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The Physiological Effects of Combined Training with Breathing Resistance and Sustained Physical Exertion in Healthy Young Adults

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Abstract

Purpose: The aim of the present study was to describe the physiological effects of a combined training with breathing resistance and sustained physical exertion (CBS) program, which is a respiratory muscle training program designed to improve respiratory function and cardiorespiratory endurance, in young adults.

Methods: Pre- and post-intervention measurements were comparatively examined between a group that completed an endurance exercise training program combined with a breathing resistance component (CBS group) and a group that underwent an endurance exercise training program only (control group). Data for these participants were analyzed together with similar data obtained in a previous study, where the effects of the CBS program on the respiratory and circulatory systems of nine healthy young subjects were evaluated with preliminary position of present research. The participants of the present study additionally underwent measurements related to respiratory muscle endurance. All participants were healthy young men and women.

Results: In total, 18 participants were analyzed. After the 6-week program, the maximum oxygen uptake and peak ventilatory threshold in the CBS group showed a significant improvement relative to the baseline measurements. The maximal voluntary ventilation and respiratory muscle endurance capacity also exhibited an improvement.

Conclusions: The results of this study indicate that our CBS program improves respiratory function more effectively than conventional training programs. Furthermore, they strongly support the findings of our previous study, where it was reported that CBS improves cardiorespiratory endurance more effectively than conventional training programs.

Condensed Abstract

We described the physiological effects of a combined training with breathing resistance and sustained physical exertion program in healthy young adults. The obtained data were combined with existing comparable data. We found that the improvements in respiratory muscle function and cardiorespiratory endurance were greater with our combined program than with conventional programs.

Keywords: Respiratory muscle training; Cardio respiratory endurance; Respiratory muscle endurance

Introduction

Cardiorespiratory endurance is associated with decreased cardiovascular disease morbidity and mortality rates [1-3]; thus, increased cardiorespiratory endurance may also be beneficial in promoting overall good health. The respiratory, cardiovascular, and musculoskeletal systems collectively determine the cardiorespiratory endurance of an individual. This has led to the inclusion of respiratory muscle training in modern sports and rehabilitation programs, with the aim of effectively improving cardiorespiratory endurance through an improvement in respiratory function. Respiratory muscle training exercises include techniques that employ mechanical loading and those that promote ventilation [4], hyperpnea endurance training [5], and the abdominal pad method [6]. Some reports claim that respiratory muscle training improves cardiorespiratory endurance [7-9], while others have found no such relationship [10-12]. A program's efficacy may therefore differ depending on the specific training method(s) employed. In the abovementioned respiratory muscle training exercises, a respiratory load is applied with the subject in a standing or sitting position. Therefore, breathing resistance cannot be combined with sustained physical exertion, although individuals can effectively improve their cardiorespiratory endurance in training and rehabilitation settings by performing physical exercises in addition to respiratory muscle training [13]. In most conventional respiratory muscle training exercises, the resistive load would be applied during either inhalation or exhalation, and there was no training device that can apply a resistive load during both inspiration and expiration. Increased ventilation during exercise necessitates expiratory muscle activity in addition to inspiratory muscle activity [14]. Therefore, application of a resistive load on both muscle sets will aid in improving cardiorespiratory endurance.

