ORIGINAL ARTICLE

Acute Impact of Modified Inspiratory Muscle Training on Maximal Oxygen Consumption

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ABSTRACT
Background: Individuals aim to maximize their performance by exercising. In this context, aerobic endurance and strength training, which may be included in a training program, also comes into prominence.
Aim: The present study was conducted to investigate the impacts of an eight-week modified acute inspiratorymuscletraining on the aerobic capacities of high school students.
Methods: The study was carried out with a total of 116 volunteer male athletes satisfying the inclusion criteria and not having any illness. The mean age, height, and weight of the experimental group (n=57) were 15.98±0.69 years, 171.3±7.99 cm, and 59.96±8.34 kg, respectively, while those of the control group (n=59) were 16.05±0.65 years, 169.2±8.44 cm, and 58.61±8.15 kg, respectively. The participants were subjected to a 20 m shuttle run, which is an indirect method, as a field test to identify their VO2max. consumption. SPSS 25.0 statistical package program was used for the analysis of the data. The normality of distribution was determined using the Kolmogorov-Smirnov test. T-test was utilized to determine the paired comparisons of the experimental and control groups over each time. In all statistical analyses, the significance level was accepted as p=0.05.
Results: As a result of analyses, the pre-test values for maximal oxygen consumption revealed no statistically significant difference between the experimental and control groups (t=-0.261; p>0.05). However, the difference between the arithmetic means of the post-test values for maximal oxygen consumption of the groups was found to be statistically significant (t=2.939; p<0.05).
Conclusion: Overall, it can be asserted that inspiratory muscle training positively affected inspiratory muscle strength and, thus, pulmonary functions and aerobic capacity compared to those exercising regularly. In addition, the Borg scale can be used to adjust the difficulty level of the training device.
Keywords: Inspiratory muscle training, Aerobic capacity, Maximal oxygen consumption

INTRODUCTION
The increase or decrease of the thoracic cavity with the movement of the chest wall and inspiratory muscles is known as pulmonary ventilation or inspiration. Many muscles are involved in inspiration. Some muscles specifically aid inspiration and are called inspiratory muscles. The muscles helping expiration are the expiratory muscles. The muscle with the most remarkable function in inspiration is the diaphragm and responsible for 75% of the air movement in the lungs. The activity of the external intercostals is responsible for bringing about 25% of the air volume entering the lungs. In addition to the diaphragm and external intercostals, the sternocleidomastoid, scalene, serratus anterior, pectoralis minor, pectoralis major, and upper trapezes are other auxiliary muscles facilitating inspiration.

Competition in today's sports branches creates an increase in physical demands. Athletes must have well-developed physical fitness to demonstrate a flawless performance[1, 2]. O_2 need increases in the muscles during exercise. In this context, the effective use of O_2 is critical for maintaining physical efficiency. The physiological adaptation of the inspiratory system, which will meet the necessary and sufficient oxygen during a competition or training, is a requirement of this mechanism. The increased breathing frequency during an exercise causes the inspiratory muscles to use more oxygen. The increase in the working capacity of the inspiratory muscles mechanically increases the efficiency of one's sportive activities by helping to increase the inspiration volume and to create a feasible environment for ventilation in case of loading. Thus, the person gets tired later and can recover more quickly after expending some physical efforts[3].The maximum amount of oxygen transported from the atmosphere to the tissues per unit of time in increasing loads and ongoing efforts involving large muscle groups is defined as $VO_{2max.}$and is the most effective way to evaluate aerobic capacity[4, 5]. It is known that muscle endurance and mass increase (hypertrophy) with a conscious and programmed loading on skeletal muscles[6]which is the case for the inspiratory muscles[7]. General muscle strength is an essential parameter for all physical activities. The strength of the inspiratory muscles, thanks to a robust inspiratory system, is critical in exercises where the aerobic system is dominantly utilized. The ability to continue aerobic exercises is directly related to aerobic capacity (strength) or $VO_{2max.}$ and, therefore, the role of inspiratory muscle strength stands out in exercises.). In the previous studies, researchers had people with inspiratory system diseases (COPD, Dyspnea, Asthma) do exercises oriented to increase inspiratory muscle strength to improve and increase their inspiratory functions and quality of life[8, 9]. Also, they had athletes do such exercises to improve their aerobic and anaerobic performances and increase their competitiveness[10, 11]. Most of these exercises, which usually lasted 6-12 weeks, led to a relative increase in the inspiratory muscle strength of the individuals and improvement in their endurance. It was concluded that strengthening inspiratory muscles and increasing endurance contributed to inspiratory functions of individuals and elevated their aerobic performance[12-14]. More than one different method was used in previous studies on inspiratory muscle exercises. Inspiratory muscle exercises for healthy individuals are the ones generally performed in two sessions (morning and evening) with 30 breaths per session based on a pre-determined maximal inspiration measured with a threshold device. These exercises are also done for warming up the inspiratory muscles before training[15].

