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Effects of resisted chest cage expansion exercise training on functional capacity in normal adult

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ABSTRACT

The purpose of this study was to determine whether externally applied resistance to chest wall expansion during exercise training will improve the exercise capacity or not. **Methods**: One hundred healthy, non-active adults volunteer were included for the study with age group between 20-30 years. Both the groups performed aerobic exercise three days a week up to 35-40 minutes. The exercise testing was performed by using Bruce protocol to predict VO2 max value. Time to exhaustion and PFT were calculated. **Results** showed that VO2max and time to exhaustion improved significantly after twelve weeks of aerobic training for both the groups. **Conclusion:** Training with thoracic band exercise significantly increased aerobic capacity. Time-to-exhaustion significantly increased in chest wall constriction group after twelve weeks than the non chest wall constriction group.

Key word: Functional Capacity, Vo2 max, Pulmonary function, Chest wall constriction

INTRODUCTION

Chest wall-restrictive loading reduces a person's ability to expand the chest wall during inhalation and results in decrements in lung capacities, resting pulmonary function, and ultimately, exercise performance. Current research examining the physiological effects of chest wall restriction in the workplace as well as in pathological conditions reveals significant reductions in measures of resting lung volumes, pulmonary function and exercise capacity[1-5].

Measurement of lung capacities have been collected, but at the same time, minimal assessment of the effect of chest wall restriction on forced spirometric volumes and maximal exercise performance has been performed [6,7].

The use of resisted chest cage expansion has been shown to limit exercise performance, but it has not been studied as a mode of muscular conditioning to enhance performance in healthy adults[8,9]. Studies have indicated that the respiratory skeletal muscles, like muscles of the limbs, fatigue under conditions of intense activity, leading to respiratory failure[10,11]. Special breathing exercises, breathing against a flow or threshold

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resistor, or doing maximum voluntary ventilation maneuvers several times a day has been shown to strengthen the ventilatory muscles in the clinical populations[12].

The purpose of this study was to determine whether externally applied resistance to chest wall expansion during exercise training will improve the exercise capacity or not. Studies have shown that resistance to chest wall (external thoracic restriction) during moderate intensity exercise limits an individual's respiratory muscle function and exercise performance. However, available information regarding the use of chest restriction as a training mode during exercise has yet to be studied. If shown to improve these components, the use of chest restriction could be introduced into the non-active population as a mode of training.

Methods

One hundred healthy, non-active adults volunteer were included for the study with age group between 20-30 years. It is assumed that all individuals volunteering to participate in the study will offer their best effort during pre-test, mid-test(six week) and post-test(twelve week) assessments. To ensure maximum effort and complete understanding of the protocol, the researcher explained to each participant what is expected. Details of the participants were recorded in Assessment Performa based on the guidelines of AHA, 2002. Participants completed a Physical Activity Readiness Questionnaire (Par-Q). Participants signed an informed consent form prior to the commencement of the study. Exercise Testing Termination Criteria was kept in to consideration while conducting the test. Testing took place, the week prior to, at the end of sixth week and the end of the twelve-week study period. Both stages of testing include a pulmonary lung function test and a VO_{2max} treadmill test were estimated by a prediction formula. Active and sedentary men - Foster et al. 1984. Men VO2 max=$14.8-(1.379\times T)+(0.451\times T^2)-(0.012\times T^3)$, and for women VO_2 max=4.38xT-3.9 ("T" is the total time of the test expressed in minutes and fractions of a minute)[13].

Variables

The dependent variables for this study were pulmonary function, forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory flow from 25 to 75 percent of the vital capacity (FEF25-75%), peak expiratory flow (PEF), VO2max, and time to exhaustion. The control variables for this study were age, gender, and history of exercise. The extraneous variables for this study were participants' other daily physical activities

Procedures

Both the groups performed aerobic exercise three days a week for approximately started with initial stage of 15-20 minutes and progressed up to 35-40 minutes at a moderate intensity estimated at 40 to 85 percent of their HRR, with at least one day of rest between exercise sessions.

