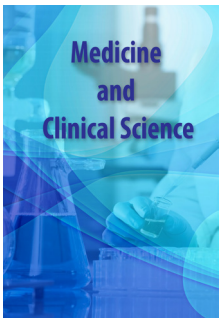
Medicine & Clinical Science

Original Article



Effect of pursed lips breathing on exercise-induced desaturation in patients with oxygen therapy

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Abstract

Introduction: The flying disc accuracy (FDA) game for the subjects with oxygen therapy could become one of the attempts to make patients go outside. However, the resolution against the decrease of percutaneous arterial oxygen saturation (SpO_2) during the game could be necessary. We hypothesized that the decline of SpO_2 during the FDA game could be suppressed by pursed lips breathing (PLB) and that the improvement could be partly associated with decreased breath-holding time. Materials and methods: FDA game was conducted for 15 subjects with chronic obstructive pulmonary disease (COPD) and oxygen therapy. The effect of PLB on the decline of SpO_2 during the game and the effect of PLB on breath-holding time were evaluated. Results: The SpO_2 decreased during the FDA game in subjects with oxygen therapy. The decrease of SpO_2 in game period was significantly suppressed by PLB (difference 1.165; 95% CI 0.030, 2.299; p=0.044), and the decline of SpO_2 from pre-game to game period was suppressed by 2% or less. The breath-holding time was significantly shorter with PLB than without PLB (0.860 sec, 0.243 sec, respectively; p<0.001). Conclusion: The decline of SpO_2 during the FDA game in subjects with oxygen therapy was significantly improved by PLB, which could be partly associated with reduction of the breath-holding time.

Introduction

Providing oxygen at home for patients with chronic obstructive pulmonary disease (COPD) and chronic severe resting hypoxemia, has many benefits including survival [1,2], pulmonary hemodynamics [3,4], neuropsychological function [5,6], sleep quality [7], and quality of life (QOL) [8]. Oxygen therapy has been widely accepted as the treatment of chronic cardiorespiratory conditions with severe hypoxemia, but the evidences were mainly derived from patients with COPD. The physical activity in patients with COPD is decreased [9,10] and is the strongest predictor of all-cause mortality [11], furthermore, that with COPD and long-term oxygen therapy was markedly suppressed [12]. The decreased physical activity could induce a muscle dysfunction, decreased neuropsychological function, and increased further dyspnea on exertion.

In order to enhance physical activity in patients with oxygen therapy, many patient societies have conducted the attempts to make patients go outside (e.g. attendance to the general meeting or the recreational activities). At several patient societies for oxygen therapy in Japan, the flying disc accuracy (FDA) game has been introduced. Furthermore, a symposium about introducing the FDA game to subjects with oxygen therapy was discussed at the 2015 annual meeting of the Japan Society for Respiratory Care and Rehabilitation.

Flying disc game includes several articles (e.g. Ultimate, Guts, Disc Golf, Freestyle, Distant, Accuracy, and so on) and The World Flying Disc Federation is an international federation recognized by the International Olympic Committee and the International Paralympic Committee [http://www.wfdf.org/]. FDA game is one of the flying disc games and is a sport without any anti-gravity action or movement. It is selected as one of the events at the annual National Sports Festival for People with Disabilities in Japan. However, contestants in the FDA game are limited to physically or mentally disabled subjects, and subjects with oxygen therapy are not allowed. This might be caused by the concern about the further hypoxemia during the game, though the FDA game could be performed relatively safely for subjects with oxygen therapy [13].

Generally, pursed lips breathing (PLB) has been introduced as a method to reduce dyspnea in patients with COPD [14-17]. PLB reduces arterial oxygenation at submaximal intensity exercise [18], but it is unclear whether PLB can prevent a decrease of oxygenation in patients with oxygen therapy while participating in the FDA game, which is a light exercise without anti-gravity action. Furthermore, increased oxygenation by PLB could be caused by decreased dynamic hyperinflation [18] and probably improved ventilation / perfusion (VA/Q) inequality, however, the decreased breath-holding time during FDA game might be another reason.

