRQ score from 97.0 ± 23.1 points to 111.8 ± 18.2 points ($P < 0.01$). Dyspnea scores improved, increasing from 21.5 ± 7.7 points to 25.8 ± 6.2 points ($P < 0.01$), as did scores for fatigue [from 19.3 ± 6.7 points to 21.5 ± 4.9 points ($P < 0.05$)], emotion [from 36.0 ± 10.0 points to 42.1 ± 5.3 points ($P < 0.01$)], and mastery [from 20.7 ± 4.5 points to 23.0 ± 5.3 points ($P < 0.05$)]. No significant changes were seen in the control group (Table 3).

Discussion

In this study, the $\dot{V}O_2$ values for the aerobic CSC performed at a TDR of 2 indicated a low intensity of exercise, at 39.4–52.1% of the peak $\dot{V}O_2$ values from the 6MWT. Although the setting of exercise strength is

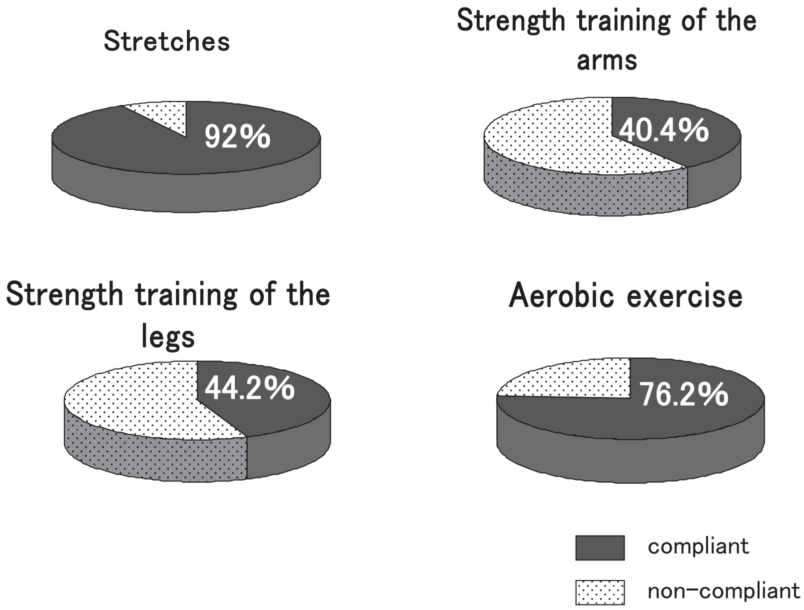

Figure 6. Adherence to home exercise

wide, with low intensity at a $\dot{V}O_2$ of 40–60% and high intensity at 60–80%, high intensities result in lower adherence to exercise programs [4, 18]. Since exercise prescriptions calculated from the Shuttle Walking Test have been reported to be unsuitable [19] and the use of the Borg scale and the perception of fatigue have been considered more suitable than heart rate [20, 21], the use of the TDR for home exercise prescription in the present study can be considered to be more realistic.

The actual home implementation rates of PR were investigated in 14 stable COPD patients when PR was first introduced in our hospital. The exercise training our patients were performing at home prior to the introduction of CSC involved arm strength training using plastic bottles and cans, leg strength training performed with bags of salt or sugar wrapped in a cloth wound around the feet, and walking exercise. The actual home implementation rates for stretching calisthenics was 57.1%, for arm strength training was 14.3%, leg strength training was 0%, and aerobic exercise by walking was 21.4%. At this point, home visits were conducted and we tried to cultivate an awareness of the importance of PR and repeated the guidance for exercise training. The results of another visit conducted 2 months later revealed an increase in actual implementation with stretching calisthenics at 85.7%, arm strength training at 28.6%, leg strength training at 14.3%, and walking exercise at 28.6%. The actual implementation rates after introducing the CSC were also high: stretching, 92.0%; arm strength training, 40.4%; leg strength training, 44.2%; and aerobic exercise, 76.2%.

Before the introduction of the CSC program, patients had indicated that muscle strengthening using tools was difficult to sustain and outdoor walking was not possible during inclement weather. However, the CSC does not require tools, are performed easily indoors, and can be performed while watching television or listening to the radio. The sum of these advantages are thought to have resulted in the increase in sustained implementation for the CSC program.

In general, high-intensity exercise is considered more effective than low-intensity exercise for PR [22–24]. However, the RCT investigation reported by Puhan et al. [25] concludes that there is insufficient evidence to recommend high-intensity exercise training for COPD patients. An improvement in exercise tolerance and dyspnea occurs after performing low-intensity distal-muscle exercise at home [26]. Furthermore, no difference in exercise tolerance and HRQOL was found between a group that performed continuous training at 50% of the maximum exercise intensity and a group that performed interval training at 30-s increments at 100% of the maximum exercise intensity. This finding indicated that the effect of halving exercise intensity and doubling the exercise time results in the same effect [27]. Finally, no difference in improvement in exercise tolerance, HRQOL, or dyspnea was found between a group that underwent high-intensity exercise therapy (>80% of the maximum exercise intensity, 30 min twice weekly for 8 weeks) and a group that underwent low-intensity limb training (calisthenics, 30 min twice weekly for 8 weeks) [28]. The 2007 ACCP/AACVPR guidelines consider both low-intensity and high-intensity exercise therapies to be clinically effective and give both a 1A rating [4].