Fig 1: Subject performing PFT

Participants entered the study from sedentary life styles, thus exercise intensity was generally described as being winded but still able to hold a conversation. Participants used treadmill for exercise testing and training.

Participants' VO_{2max} levels were assessed using Bruce treadmill Protocol. The Bruce Protocol is a maximal exercise test where the athlete works to complete exhaustion as the treadmill speed and incline is increased every three minutes.

Bruce Treadmill Test Stages

Stage1=1.7mph at 10% Grade

Stage2 = 2.5 mph at 12% Grade

Stage3 = 3.4 mph at 14% Grade

Stage4 = 4.2 mph at 16% Grade

Stage5 = 5.0 mph at 18% Grade

Stage6 = 5.5 mph at 20% Grade

Stage7 = 6.0 mph at 22% Grade

Stage8 = 6.5 mph at 24% Grade

Stage 9 = 7.0 mph at 26% Grade

Fig 2: Subject undergoing training with chest wall restriction

The length of time on the treadmill is the test score and can be used to estimate the $VO_{2\ max}$ value. During the test, heart rate, blood pressure and ratings of perceived exertion are often also collected.

The test continued until the participant reached complete physical failure or stopped at volition request. A Treadmill Stress test system RMS Vega-201, Chandigarh, India was used. Participants were attached to the ECG leads for monitoring heart activity and Blood pressure was recorded. Pulmonary function tests were performed with the subject standing, through a disposable pneumotach mouthpiece attached to the Digital Spiro meter. The subjects was performed forced

Fig 3: Subject undergoing Exercise testing

vital capacity (flow volume loop) maneuvers until three reproducible measurements was recorded and stored on a computer for later analysis.

Each subject in the CWC group had chest wall restricted with the use of an elastic strap (widths 14 cm) was adjusted to fit just beneath the axillae and around the chest to envelop the rib cage. The desirable degree of lung constriction was achieved by manually tightening the straps. A 10% reduction in FVC from baseline was considered the target constriction. It is worth noting that this apparatus does not prevent the chest wall from expanding like earlier studies, but offers elastic concentric resistance for the inspiratory muscles to work against.

VO_{2max} was calculated by validated equation for the use of a Bruce treadmill protocol. Exercise testing was terminated as per the indication for stopping an exercise test in low risk adults. The exercise training session began with 5-10 minutes of low intensity large muscle activity as warm up (10-30% HRR). Cool down for 5 minutes of slower walking or jogging was prescribed for the subjects, Exercise training progression was done as per the ACSM guidelines for sedentary adults[14].

RESULTS

Data analysis was performed using the software package SPSS collected data was expressed in terms of mean and standard deviation. The general linear model (GLM), repeated measure analysis of variance (ANOVA) was used to examine changes in all dependant variables for within group analysis. Independent t-test was used to compare the difference between groups. The significance level set for this study was $p < 0.05$

Table 1: Exercise training session with percentage HRR

Week	Exercise frequency (session/wk^{-1})	Exercise intensity (%HRR)	Exercise duration (min)
1	3	40-50	15-20
2	3-4	40-50	20-25
3	3-4	50-60	20-25
4	3-4	50-60	25-30
5	3-4	60-70	25-30
6	3-4	60-70	25-30
7	3-4	60-70	25-30
8	3-4	60-70	30-35
9	3-4	60-70	30-35
10	3-5	65-75	30-35
11	3-5	65-75	30-35
12	3-5	70-85	35-40

One hundred healthy non-active 20 to 30 years-old volunteers participated in the twelve-week study. Participants were then randomly assigned using "chit method" to one of two groups on the basis of screening. Group One i.e. Chest Wall Constriction Group (CWC; n=50; male=33, female=17) and Group Two i.e. Non-Chest Wall Constriction Group (NCWC; n=50; male=32, female=18).