Considering these options, our research group hypothesized that a training program would achieve improved efficacy if simultaneous sustained physical exertion and breathing resistance were applied. Specifically, the application of a resistive load during both inspiration and expiration would benefit participants in the program by increasing their inspiratory and expiratory muscle activity and improving their respiratory function and cardiorespiratory endurance. For preliminary analysis, we proposed a 6-week program that combined sustained physical exertion with simultaneous respiratory training (combined training with breathing resistance and sustained physical exertion; CBS). In this program, resistance was generated during inhalation and expiration by a mask-type device, which allowed inspiration only through the nose and expiration only through the mouth. After the intervention period, the maximal voluntary ventilation in 12s (MVV12) and ventilatory threshold (VT) of participants who followed the CBS program showed a greater improvement compared with those of participants who followed a physical exercise program of the same intensity without a respiratory load [15]. However, the following three issues became clear in that study. First, the small sample size (n=9) resulted in inconclusive results regarding the effects of the CBS program on respiratory muscle strength and breathing patterns. Second, VT improved significantly with the CBS program alone, whereas the peak maximum oxygen uptake at the maximum exercise intensity improved significantly from baseline after both the CBS and conventional training programs. In addition, comparisons after training showed no significant differences between the two programs. Therefore, the CBS program may have resulted in specific training adaptation during exercise at VT intensity. However, in the previous study, there was no significant change in respiratory system parameters after exercise at VT intensity. VT_{tv}, which influences the ventilation efficiency, could have resulted in type II error in the previous study because the detection power was 0.616. Third, we assessed respiratory muscle function in terms of the maximum inspiratory mouth pressure (PI_{max}), maximum expiratory mouth pressure (PE_{max}), and MVV12, but we did not verify the effects of the program on the respiratory muscle endurance capacity, improvements in which are believed to be strongly associated with improved endurance. Because respiratory muscle training exerts different effects on the respiratory muscle strength and respiratory muscle endurance capacity, it is necessary to clarify the degree of effects of the new CBS program on the respiratory muscle endurance capacity. Resolution of the abovementioned issues would enable not only detailed verification of efficacy differences between the CBS program and conventional training programs but also clarification of the mechanism underlying the efficacy of the CBS program. With this information, intervention research could be conducted for adapting the program to the elderly and patients, with the aim of effectively improving their cardiorespiratory endurance to an extent greater than that achieved with conventional means. Accordingly, in the present study, we increased our sample size and analyzed several physiological indices, including additional respiratory muscle endurance capacity outcomes, before and after a 6-week CBS training program and a conventional training program. The objective was to describe the physiological efficacy of the CBS training program.

Methods

Participants and setting

The research contents and objectives were explained to all participants before they began the experiments. The study was performed after obtaining the approval of the Saitama Prefecture University Ethics Committee (Approval No. 26873).

The participants were 14 young men and women without abnormalities in respiratory or circulatory function. They were randomly assigned to the intervention group (CBS) or a control group (only sustained physical exertion training; OST; n=7 each). The CBS group performed endurance-type exercises while wearing a nasal respiration training mask-type device (ReBNA: Patent Works Inc.), while the OST group performed the same exercises without a mask. The obtained data were analyzed in combination with data for five CBS group participants and four OST group participants from our previous study [15].

Exercise protocol

The CBS group wore the ReBNA, a mask-type device with valves arranged in a manner that permits inhalation only through the nose and exhalation only through the mouth. Ventilation through two inspiratory valves and two expiratory valves produces a respiratory load. Before training, the internal mask pressure during inspiration and expiration was measured for five individuals during three maximal breaths. The mean mask pressure was −14.9 ± 0.9 cm H_2O during maximum inspiration and 37.9 ± 3.9 cm H_2O during maximum expiration (mean ± standard error).

Both groups underwent 6 weeks of training in three 2-week courses. The training intensity was set using the heart rate reserve (HRR; Karnoven formula) method [16]. HRR was calculated by subtracting the heart rate at rest (HR_{rest}) from the maximum heart rate (HR_{max}), which was estimated by the following formula: HR_{max} = 220−age [17]. The target heart rate during exercise was then calculated using the following formula:

$$\text{Target HR} = [(HR_{max} - HR_{rest}) \times \%\ \text{intensity}] + HR_{rest}$$

The target HR was calculated separately for each patient and was set at 75% HRR during the first course, 80% HRR during the second course, and 85% HRR during the third course.