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We hypothesized that the decline of percutaneous arterial blood oxygen saturation (SpO_2) during the FDA game is suppressed by PLB, and this improvement is partly associated with decreased breath-holding time. To prove this hypothesis, we investigated the effects of the introduction of PLB on SpO_2 during the FDA game in patients with oxygen therapy and investigated the changes of breath-holding time by PLB. These studies were conducted as observational study designs.

Material and Methods

Subjects

To evaluate the effects of PLB on SpO_2 during FDA game in patients with oxygen therapy (Study 1), the stable subjects with COPD and oxygen therapy were recruited from among attendees of the 2017 Meeting of the Home Oxygen Therapy Patients Association of Wakayama prefecture (4 subjects) and Nagano prefecture (7 subjects), and from the out-patients of Third Department of Internal Medicine, Wakayama Medical University (4 subjects) (Figure 1). As a comparison, the subjects with COPD but without oxygen therapy were recruited from among out-patients of Third Department of Internal Medicine, Wakayama Medical University. COPD was diagnosed as forced expiratory volume in one second (FEV1) / forced vital capacity (FVC) <0.7. Subjects with exacerbations in the past 3 months, difficulty in sitting, exercise limitation in upper limbs, and SpO_2 <88% during training to throw a disc (under inhalation of prescribed oxygen flow) were excluded. To evaluate the effect of PLB on breath-holding time (Study 2), the stable out-patients of COPD without oxygen therapy were recruited from Third Department of Internal Medicine, Wakayama Medical University, because the waveform might be interfered by the flow of inhaled oxygen in subjects with oxygen therapy. Written informed consent was obtained from all participants, and the study was approved by the local ethics committee (Committee: IRB committee of Wakayama Medical University; authorization number: 2005, approval date: May 8, 2017), and registered with the university hospital Medical Information Network (UMIN000027220).

The flying disc accuracy game

A flying disc is a round-shaped plastic disc. We used a disc with a diameter of 23.5 cm in the flying disc accuracy game. The participants throw a disc at a circular goal 91.5 cm in diameter placed 5 meters from the throwing point and try to achieve the highest number of passes through the goal among 10 throws. A staff member gives a disc to the participants one by one. The referee stands right behind the goal and determines whether the disc entered the goal circle. One throw takes about 10 seconds, requiring between 1.5 to 2 minutes for each game.

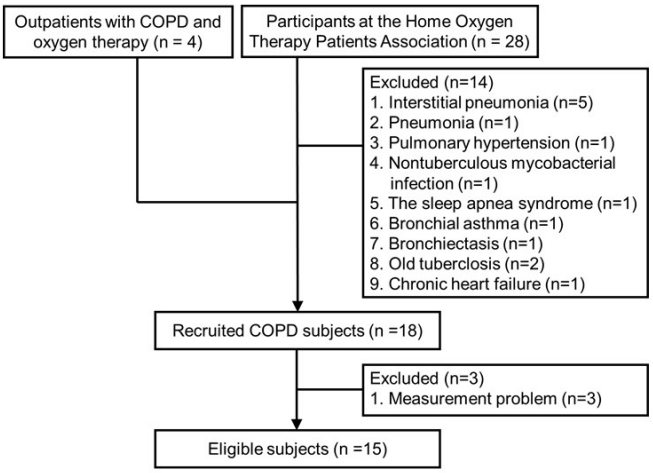

Figure 1. CONSORT diagram of study 1.

Protocol

Study 1. Effects of PLB on SpO_2 in subjects with oxygen therapy

Participants warmed up and trained to throw. They sat at the waiting place for more than 5 minutes and moved to the throwing point about 3 to 5 meters away from the waiting place. The period of 5 minutes during sitting just before moving was defined as pre-game period. The period of playing the FDA game was defined as game period, and the period of 5 minutes during sitting at the waiting place after the game was defined as post-game period. SpO_2 and heart rate were continuously monitored through 3 periods, and the Borg scale and the presence of adverse symptoms were assessed at the end of each period.