Table 2: Anthropometric data for CWC and NCWC

Group	Age (yr) M+SD	Height (m) M+SD	Weight (kg) M+SD	BMI M+SD
CWC n=44	24.57 +3.1	1.72 +2.4	69.35 +2.7	23.68 +4.4
NCWC n=44	23.95 +3.2	1.72 +3.2	69.62 +1.6	23.76 +0.4

VO_{2max}: A significant interaction was observed between groups, representing a difference in VO_{2max} scores as participants were tested from baseline to midpoint to endpoint ($P < 0.05$).

DISCUSSION

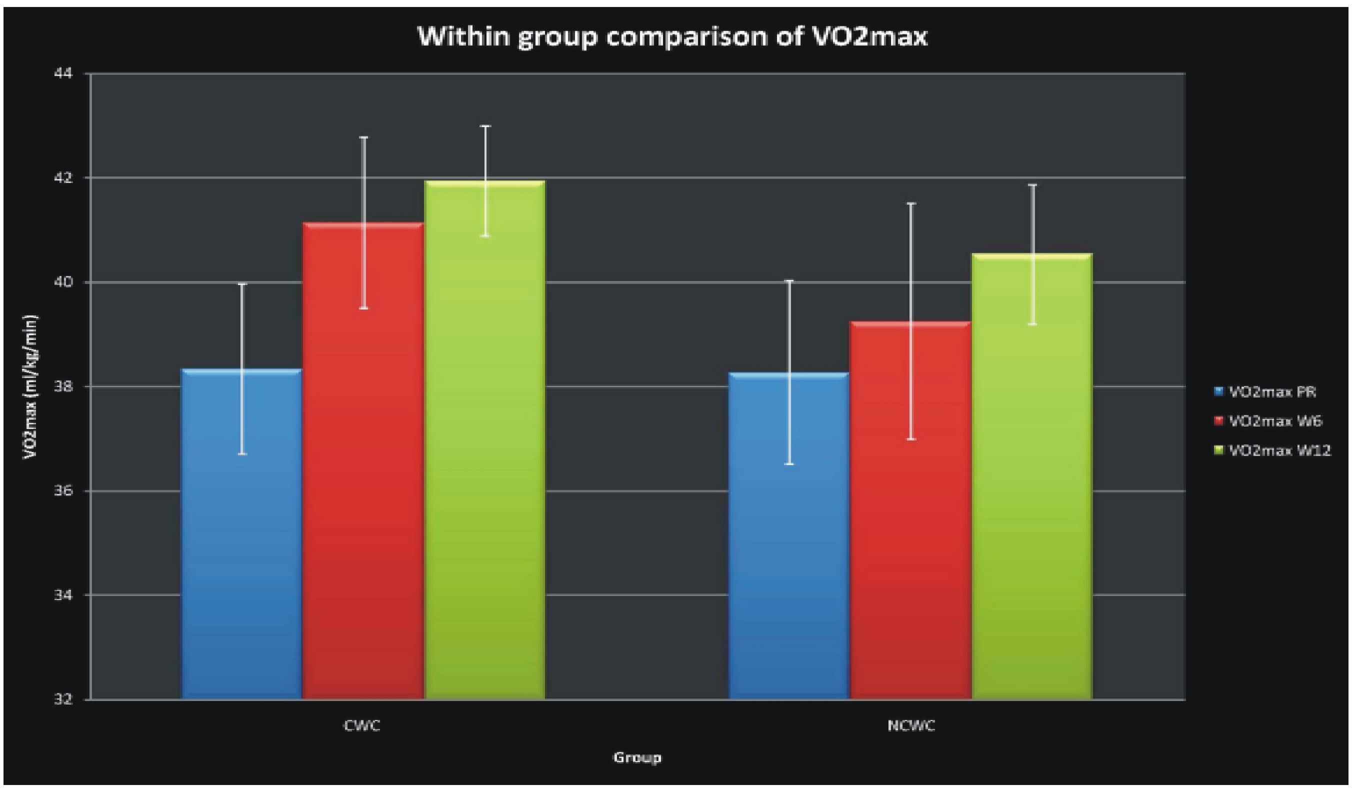
Previously very few studies have used chest wall constriction during moderate intensity