The frequency of exercise was three times per week. The participants exercised either by pedaling on a cycle ergometer or running. In the former case, participants pedaled for 30 min at a load that maintained their target HR. The pedaling cadence was 60 rpm. In the latter case, participants ran for 30 min at a speed that maintained their target HR. Height, weight, body fat percentage, and muscle mass were measured for all participants, who also underwent a pulmonary function test, an incremental inspiratory threshold loading (ITL) test [18], and an exercise load test before and after the 6-week training period.

Measurements

Pulmonary function test

Vital capacity (VC), forced vital capacity (FVC), and MVV12 were measured using the FUDAC-70 spirometer (Fukuda Denshi, Ltd.). VC and FVC were measured twice each, and the larger values were used for analysis. If the two values differed by 10% or greater, measurements were repeated until the discrepancy fell below 10%. MVV12 was measured three times, and the largest value was used for analysis. P_{Imax} and P_{Emax} were measured using the HI-801 spirometer (Chest M.I., Inc.). Both P_{Imax} and P_{Emax} were measured three times, and the largest values were used for analysis.

Respiratory muscle endurance capacity

A Threshold Inspiratory Muscle Trainer (IMT: Philips Co., Ltd. Tokyo) was fitted with a replacement spring having a spring constant that was 4.3 times the constant of the manufacturer-provided default part. The Threshold IMT was inserted with an inspiratory pressure sensor (XFPN-03PGV: Fujikura Co., Ltd. Tokyo) connected to an analog-to-digital interface (AO-16CH: Applied Office Co., Ltd. Tokyo). Data were recorded on a computer and analyzed using DASYLab 9.0 software (P&A Technologies Inc. Iwate). Measurements were recorded as participants performed an incremental inspiratory threshold loading test [18] according to the ATS/ERS guidelines [18,19]. For measurements, each participant was seated in a chair and the IMT was fastened with a nose clip. The participant was then instructed to breath into a mouthpiece. All participants initially breathed for 2 min at an inspiratory load of 30% of P_{Imax}, following which they rested for 1 min. Next, participants breathed for 2 min at an inspiratory load of 40% of P_{Imax} and rested for 1 min. The inspiratory load was raised in 10% intervals as participants alternated between 2-min breathing and 1-min rest periods. The test was concluded once the participant could no longer continue because of intense breathing difficulties. The respiratory muscle endurance capacity was analyzed using the indices of the peak inspiratory pressure (P_{peak}: mean peak inspiratory pressure during maximum load), P_{peak}/P_{imax}, and PTI_{peak} (the pressure–time product at maximum load/P_{Imax}). PTI was calculated using the following formulae:

Mean inspiratory pressure (P–) = Pressure–time product (PTP)/ sampling period PTI = $P–/P_{Imax}$

Exercise load test

The exercise load test was performed using a cycle ergometer (232C xL: Combi Co., Ltd.). Exhaled gas was measured using a cpex-1 system (Inter Reha Co., Ltd. Tokyo). After 3 min of rest, participants warmed up for 3 min (load = 25 W for men, 15 W for women). The load was increased at 1-min intervals in increments of 25 W for men and 20 W for women. The cycling cadence was set at 60 rpm. Participants pedaled until their oxygen uptake stopped increasing or until the cycling cadence dropped to below 50 rpm and cooled down for 3 min after completing the exercise load test (load = 25 W for men, 15 W for women). Test discontinuation criteria were according to ACSM guidelines [20].

Data analysis

Data were first tested for normality using the Shapiro–Wilk test. Within-group data comparisons before and after the training program were performed using paired t-tests or Wilcoxon signed-rank tests. Between-group data comparisons before and after the training program were performed using unpaired t-tests or Wilcoxon rank-sum tests. All statistical analyses were performed using statistical analysis software (SPSS Statistics v.23). The significance level was set at 5%.

Results

Participant characteristics

Data for four CBS group participants and one OST group participant in the present study (conducted in 2015) were excluded from analysis; one contracted the common cold during the training period and four did not complete enough training sessions (<80%). Finally, eight CBS group participants and 10 OST group participants were analyzed after the addition of data obtained in our previous study (conducted in 2010).