All participants were instructed in how to perform PLB by physiotherapists. After that, the flying disc accuracy game was conducted using the PLB technique. The PLB was carried out while standing up, sitting down, walking and throwing a disc.

Study 2. Effects of PLB on breath-holding time

We developed the breathing pattern recording system in which a flow sensor of spirometer was connected to a face mask and breathing waveforms could be recorded for 30 seconds and be printed out. The participants threw the disc two times in one record and repeated 3 sets without PLB. After recording the waveforms, they again threw the same way with PLB. From the recorded waveforms, the breath-holding times with and without PLB were measured and each mean value of breath-holding times from 6 waveforms was compared.

PLB instruction

PLB instruction was conducted by physiotherapists who had clinical experience of at least seven years. After an explanation by physiotherapists, participants trained to perform PLB until acquisition of its technique, which took about 20 minutes. The details of the instructions were follows. While sitting: the participants were trained in abdominal breathing. Then, after inhaling deeply, the pursed their lips and exhaled slowly, taking twice the time required for the inspiration. When standing up or sitting down: after a deep inhalation just before the action, the participants pursed their lips and exhale slowly while exercising. When walking: after a deep inhalation, the participants walked 4 steps using pursed lip exhalation and 2 steps while inhaling. When throwing a disc: after a deep inhalation, the participants throw the disc using pursed lip exhalation.

Parameter measurement

SpO_2 and heart rate were measured using a pulse oximeter, PULSOX-300i (KONICA MINOLTA, Tokyo, Japan). In order to minimize measurement error, the oximeter was worn on the wrist of the opposite side of the disc throwing hand. The data were collected every one second and the average values of each period were compared. Furthermore, the difference between the average values of pre-game period and game period were also evaluated. The Borg scale was evaluated at the end of each period. The values of pulmonary function tests were employed those performed between 1 year before and 3 months after the FDA game.

Statistical analysis

GraphPad Prism 7 (GraphPad Software Inc., La Jolla, CA, USA) was used for the analysis. One-way analysis of variance (ANOVA) and Tukey's multiple comparison test were used for the comparison of the average values of SpO_2 or heart rate among 3 periods. Spearman's