Thus, the utility of low-intensity programs has recently been recognized. PR consisting of low-intensity CSC that can be performed easily without tools can therefore be considered an effective method to promote continued implementation at home, to contribute to the improvement of some aspects of respiratory function and muscular strength of the arms and legs, and to be an effective measure for improving dyspnea, exercise tolerance, and HRQOL in patients with stable COPD (Fig. 7). The improvement of respiratory function, such as VC and FVC, was considered to be due to the decrease of FRC or RV. The mechanism of the improvement of breathing difficulties in CSC was thought to be similar to the mechanism reported by Shibuya in the COPD stretch exercise [29]. Moreover, a possibility exists that the respiratory assistance at the outpatient clinic once every 2 weeks improved the mobility of the chest cage, FRC and RV, and dyspnea [30]. In addition, because inactivity is generally associated with an increase in dyspnea and the vicious circle that results in deconditioning exists in patients with COPD [31], it was thought that the individual ADL guidance improved all aspects of life and then broke the vicious circle. ADL guidance was held once every 2 weeks in the calisthenics exercise group, whereas an educational program was held once a month in the control group. The possibility that the difference in the frequencies of these 2 programs influenced these results should be clarified in future studies.

There is still no consensus regarding the improving effect of oxygen intake during exercise therapy on exercise tolerance and HRQOL outcome. However, a meta-analysis of RCTs on the short-term effects of administering oxygen during exercise indicated that it was associated with improvements in dyspnea and exercise tolerance, among other factors, in patients with moderate and severe COPD [32]. Consequently, CSC can also be used for cases in which PR is started at the bedside while oxygen is being administered and can be used as exercise therapy while preventing hypoxia. However, further investigation is necessary, and an evaluation of the specific effectiveness of CSC in severe or very severe COPD is warranted.

Non-invasive positive pressure ventilation (NPPV) has been used in some patients with COPD only at night, only during exercise training, or both at night and during exercise therapy. The use of NPPV in patients with severe COPD during exercise training reduces dyspnea and lengthens walking distance [33]. Currently, the routine use of NPPV in patients with severe COPD is not recommended [4]; however, its use with CSC could be effective in patients with severe hypercapnia whose exercise tolerance is extremely low and for whom exercising while being ventilated results in an alleviation of symptoms. A detailed investigation of the use of CSC in conjunction with NPPV in patients with severe COPD is also necessary.

In conclusion, the $\dot{V}O_2$ values for aerobic CSC performed at a TDR of 2 were in the range of 39.4–52.1% of the peak $\dot{V}O_2$ values from the 6MWT, indicating that these calisthenics were low-intensity exercises. The home implementation rates of CSC were higher than the continued implementation rates of the program in place prior to the introduction of CSC. Significant improvement was obtained in respiratory function, exercise tolerance, and HRQOL 3 months after the introduction of CSC, suggesting that PR composed of CSC was effective in patients with stable COPD.

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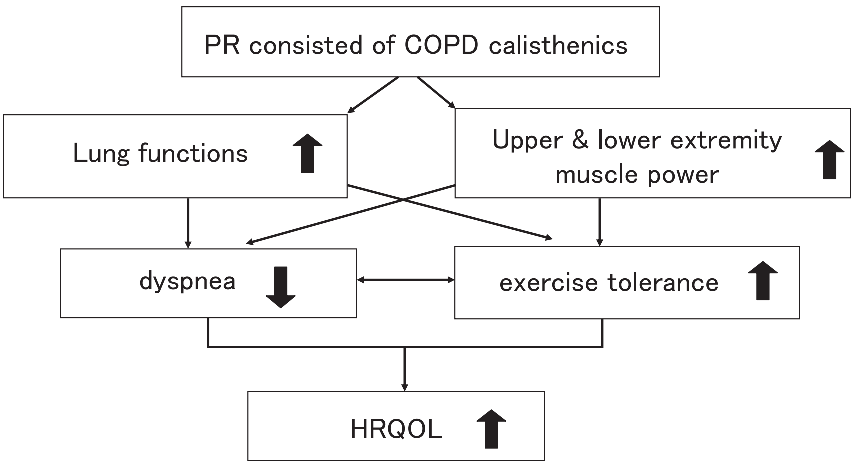

Figure 7. Possible mechanisms of improvement of HRQOL by PR

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