Table 3: Effect of training on VO_{2max}

	PRT M±SD	PST6 M±SD	PST12 M±SD	RMANOVA F	RMANOVA p
CWC	38.32±1. 3	41.14+1.6	41.94±1. 5	135.72	0.000
NCWC	38.26+1. 5	39.24±2.2	40.53+1. 3	53.70	0.000
Post Hoc Analysis					
PRTvsPST6	PRTvsPST12	PST6vsPST12			
0.000	0.000	0.000			
0.000	0.000	0.000			

Follow-up post-hoc investigation indicated that the experimental group had a significant improvement in VO_{2max} after six weeks of exercise (from 38.32±1.63 to 41.14±1.63 ml.min-^{1}kg-^{1}±SD) compared to the control group (from 38.26±1.75 to 39.24±2.25 ml.min-^{1}kg-^{1}±SD).

Fig 4: Within group comparison of VO_{2max}

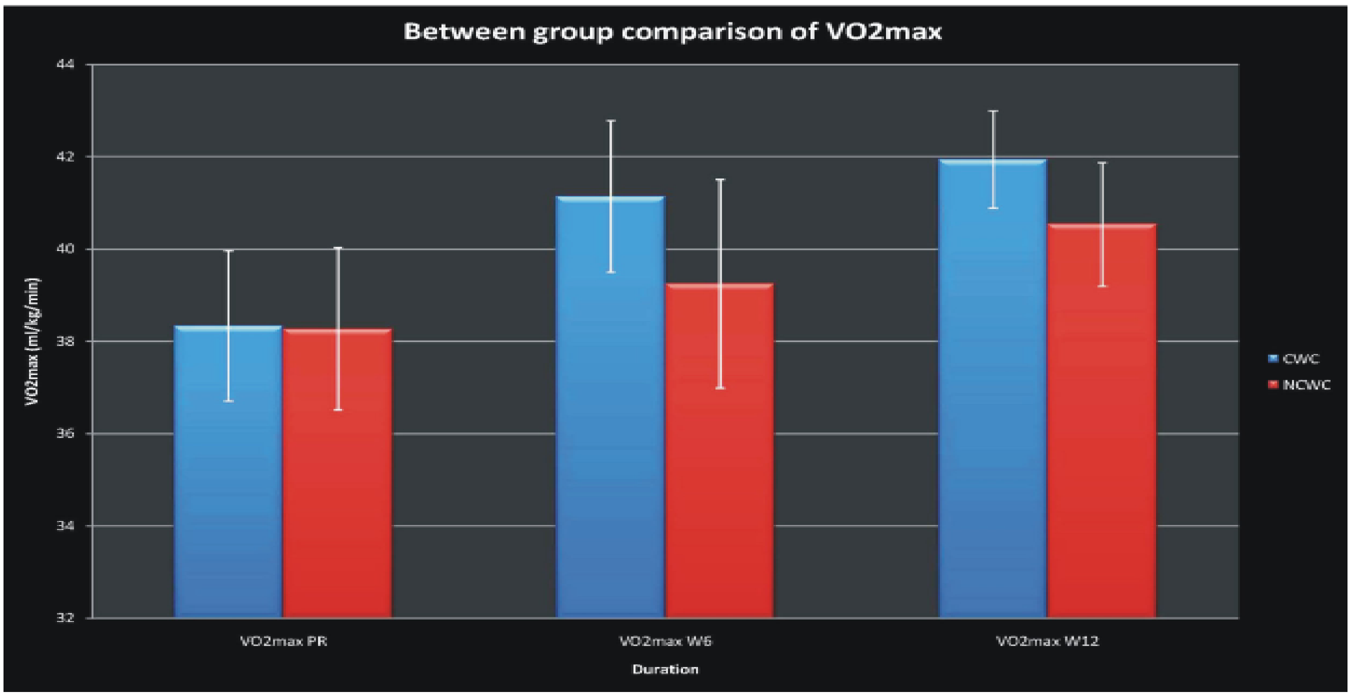


At twelve weeks experimental and control groups had significant increases compared to baseline in VO_{2max} 38.32±1.63 to 41.94±1.05 and 38.26±1.75 to 40.53±1.33 ml.min-^{1}kg-^{1}±SD respectively.