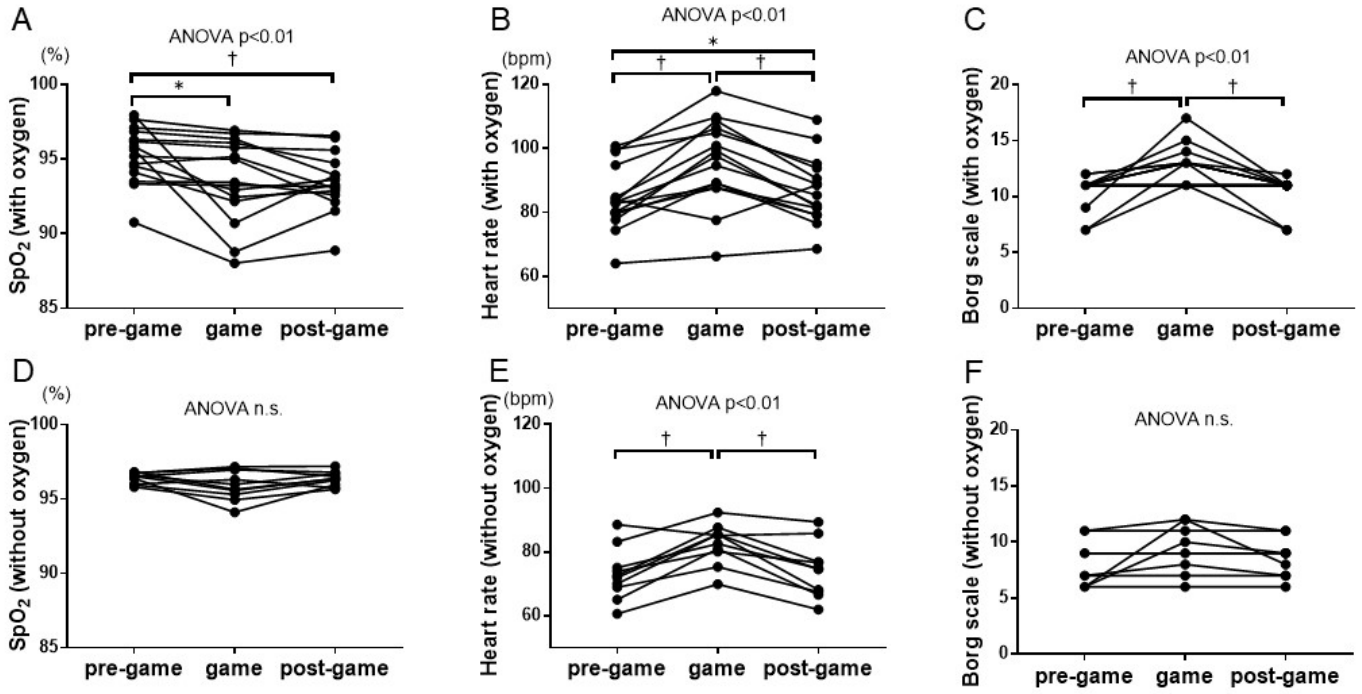

Figure 2. Changes of SpO_2, heart rate and Borg scale between periods without PLB.
A, D, SpO_2; B, E, heart rate; C, F, Borg scale; A, B, C, subjects with oxygen therapy; D, E, F, subjects without oxygen therapy. PLB, pursed lips breathing; ANOVA, analysis of variance; n.s., not significant. *p<0.05, †p<0.01 with Tukey's multiple comparison test.