Ultimately, this study was carried out to investigate the impacts of the modified version of the available inspiratory muscle exercise on VO2max. of young athletes enrolled in a high school.

MATERIAL & METHODS

Sample Selection: A total of 116 male students between the ages of 16-17 who were studying at Adana Sarıçam Sports High School voluntarily participated in our study. Relevant permissions were obtained from the parents of each athlete and the school administration. The participants were informed about the content and significance of the study before the research procedures.

The participants' ages, heights, body weights, body mass indices (BMI), and $VO_{2max.}$ consumptions were determined and noted. Volunteers were divided into two groups (experimental and control) using the purposive sampling technique so that there would be no difference among the participants by BMI and $VO_{2max.}$.consumption measurements.

Data Collection:

The body weights of the volunteers were measured with a computer-controlled weighing device (Tanita BC 418 MA MODEL) with a sensitivity of 0.1, while wearing only shorts on bare feet. On the other hand, heights were measured with the help of a Holtaine brand stadiometer while standing in an upright position on bare feet and noted with an accuracy of 0.01 cm. Body mass indices were determined using the kg/height $(m)^2$ formula. The participants were subjected to a 20 m shuttle run, which is an indirect method, as a field test to identify their $VO_{2max.}$ consumption. The results of each participant were noted as ml/kg/minute by the Kartesks formula applied for children under 18 years old. All measurements were taken twice, at the beginning and end of the study (pre-exercise and post-exercise).

Modification and Implementation of Inspiratory Muscle Exercises

Inspiratory muscle exercises are usually done to warm up the inspiratory muscles by athletes in the dressing room just before training or by individuals twice a day (morning and evening) with 30 breaths per session 15. Inspiratory muscle exercises used out of training were used in training in this study. The athletes did these exercises with the POWERbreatheRedPlus device by closing their noses with a ratchet. While the device did not allow inspiration without exceeding a certain threshold, it did not apply any pressure during expiration. The difficulty level of the device, on the other hand, was determined using the Borg scale, which is a method of determining the perceived difficulty level for each athlete. The pressure level, which indicates the difficulty level of the device, was adjusted manually by the Borg scale to be slightly difficult for each individual.

Physical education and sports classes were taught in both groups in accordance with the curriculum. Unlike the control group, the experimental group was subjected to inspiratory muscle exercises in the aerobic warm-up phases at pre-determined pressure levels for each athlete for 15 minutes a day, 3 days a week, and a total of 8 weeks. During exercises, in the case of extreme strains of athletes due to the increase in inspiratory rates and frequencies with the impact of exercise, the severity of the load was modified to be between difficult and very difficult by the Borg scale and continued to be implemented for 15 minutes.