Table 4: Difference in training effect between CWC and NCWC at 0, 6th & 12th weeks.

	CWC M+SD	NCWC M+SD	T-Test	
			t	p
PRT0	38.32+1.(3	38.26+1.7	0.162	0.872
PST6	41.14+1.(3	39.24+2.2	4.512	0.000
PST12	41.94+1.(5	40.53+1.3	5.506	0.000

Fig 5: Between group comparison of VO_{2max}



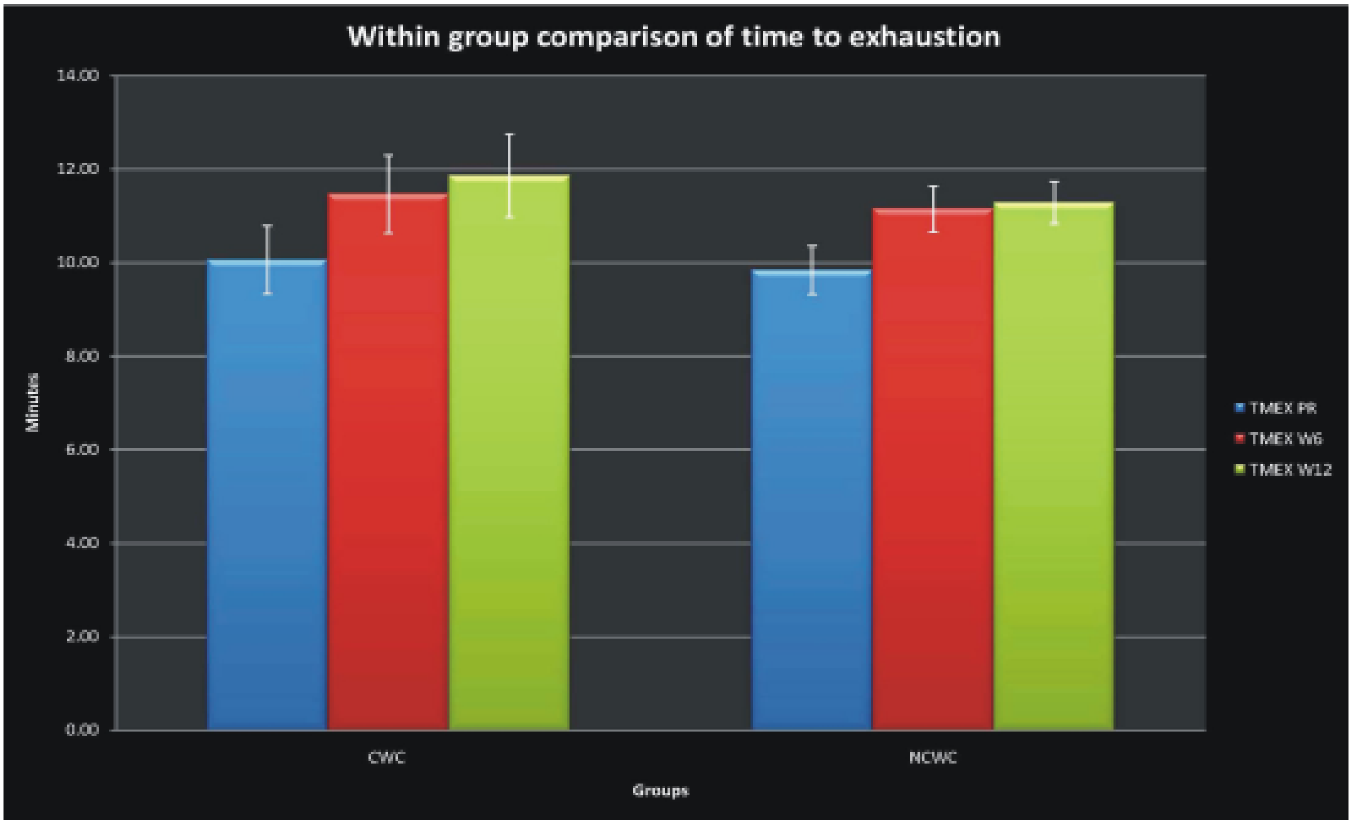
Time-to-Exhaustion: A significant difference in time-to-exhaustion was observed for both groups as participants were tested from baseline to midpoint to endpoint ($P < 0.05$). Time was recorded to the nearest 15 seconds.