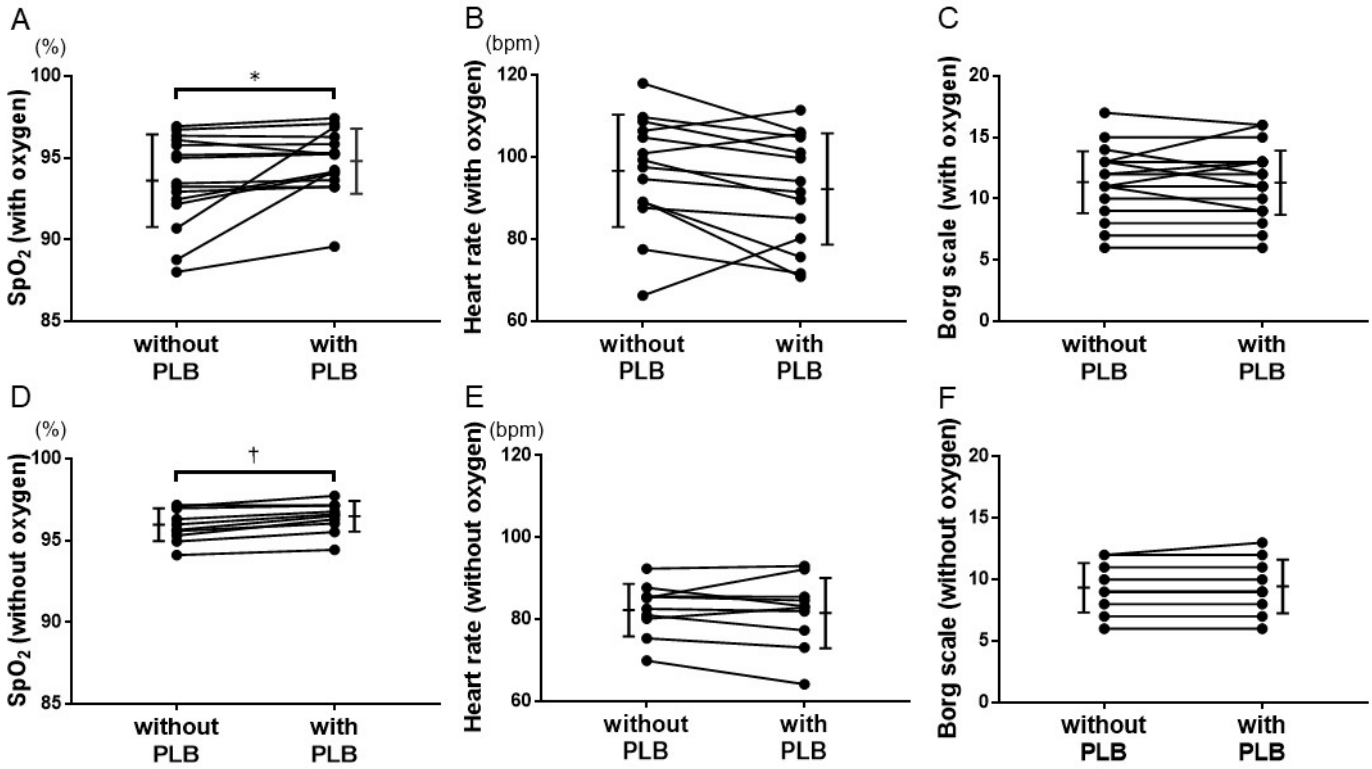

Figure 3. SpO_2, heart rate and Borg scale in game period with or without PLB.
A, D, SpO_2; B, E, heart rate; C, F, Borg scale; A, B, C, subjects with oxygen therapy; D, E, F, subjects without oxygen therapy. PLB, pursed lips breathing. Horizontal bars indicate mean and SD. *p<0.05, †p<0.01 with paired t-test.

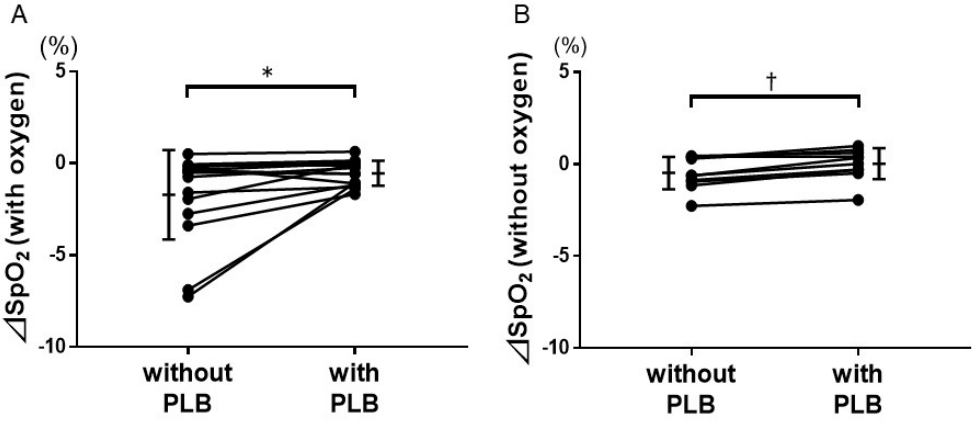

Figure 4. Change of SpO_2 from pre-game to game period by PLB.
A, subjects with oxygen therapy; B, subjects without oxygen therapy. PLB, pursed lips breathing; ΔSpO2, changes in SpO2 from pre-game period to game period. Horizontal bars indicate mean and SD. *p<0.05, †p<0.01 with paired t-test.