Data Analysis

The data were analyzed using the SPSS for Windows Release 21.0 (Statistical Package for Social Sciences Inc. Chicago, IL, USA). In the data analysis, the data set was examined primarily in terms of erroneous values, outliers, and normality of the distribution. The Kolmogorov-Smirnov test revealed that the data were normally distributed ($p>0.05$). In the present study, the variables determined by measurements were indicated as mean ($\bar{x}$) and standard deviation (SD). Independent Samples T-Test was utilized to determine the paired comparisons between the experimental and control groups over each time.In all statistical analyses, the significance level was accepted as $p=0.05$.

RESULTS

Findings

Anthropometric characteristics (age, body weight, height, BMI, and pre- and post-test values of $VO_{2max.}$) of the groups are shown in Table 1.

Table 1. Physical Characteristics of Participants

Variable		Experimental Group (n=57)	Control Group (n=59)
		$\bar{x}$±SD	$\bar{x}$±SD
Age (year)		15.98±0.69	16.05±0.65
Body weight (kg)		59.96±8.34	58.61±8.15
Height (cm)		171.3±7.99	169.2±8.44
BMI (kg/height^2)		20.41±0.23	20.43±0.21
$VO_{2max.}$ (ml/kg/min)	Pre-test	42.21±5.74	42.51±6.42
	Post-test	45.63±4.97	42.55±6.22

Table 2. Comparison of $VO_{2max.}$ values between the groups

	Group	N	$\bar{x}$	SE	t	df	p
Pre-test	EG	57	42.21	,760	-.261	114	.795
	CG	59	42.51	,836			
Post-test	EG	57	45.63	,658	2.93	114	**.004**
	CG	59	42.55	,810			

Independent Samples T-test was conducted to identify whether the mean maximal oxygen consumptions showed a significant difference between the groups. The results suggested that the difference of mean pre-test consumption values was not statistically significant between the groups (t=-0.261; p>0.05).

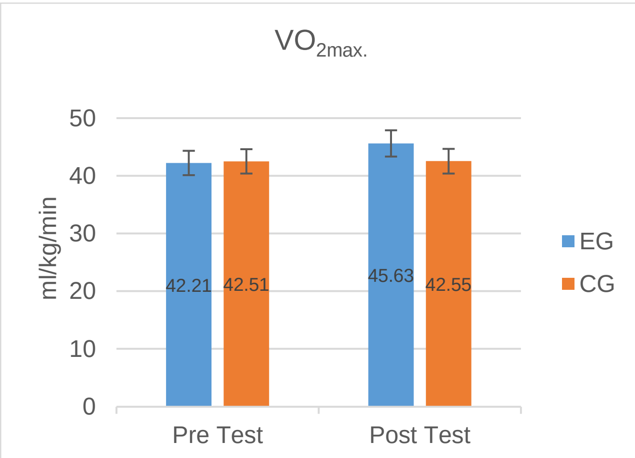

Figure 1: The mean pre- and post-test VO2max. values of the groups

However, the experimental and control groups showed a statistically significant difference by the post-test values of maximal oxygen consumption (t=2.939; p<0.05).

DISCUSSION

A total of 116 athletes between the ages of 16-17 attending a sports high school participated in this study. These participants were divided into two groups as experimental (n=57) and control (n=59) using the purposive sampling technique so that there would be no difference in their BMI and $VO_{2max.}$ consumption measurements. The mean age and height of the experimental group were 15.98±0.69 years and 171.3±7.99 cm, respectively. These were 16.05±0.65 years and 169.2±8.44 cm in the control group, respectively. Accordingly, the groups were similar to each other by some of their physical characteristics.

The amount of oxygen consumed by athletes increases linearly with increasing intensity during exercises. The success of athletes depends on their ability to perform high-intensity activities. However, the ability to repeat high-intensity activities at the same level throughout the competition totally relies on how effective and fast athletes are able to replenish their PCr and glycogen stores, which is directly related to aerobic capacity affecting the replenishment rate[16].