Table 5: CWC and NCWC group's estimated marginal means of time to exhaustion at baseline, 6th & 12th weeks.

	PRT M+SD	PST6 M+SD	PST12 M+SD	RMANOVA	
				F	p
CWC	10.57±0.7 3	11.45+0.: 3	11.85+0.: 8	68.80	0.000
NCWC	9.89+0.5	11.14±0. 8	11.28±0. 5	151.89	0.000

Post Hoc Analysis		
PRTvsPST6	PRTvsPST12	PST6vsPST12
0.000	0.000	0.021
0.000	0.000	0.005

Fig 6: Within group comparison of time to exhaustion.



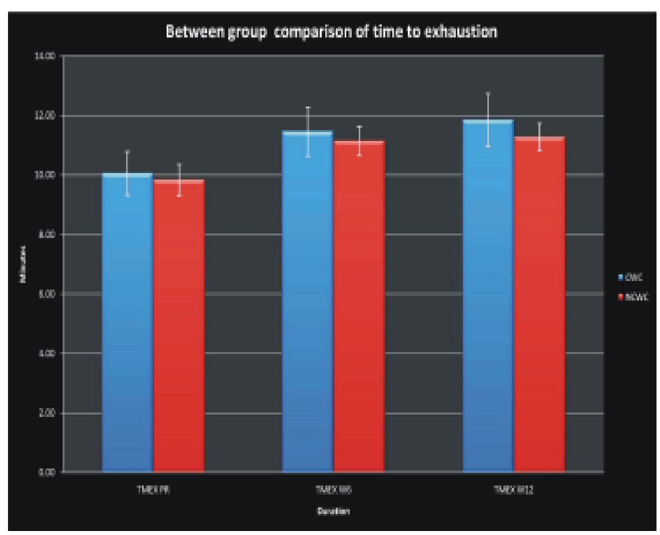
Follow-up post-hoc observation indicated that there was no difference in time-to-exhaustion between both groups.

Table 6: Difference in training effect between CWC and NCWC at 0, 6th & 12th weeks.

	CWC M±SD	NCWC M±SD	T-Test t	T-Test p
PRT	10.57±0.73	9.83±0.5	1.636	0.105
PST6	11.45+0. 3	11.14+0. 8	2.155	0.034
PST12	11.85±0.88	11.28±0. 5	3.842	0.000

At twelve weeks both groups had significant increases in time-to-exhaustion from 10.57±0.73 to 11.85±0.88 and from 9.83±0.51 to 11.28±0.45 minutes, respectively.

Fig 7: Between group comparison of time to exhaustion



However, non significant changes on pulmonary function test variables were observed in either group after the completion of twelve weeks of training.

exercise[15,16,17]. These studies showed that chest wall constriction limits individual's respiratory muscle function and exercise performance[18]. This is the first study of its kind to use chest wall constriction during exercise and show the effects of exercising with an elastic strap around the chest over a twelve-week training period. This study examined whether chest constriction could be used as a training mode and the long-term effects, if any. Previous studies documented only acute responses to chest constriction during exercise.