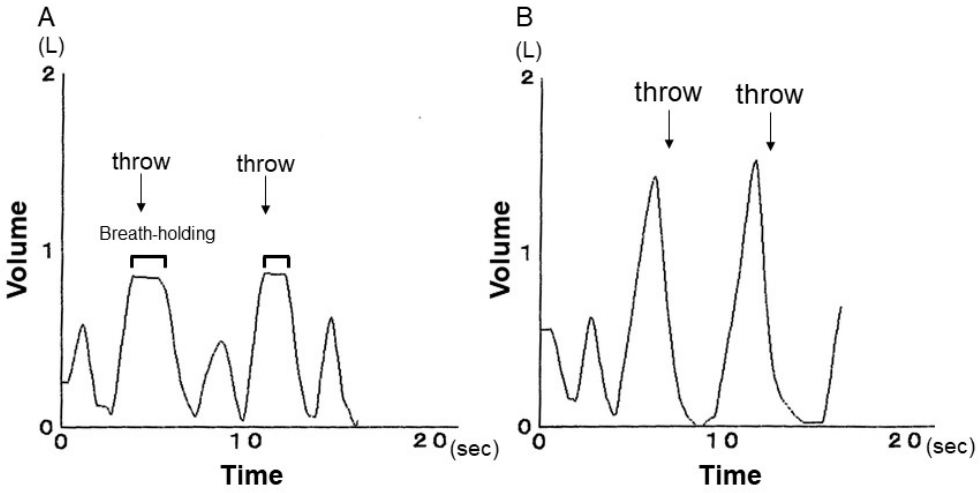

Figure 5. Representative breathing waveforms while throwing a flying disc.
A, throwing the disc without PLB; B, throwing the disc with PLB. PLB, pursed lips breathing.

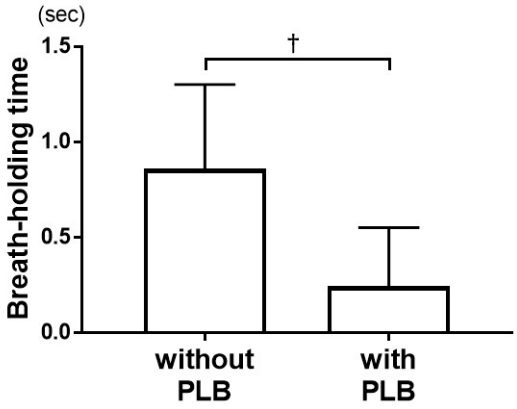

Figure 6. Breath-holding time with or without PLB.
PLB, pursed lips breathing. Data are presented as mean ± SD. †p<0.01 with paired t-test.

	with oxygen	without oxygen
Gender (M/F)	13/2	10/0
Age (years)	74.6 ± 5.8	73.2 ± 7.8
BMI (kg/m^2)	20.2 ± 3.2	21.2 ± 2.5
Smoking		
(pack·years)	67.5 ± 43.2	59.5 ± 30.8
(non/ex/curr)	0/15/0	0/9/1
GOLD stage (I/II/III/IV)	0/1/11/3	2/7/1/0
mMRC (0/1/2/3/4)	1/2/3/9/0	6/4/0/0/0
Pulmonary function		
FEV1 (L)	0.95 ± 0.46	2.00 ± 0.54
FEV1 % pred (%)	37.2 ± 12.5	70.4 ± 15.8
FVC (L)	2.38 ± 0.81	3.22 ± 0.53
FVC % pred (%)	75.4 ± 22.9	95.4 ± 15.3
FEV1/FVC (%)	39.8 ± 9.6	60.6 ± 10.4

Data are mean ± standard deviation. abbreviations: M, male; F, female; BMI, body mass index; non, non- smoker; ex, ex-smoker; curr, current smoker; GOLD, global initiative for chronic obstructive lung disease; mMRC, modified Medical Research Council dyspnea scale; FEV1, forced expiratory volume in one second; FVC, forced vital capacity. P values are comparison between the patients with and without oxygen therapy.

Table 1. Characteristics of subjects.

COPD (n)	11
Gender (M/F)	8/3
Age (years)	77.9 ± 8.9
BMI (kg/m^2)	23.0 ± 2.6
Smoking	
(pack·years)	25.4 ± 25.0
(non/ex/curr)	4/7/0
GOLD stage (I/II/III/IV)	6/5/0/0
mMRC (0/1/2/3/4)	8/2/1/0/0
Pulmonary function	
FEV1 (L)	1.86 ± 0.59
FEV1 % pred (%)	83.6 ± 21.1
FVC (L)	2.93 ± 0.85
FVC % pred (%)	105.5 ± 21.4
FEV1/FVC (%)	62.1 ± 6.9

Data are mean ± standard deviation. abbreviations: M, male; F, female; BMI, body mass index; non, non-smoker; ex, ex- smoker; curr, current smoker; GOLD, global initiative for chronic obstructive lung disease; mMRC, modified Medical Research Council dyspnea scale; FEV1, forced expiratory volume in one second; FVC, forced vital capacity. P values are comparison between the patients with and without oxygen therapy.