In our study, a 20 m shuttle run field test, which is an indirect method for determining aerobic endurance, was implemented to measure $VO_{2max.}$values. A $VO_{2max.}$ value reflects the physical fitness of an athlete, and it was previously shown that there was a positive relationship between VO2max. and many high-intensity activities[17]. This study aimed to investigate the impacts of inspiratory muscle training on VO2max. levels of athletes in the experimental group. It was found that there was an increase in the pre- and post-test $VO_{2max.}$values (42.21±5.74 - 45.63±4.97 ml/kg/min) of the experimental group (Table 1; Figure 4). The change corresponded to an increase of 8%. Nevertheless, VO2max. values of athletes in the control group increased only by 0.7%

In the relevant literature, the mean $VO_{2max.}$ value of 38 male basketball players under the age of 19 was determined to be 52.8±2.4 ml/kg/min[18]. In the study conducted on young male basketball players, the mean VO2max. value was measured as 59.509±7.9 ml/kg/min, while this value was calculated as 50.7 ± 4.0 ml/kg/min in another study with the Israeli youth team[19, 20].

The difference, which was found to be statistically significant in favor of the experimental group after the $VO_{2max.}$ measurements at the 8th week, was in parallel with many studies in the literature examining the impacts of inspiratory muscle training on athletes competing in different sports branches (e.g., basketball, football, cycling, athletics, etc.). Inspiratory muscle training is effective in improving the ability of athletes to maintain deeper and slower inspiration[21].

$VO_{2max.}$ values of male and female cyclists were found to show statistically significant differences as a result of inspiratory muscle training with 50% of the maximal inspiratory pressure for 5 days a week and twice a day[22]. Another study on the impacts of inspiratory muscle training on maximal oxygen consumption reached a significant difference in the post-training $VO_{2max.}$ values of athletes[23].

Investigated the effects of inspiratory muscle training on $VO_{2max.}$ and inspiratory functions of 12 triathlon runners. They found an increase of 0.92% in $VO_{2max.}$ values between pre- and post-tests after 4-week (2 times a day) exercises with 30 breaths per session[6]. Charlini S. Hartz et al. demonstrated that 12-week inspiratory muscle exercises, in which the maximal inspiratory pressure gradually increased from 50% to 70%, also elevated the VO_{2max}. values[24]. Besides, the previous research suggested a negative relationship between VO2max. and fatigue[25]. In another study, it was shown that athletes with higher $VO_{2max.}$ values had higher oxygen consumption rates and experienced less performance decline than those with lower $VO_{2max.}$values during activities with constant intensity[25].

The maximal inspiratory pressures of the individuals were generally pre-determined in studies on inspiratory muscle exercises. Among soccer players aged 16-19, when compared with the control group, there was a significant elevation in $VO_{2max.}$ values of the experimental group performed inspiratory muscle training as 25-35 breaths per session with 55% of the maximal inspiratory pressure for 5 days a week and twice a day. In the same study, $VO_{2max.}$values of the experimental group significantly increased after inspiratory muscle training as 45-55 breaths per session with 40% of the maximal inspiratory pressure[26].

Considering the comparison between the groups, a significant difference was found between the mean pre- and post-test $VO_{2max.}$values (p <0.05). According to these results, the Borg scale can be used to adjust the difficulty level of the device instead of maximal inspiration measurements. It can be asserted that the $VO_{2max.}$values found in the present study are in parallel with physical and aerobic capacity levels suggested in the literature. Although the control group did not engage in inspiratory muscle training, it is thought that the increase in their $VO_{2max.}$ values, albeit minimal, was thanks to the athletes doing regular sports activities. In addition, there is a need to compare the extent to which the use of such exercises within or out of training affects $VO_{2max.}$values.

CONCLUSION

In light of these results, it may be recommended to add inspiratory muscle exercises to training programs of athletes engaging in individual or team sports to increase their aerobic-anaerobic capacities and performance.

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