Previous studies used smaller numbers of participants than the 88 participants in this study: n= 2 (Harty et al., 1999), n=12 (O'Donnell et al., 2000), n=18 (Coast and Cline, 2004), n=11 (Wang and Cerny, 2004), n=7 (O'Connor et al., 2000). The participants in this study were about the same age as those used in the other studies. Healthy, non-active individuals were recruited to participate in this study and the same population that was used in two of the seven studies[16,17]. The other studies used active individuals[18] or healthy individuals[8,26,] thus allowing the reader to assume they were active. Of the 12 subjects used in the study by Harty et al. (1999), six subjects had previously participated in studies involving exercise testing and the level of physical fitness of the other six participants was not indicated.

In agreement with previous studies[19,20,21,25], VO_{2max} increased significantly after twelve weeks of aerobic training for both groups. These results support the hypothesis that an externally applied thoracic constriction band during aerobic exercise may assist in increasing aerobic capacity more rapidly than training without a constriction band, because of the greater increase in VO_{2max} seen within the first six weeks for the CWC group compared to the NCWC group. For the CWC group, increases in VO_{2max} were greater between weeks one through six and started to level off through week twelve. These results agree with Daniels et al. (1978), which indicated increases in VO_{2max} during the first six weeks of training but no increases after that. However, for the NCWC group, VO_{2max} continued to increase throughout the twelve-week training period.

A more rapid improvement was seen in the CWC group VO_{2max} within the first six weeks compared to the NCWC group. This increase in VO_{2max} may be the result of the training itself or the result of an increase in respiratory muscle strength. To determine if increases in VO_{2max} are the result of increased respiratory muscle strength, measurements of PImax and PEmax are needed. However, studies have shown that increases in PI max and PE max have no direct effect on VO2max[22,23].Serious consideration must be given to the possibility that the change in VO_{2max} is not a uniquely valid index of adaptation to training. Daniels et al. (1978) suggest that although the change in VO_{2max} is a useful measure of the response to the onset of training, it is a relatively insensitive measure of the overall response to training. Future efforts to understand the training response might be directed beneficially toward other measures of the body's functioning, such as cardiac output and arteriovenous oxygen difference.

Pulmonary Function; Differences in FVC, FEV1, $FEF_{25-75\%,}$ and PEF from week one to week twelve for both groups did not change. The same results were seen in previous studies after 4 to 16 weeks of IMT [22,23,24]. state that no change in FEV1 and PEF probably demonstrates the specificity of the effects of inspiratory training on expiratory lung function, while FVC is generally dictated by the individual's stature and not influenced by training.

Time-to-exhaustion is determined by the amount of time (in 15 second intervals) it takes the subject to reach complete exhaustion during the exercise test. Both groups demonstrated significant increases; however, there was no difference between groups, suggesting that these increases may be the result of training and not the elastic strap.

CONCLUSIONS

Training with an externally applied thoracic constriction band exercise significantly increased aerobic capacity more rapidly than training without the band. Time-to-exhaustion significantly increased in chest wall constriction group after twelve weeks than the non chest wall constriction group. Where as no significant differences in pulmonary function for both groups were observed. The result of this study may infer exercise protocol of chest wall constriction group.

Recommendations for further research: This study has raised further questions regarding the effects of chest constriction on aerobic capacity during exercise, including the potential benefit of chest restriction during exercise. The relatively short twelve-week duration of this study did not provide enough statistical information to answer any of these questions. Therefore, additional research is required. Further this protocol may be recommended for Restrictive lung disorder e.g. scoliosis, kyphoscoliosis, during their pulmonary rehabilitation regimen to improve their aerobic capacity and time to exhaustion. This study may pave the path for future study to apply the chest wall constriction protocol in restrictive lung disorder patients to improve their aerobic capacity, time to exhaustion and their pulmonary function.

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