No significant differences were observed in any measurement parameters at baseline between the two groups. The participant characteristics are shown in Table 1.

	CBS group (n=8)	OST group (n=10)
Age, years	21 ± 2.9	22 ± 2.9
Sex, Male/Female	5-Mar	5-May
Training, ergometer/ running	2-Jun	2-Aug
Height, cm	165.0 ± 10.5	165.3 ± 6.3
Weight, kg	57.3 ± 8.6	58.3 ± 6.5
Body mass index, kg/m^2	21.3 ± 10.9	19.7 ± 8.4
Body fat percentage, %	21.0 ± 1.5	21.0 ± 3.9
Muscle mass, kg	43.2 ± 11.5	44.3 ± 6.0
VO_2 peak, ml/min/kg	33.8 ± 6.6	38.0 ± 7.0
VT, ml/min/kg	18.6 ± 3.6	21.6 ± 5.6

Data are presented as means ± standard deviations unless otherwise noted. VO_2: peak maximum oxygen uptake, VT: ventilatory threshold

Table 1: Baseline characteristics of participants who underwent a combined training with breathing resistance and sustained physical exertion (CBS) program and those who underwent a conventional exercise (OST) program.

Training completion status

The training completion rate was 95.8% for the CBS group and 96.7% for the OST group. The target HR values for each training course in each group are shown in Table 2.

	CBS group (n=8)	OST group (n=10)
1st course	165 ± 5	166 ± 4

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2nd course	172 ± 4	172 ± 3
3rd course	178 ± 4	178 ± 3
The programs were conducted in three 2-week courses, for a total of 6 weeks. Data are presented as means ± standard deviations.		

Table 2: The target heart rate during each training session for participants who underwent a combined training with breathing resistance and sustained physical exertion (CBS) program and those who underwent a conventional exercise (OST) program.

Measurement results

The pulmonary function test and exercise load test results at baseline (BL) and after the 6-week training period (6W) are shown in Table 3. Data are expressed as means ± standard errors or medians (interquartile ranges). In the OST group, %VC was significantly higher at 6W than at BL [110.5% (109.4%–112.7%) vs. 108.2% (97.0%–110.0%); $p<0.05$], as was FVC (4.10 ± 0.25 vs. 4.02 ± 0.25 L; $p < 0.05$) and %FVC [118.6% (106.6%–111.3%) vs. 105.6% (99.0%–108.5%); $p<0.01$]. In the CBS group, MVV12 was significantly higher at 6W than at BL (131.9 ± 12.6 vs. 113.5 ± 13.3 L/min; $p<0.01$), as was P_{Imax} (104.7 ± 8.9 vs. 92.7 ± 7.2 cmH2O; $p<0.01$). P_{Imax} was also significantly higher at 6W than at BL in the OST group (116.6 ± 10.5 vs. 103.6 ± 8.9 cm H_2O; $p<0.05$).