Table 2. Characteristics of subjects.

regression analysis was used for the relationship between the change of SpO_2 and FEV1 % of predicted. Paired t-test was used for the comparison of the values of SpO_2, heart rate and Borg in game period between with and without PLB, and for the changes of SpO_2 from pre-game period to game period between them. Paired t-test was used for the comparison of the breath-holding time between with and without PLB. Significance was set at $P<0.05$

Results

Fifteen subjects with COPD and oxygen therapy aged 74.3 ± 5.8 years and 10 without oxygen therapy aged 73.2 ± 7.8 years were included (Table 1). Without PLB condition, SpO_2 and the Borg scale significantly changed between periods (SpO_2: p=0.004 with ANOVA, Borg scale: p=0.002 with ANOVA) and these levels were lower in game period than in pre-game period in the subjects with oxygen therapy (SpO_2: difference - 1.728; 95%CI -3.364, -0.092; p=0.038, Borg scale: difference 2.200; 95%CI 0.561, 3.839; p=0.009) (Figures 2A and 2C). Heart rate significantly changed (p<0.001 with ANOVA; Figure 2B) and the levels were higher in game period than in pre-game period in the subjects with oxygen therapy (difference 11.28; 95%CI 5.757, 16.810; p<0.001) In contrast, no significant change in SpO_2 or the Borg scale was observed between periods in the subjects without oxygen therapy (Figures 2D and 2F) except in heart rate (Figure 2E). No correlation was observed between the change in SpO_2 from pre-game period to game period and FEV1 % of predicted in the subjects with oxygen therapy (r=-0.357; p=0.192 with Spearman's correlation coefficient).

With PLB, the average value of SpO_2 in game period was significantly increased compared to that without PLB in both the subjects with and without oxygen therapy. The difference and 95%CI in the subjects with oxygen therapy were 1.179 and 0.053, 2.305 (p=0.041 with paired t-test; Figure 3A), and those in the subjects without oxygen therapy were 0.511 and 0.294, 0.729 (p<0.001 with paired t-test; Figure 3D). Even in the subjects with oxygen therapy, the values of SpO_2 with PLB could be maintained at 92% or higher except in one subject with 89.6%. On the other hand, the average values of heart rate and the Borg scale in game period did not differ between with and without PLB in both the subjects with and without oxygen therapy (Figures 3B, 3C-3 F). The decline of SpO_2 from pre-game period to game period with PLB was significantly suppressed compared to that without PLB in both the subjects with oxygen therapy (difference 1.165; 95%CI 0.030, 2.299; p=0.045 with paired t-test; Figure 4A) and without oxygen therapy (difference 0.511; 95%CI 0.296, 0.726; p<0.001 with paired t-test; Figure 4B). Furthermore, even in the subjects with oxygen therapy, the decline in SpO2 from pre-game period to game period was suppressed by only 2% or less with PLB technique (Figure 4A).

In study 2, eleven subjects with COPD aged (77.9 ± 8.9) were included (Table 2). Breath-holding time could be measured on the breathing waveforms (Figures 5A and 5B). The average values of breath-holding time per throw was 0.860 seconds with PLB compared to 0.243 seconds without PLB. It was significantly shorter with PLB than that without PLB (difference -0.617; 95%CI -0.899, -0.336; p<0.001 with paired t-test; Figure. 6).

Discussion

The levels of SpO_2 and Borg scale were significantly deteriorated by the FDA game in the subjects with oxygen therapy but not in those without oxygen therapy. The levels of heart rate were increased by the game in both the subjects with and without oxygen therapy. The average values of SpO_2 in game period were increased by PLB in both groups and the degree of decline of SpO_2 from pre-game period to game period was suppressed by 2% or less. The breath-holding time during the game was significantly decreased by using PLB technique.