	CBS group (n=8)		OST group (n=10)	
	BL	6W	BL	6W
VC (L)	3.73(3.30-5.19)	3.80(3.44-5.06)	3.62(3.46-3.99)	3.72(3.61-4.30)
%VC (%)	119.2(104.3-122.4)	116.4(110.2-126.4)	108.2(97.0-110.0)	110.5(109.4-112.7)[b]
FVC (L)	3.99 ± 0.38	4.12 ± 0.37	4.02 ± 0.25	4.1 ± 0.25[a]
%FVC (%)	117.7(107.2-121.0)	114.7(107.9-123.3)	105.6(99.0-108.5)	108.6(106.6-111.3)[b]
FEV1 (L)	3.59 ± 0.32	3.62 ± 0.3	3.55 ± 0.24	3.58 ± 0.24
FEV1% (%)	87.8 ± 1.6	88 ± 1.68	88.2 ± 1.6	87.3 ± 1.5
MVV12 (L/min)	113.5 ± 13.3	131.9 ± 11.7[aa]	141.1 ± 12.6	145.8 ± 11.1
P_{Imax} (cmH_2O)	92.7 ± 7.2	104.7 ± 7.5[aa]	103.6 ± 8.9	116.6 ± 10.5[a]
P_{Emax} (cmH_2O)	119.5 ± 14.9	124.2 ± 12.5	123.9 ± 12	124.7 ± 12.6
$Watt_{peak}$ (W)	190.6 ± 24.5	213.5 ± 24.8[aa]	205.9 ± 14.6	226.7 ± 14.2[aa]
VO_2 peak (mL/min/kg)	33.5(29.3-36.3)	37.3(35.0-43.3)[b]	36.6(32.2-42.5)	36.6(33.9-44.7)
VCO_2 peak (mL/min/kg)	39.3(36.0-48.6)	50.1(42.9-55.3)[b]	43.2(42.2-56.3)	47.6(43.8-56.9)
VE_{peak} (L/min)	78.2(56.7-106.6)	93.5(69.1-111.0)	81.5(69.4-91.0)	85.3(79.3-93.6)
HR_{peak} (bpm)	183.0(181.8-185.3)	185.5(184.8-186.8)	178.0(172.0-187.0)	172.0(171.0-189.8)
RR_{peak} (breaths/min)	38.4(32.4-41.0)	39.9(31.8-44.3)	40.3(39.2-43.8)	42.9(41.3-45.7)
Tv_{peak} (L)	2.04 ± 0.22	2.2 ± 0.22	2.02 ± 0.15	2.12 ± 0.17
VE/VO_2 peak	44.1 ± 4.5	43 ± 3.19	40.4 ± 2	40.9 ± 2.4
VE/VCO_2 peak	35 ± 2.3	33.6 ± 1.7	32 ± 1.4	31.6 ± 1.4
VT (ml/min/kg)	18.6 ± 1.3	24.1 ± 1.8[aa]	21.6 ± 1.8	21.5 ± 1.7
RR_{VT} (breaths/min)	26.6 ± 1.9	26.2 ± 1.2	24.3 ± 2	26.1 ± 2.3
Tv_{VT} (L)	1.16 ± 0.13	1.45 ± 0.13[a]	1.25 ± 0.11	1.29 ± 0.11
VE/VO_2 VT	25.7 (22.9-28.3)	25.8(24.8-28.5)	26.0(21.4-31.3)	27.9(25.4-30.5)
VE/VCO_2 VT	29.1 ± 1.4	28.2 ± 1	28.3 ± 1.2	29.6 ± 1
VEVT (L/min)	27.6 (23.0-29.5)	36.9(31.8-41.9)[b]	27.1(22.5-35.1)	32.2(29.2-34.4)

Data are presented as means ± standard deviations or medians (interquartile ranges).
[a]Comparison of baseline values and values after the 6-week program within groups (paired t-tests; $p<0.05$)
[aa]Comparison of baseline values and values after the 6-week program within groups (paired t-tests; $p<0.01$)
[b]Comparison of baseline values and values after the 6-week program within groups (Wilcoxon signed-rank tests; $p<0.05$).

Table 3: Outcomes of the respiratory function and exercise load tests for participants who underwent a combined training with breathing resistance and sustained physical exertion (CBS) program and those who underwent a conventional exercise (OST) program.

$Watt_{peak}$ values in the CBS and OST groups were 190.6 ± 24.5 and 205.9 ± 14.6 W, respectively, at BL and 213.5 ± 14.6 and 226.7 ± 14.2 W, respectively, at 6W. In both groups, the values were significantly higher at 6W ($p<0.01$). In the CBS group, VO2 peak [37.3 (35.0–43.3) vs. 33.5 (29.3–36.3) mL/min/kg; $p < 0.05$], VCO_2 peak [50.1 (42.9–55.3) vs. 39.3 (36.0–48.6) mL/min/kg; $p<0.05$], and VT (24.1 ± 1.8 vs. 18.6 ± 1.3 mL/min/kg; $p<0.01$) were significantly higher at 6W than at BL.