The SpO_2 and Borg scale in game period were significantly decreased in the subjects with oxygen therapy, but neither decreased in those without oxygen therapy. Exercise led to a significant fall in the arterial partial pressure of arterial oxygen (PaO_2) in patients with severe COPD, which was derived from decreased mixed venous pressure of oxygen from increased respiratory muscle activity and could not be compensated by any redistribution of VA/Q ratio [19,20]. However, exercise led to an increase in PaO_2 in patients with mild-to-moderate COPD, which was derived from the improvement of VA/Q ratio [21]. These reports were compatible our results. Furthermore, the change in SpO_2 by the FDA game was not significantly related to the respiratory function in the current study. This suggests that the muscle exhaustion might more influenced the change in SpO_2 than airflow limitation in patients with oxygen therapy. The heart rate was increased by the game in both the subjects with and without oxygen therapy. Liu et al. [22] reported that the heart rate changed during the 6-minute walk test from 85.6 ± 13.6 bpm to 114.5 ± 15.8 bpm in COPD patients, and from 72.3 ± 11.9 bpm to 119.6 ± 18.6 bpm in healthy subjects. As the increase in the heart rate by the FDA game was within the range of healthy subjects, these changes could be a physiological reaction within an allowable range.

The average value of SpO_2 in game period was significantly increased by PLB, and the change in SpO_2 from pre-game period to game period was significantly reduced in both the subjects with and without oxygen therapy. Faager et al. [23] reported that the SpO_2 decreased during the endurance shuttle walking test, and the values of SpO_2 in patients with PLB were significantly higher than those without PLB, which supported our results.

The increased residual volume and reduced inspiratory capacity cause dynamic hyperinflation in COPD subjects, which makes it difficult to maintain a sufficient tidal volume during exercise [24-26]. PLB could extend the expiratory time, increase the tidal volume and decrease the respiratory rate [27]. O'Donnell [28] reported that the reduction in hyperinflation by the reduction in the end expiratory lung volume results in an improved ability to increase the tidal volume for a given effort. The improvement of SpO_2 by PLB might be caused by the increased inspiratory capacity and reduced dynamic hyperinflation followed by the increased tidal volume and possibly improved VA/Q inequality during the FDA game.

Another possible reason for the improvement of SpO_2 was the reduction in breath-holding. Takahashi et al. [29] reported that PLB was recommended for the prevention of hypoxemia caused by breath-holding during walking or exertion. Breath-holding might occur when participants throw a disc owing to the concentration on the FDA game. Actually, when we measured the breath-holding time during the FDA game in 11 elderly persons, PLB could prevent the breath-holding followed by the improvement in SpO_2. This effect of reduced breath-holding time might be one of the reasons for improved SpO_2 during the FDA game.

This study had several limitations. First, the number of recruited subjects was small. A larger study is required to clarify further the effects of PLB on SpO_2 during a FDA game. Second, the respiratory functions were different between in the subjects with and without oxygen therapy though this study was mainly focused on the patients with oxygen therapy. The difference between those groups might be caused by not only oxygen therapy but also by differences in the severity of the airflow limitation. To evaluate the effect of oxygen therapy, the subjects with oxygen therapy should be compared with those without oxygen therapy with similar pulmonary function. Third, the effects of latent co-morbidities were not completely excluded. Further study is required to determine the effects of co-morbidities. Fourth, since this study was an observational study, the learning effect of the FDA game was not excluded. Once subjects have learned PLB, however, it is difficult to play the game without PLB. So, a crossover study is difficult to perform. Fifth, heart rate was measured by a pulse oximeter, but not by an electrocardiogram, so the value of heart rate might be less accurate. An electrocardiogram could be another way to evaluate the change in heart rate.

Conclusion

The decline of SpO_2 during the FDA game in subjects with COPD and oxygen therapy was improved by using the PLB technique, which was partly associated with the reduction of breath-holding time. The FDA game could be carried out more safely with instruction in PLB.

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This study registration number: UMIN000027220

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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