Respiratory Rate in VT (RRVT) was similar at 6W and BL (26.2 ± 1.2 vs. 26.6 ± 1.9 breaths/min), whereas Tidal volume in VT (T_{vVT}) was significantly higher at 6W than at BL (1.45 ± 0.13 vs. 1.16 ± 0.13 L; $p<0.05$).

Data from the respiratory muscle endurance test performed by the participants in the present study are shown in Table 4. P_{peak} was 23.4 cmH_2O higher at 6W than at BL in the CBS group and 7.2 cm H_2O higher at 6W than at BL in the OST group. In addition, P_{peak}/P_{Imax} increased by 11.5% in the CBS group and decreased by 10.1% in the OST group over the same time period. PTI_{peak} increased by 0.09 and decreased by 0.09 in the CBS and OST groups, respectively.

	CBS group (n=3)			**OST group (n=6)**		
	BL	**6W**	**Change**	**BL**	**6W**	**Change**
P_{peak}, cmH_2O	75.2 ± 20.0	98.6 ± 9.5	23.4	97.5 ± 7.8	104.6 ± 24.5	7.2
P_{peak}/P_{Imax}, %	72.9 ± 4.0	84.4 ± 10.0	11.5	92.6 ± 22.2	82.5 ± 20.8	−10.1

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PT_{Ipeak}	0.20 ± 0.06	0.29 ± 0.09	0.09	0.31 ± 0.14	0.22 ± 0.08	−0.09

Data are presented as means ± standard deviations.
Change indicates the change after the 6-week intervention program.

Table 4: Outcomes of the incremental inspiratory threshold loading test for participants who underwent a combined training with breathing resistance and sustained physical exertion program and those who underwent a conventional exercise program.

Discussion

In the present study, we described the physiological effects of CBS, a novel training program combining breathing resistance with sustained physical exertion, with focus on cardiopulmonary endurance and respiratory function outcomes. The data obtained in the present study add to measurement data obtained by us in a similar study conducted in 2010 [15]. We increased the sample size for analysis by adding data for newly assessed participants (Table 5). The participants in the present study were also evaluated in terms of respiratory muscle endurance indices; this additional data was not collected in our previous study. The results of the present study suggest that CBS improves VO_{2peak} and changes breathing patterns more effectively than the same exercise without a breathing resistance component. Moreover, CBS tends to improve respiratory muscle endurance.

In the previous study [15], VT significantly improved only in the CBS group; however, the corresponding improvements in VO_{2peak} were not significantly different between the two groups. On the other hand, both VO_{2peak} and VT significantly improved only in the CBS group in the present study. These results more strongly suggest that breathing resistance effectively improves cardiorespiratory endurance.

Till date, one study has reported that the improvement in cardiorespiratory endurance is greater after respiratory muscle training and physical exercise training performed at different times than after physical exercise training alone [13]. However, our search yielded no studies reporting that effective improvements in cardiorespiratory endurance were achieved by a program involving simultaneous implementation of sustained physical exertion and breathing resistance. Therefore, we consider our findings novel. It is highly likely that training methods that can effectively improve cardiorespiratory endurance will serve as beneficial exercise therapy for individuals with diminished cardiorespiratory endurance, such as the elderly and individuals with disabilities. We believe that investigations on the application of CBS training for these populations will be of high value.

	In the present study	**In the previous study [15]**
P_{Imax}	P_{Imax} significantly improved with both the CBS and OST programs.	P_{Imax} no significantly improved with both the CBS and OST programs.
$Watt_{peak}$	$Watt_{peak}$ significantly improved with both the CBS and OST programs.	$Watt_{peak}$ significantly improved only with the CBS programs.
VO_{2peak}	VO_{2peak} significantly improved only with the CBS program	VO_{2peak} significantly improved with both the CBS and the OST program
VCO_{2peak}	VCO_{2peak} significantly improved only with the CBS program	VCO_{2peak} significantly improved both with the CBS and the OST program
TV_{VT}	TV_{VT} significantly improved only with the CBS program	TV_{VT} no significantly improved both with the CBS and the OST program

Reference 15: Kido S, Nakajima Y, Miyasaka T, Maeda Y, Tanaka T, et al. (2013) Effects of combined training with breathing resistance and sustained physical exertion to improve endurance capacity and respiratory muscle function in healthy young adults. J Phys Ther Sci 25: 605-610.
OST: only sustained physical exertion training
CBS: combined training with breathing resistance and sustained physical exertion
VO_2: peak maximum oxygen uptake, VT: ventilatory threshold

Table 5: Parameters that exhibited different findings in our present study and our previous study [15].

In the present study, MVV [12] significantly increased after the training period only in the CBS group. MVV [12] is affected by factors such as respiratory muscle strength, respiratory muscle endurance capacity, degree of airway obstruction, and thoracic compliance [19]. Respiratory muscle training slightly alters the airway resistance and thoracic compliance in healthy young adults [21]. In addition to the fact that none of our participants had any respiratory function abnormalities, we believe that MVV [12] was improved in the CBS group because of increased instantaneous respiratory muscle strength, increased respiratory muscle endurance capacity, or both. However, in the present study, both groups exhibited a significant increase in P_{Imax} but no change in P_{Emax} relative to the baseline values, suggesting that the improvement in MVV12 observed in the CBS group was greatly influenced by factors unrelated to instantaneous respiratory muscle power. On the other hand, P_{peak} appeared to increase in both groups, whereas P_{peak}/P_{Imax} and PTI_{peak} increased only in the CBS group. These two findings suggest that CBS improves sustained rather than instantaneous respiratory muscle function, at least over the range of resistances applied in the present study. Moreover, given that athletes in endurance competitions such as marathons have high respiratory muscle endurance [22], improved respiratory muscle endurance capacity following a CBS program may be positively associated with improved cardiorespiratory endurance.

T_{vVT} significantly increased over the training p only in the CBS group in the present study. We believe that the application of a respiratory load during sustained physical exertion improved respiratory muscle function and other factors in the CBS group participants, leading to the development of deep breathing patterns. An increased tidal volume raises ventilation efficiency by decreasing the dead-space ventilation rate. As a result, patients taking deeper breaths during exercise can decrease the respiratory muscle workload per tidal volume, thereby improving their cardiorespiratory endurance.

Study Limitations

Respiratory muscle endurance capacity was analyzed for few participants in the present study (three from the CBS group and six from the OST group), necessitating an increase in the sample size and performance of a more detailed investigation. In addition, the present study included healthy young adults. The CBS training program's efficacy may differ in the elderly and individuals with disease, depending on differences in their physical function and pulmonary mechanics.

Conclusions

In conclusion, our study findings suggest that a 6-week CBS training program helps participants in developing breathing patterns characterized by good ventilation efficiency due to an increased tidal volume and in improving their inspiratory muscle endurance. These novel findings were obtained by increasing the number of participants relative to the number in our previous study and by adding respiratory muscle endurance outcomes in the present analysis. Our study demonstrated the potential effectiveness of CBS, a novel training program, in helping healthy young adults to develop deep breathing patterns during exercise, improve sustained respiratory muscle function, and improve cardiorespiratory endurance. The inclusion of CBS in exercise therapy interventions for the elderly and patients with respiratory diseases can effectively improve their physical function. The results obtained in the present study serve as basic information that will aid professionals in selecting diseases suitable for CBS application, optimizing resistive loads and intervention lengths, and improving intervention techniques.

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