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Original Article

The effect of respiratory muscle training on young track-and-field athletes

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Abstract:
The study aimed to present the effect of respiratory muscle training on lung function, pulmonary ventilation and endurance in adolescent track and field athletes as a part of their pre-competition training. Twenty-four competitive junior athletes (mean age 15.1 ± 1.4 years, height 169.3± 6.0 cm, body mass 56.3 ± 7.7 kg) participated in this study. Participants were randomly assigned into two groups: control group (CG, n = 12: 4 males and 8 females) and respiratory muscle training group (RMT group, n = 12: 4 males and 8 females). The anthropometric parameters voluntary inspiration apnea and voluntary expiratory apnea as well as the spirometric parameters were measured in all participants. The state of the respiratory and cardiovascular system was examined by Ruffier squat test. All investigated parameters were determined at rest and during forced exhalation at the beginning and at the end of the study. During the 4 weeks, the CG had to perform only the track and field training given by the coach, while the RMT group additionally did respiratory muscle training with a specialized device (Spirotiger) for 15 min. At the end of the study a significant increase (p<,05) in the duration of the breath-holding tests and chest expansion measurement was found in the RMT group, as compared to CG, as well as a more pronounced decrease of the Ruffier index. Further, for RMT group was established a significant increase (p<0,05) in vital capacity (20%), tidal volume (24%), inspiratoty reserve volume (60%) and also for the dynamic characteristics of respiratory function (peak expiratory flow - with 37% and maximal expiratory flow-75% with 37 %). These results reveal evidence that progressive RMT, through isocapnic hyperpnea, in addition to the pre-competition training of athletes, improves the function of the inspiratory and expiratory muscles, leading to a greater endurance of the cardiorespiratory system. Therefore, RMT can be considered a worthwhile ergogenic aid for young track-and-field athletics.

Key Words: **- spirometry, respiratory muscle training, Spirotiger, young athletes**

Introduction

Respiratory muscle training (RMT) is defined as a technique that aims to improve the function of the respiratory muscles through specific exercises. RMT has been shown to improve respiratory function, reduce the sensation of dyspnea and improve endurance in hypoxic conditions (Alvarez-Herms et al., 2018). The need for targeted breathing training dates back to the end of the last century. In 1976, Leith and Bradley proved that the respiratory muscles could be trained, and in 1982, Martin and co-authors reported that respiratory muscle fatigue significantly reduced the ability to exercise throughout the body. Dempsey et al. (1982) found that maximal physical exertion can reduce blood O_2 saturation. Bergofsky (1979) found that loading the respiratory muscles allows them to respond to training stimuli by adapting to their structure in the same way as all other skeletal muscles. The positive role of RMT on the endurance and performance in athletes from various sports disciplines has been proven. (Lemaitre et al., 2013; Sales et al., 2016; Sperlich et al., 2016; Mackała et al., 2019). The relation between inspiratory muscle strength, change of limb blood flow and sports performance still requires investigation, especially in short-duration exercise, anaerobic or both aerobic and anaerobic exercise. The impact of RMT in track and field athletes is not well understood, whereas the physiological and biomechanical mechanisms of distance-specific running performance in humans are well studied (Romer et al., 2006; Thompson, 2017). Respiratory muscles can fatigue during prolonged and maximal exercise, thus reducing performance related to the various disciplines in athletics: running, jumping, throwing, and walking. In most sports, especially on track and field, a type of workout is endurance running performance. As an aerobic-based exercise, cardiopulmonary endurance and respiratory muscle strength are fundamentally required and should develop to enhance cardiorespiratory health. The diaphragm, one of the respiratory muscles, is essential to respiratory movement (Chang et al., 2021). Maximal running speeds observed in sprint disciplines are achieved by high vertical ground reaction forces applied over short contact times. To create this high force output, sprint events rely heavily on anaerobic metabolism, as well as on a high number and large cross-sectional area of type II fibers in the leg muscles. Middle distance running performance is characterized by intermediates of biomechanical and physiological parameters, with the possibility of unique combinations of each leading to

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high-level performance. The relatively fast velocities in mid-distance events require a high mechanical power output, though ground reaction forces are less than in sprinting. Aerobic capacity starts to become an important aspect of performance in middle distance events, especially as distance increases (Thompson, 2017). The human body has a number of metabolic pathways which are well suited to meeting the demands of both high-intensity short-duration exercise and low-intensity long-duration exercise. What is important in this sport is the athlete's extraordinary ability to liberate energy at a rapid rate from the appropriate metabolic pathway(s) and to limit and tolerate the development of fatigue as the race progresses. The limitations to athletic performance and the main causes of fatigue are closely linked to the principal metabolic pathways by which adenosine triphosphate is re-synthesized to meet the energy demand of the exercise. Harms et al., 1997 have found a reciprocal relationship between the work of breathing and legs blood flow during maximal exercise on cycle ergometer. Thereafter, several authors (Chang et al., 202; Sheel et al., 2002) have concluded that the stimulus for limb vasoconstriction was a cardiovascular reflex originating within the inspiratory muscles. As reminded by McConnell, 2009, this reflex seems to be activated when metabolites are accumulated within the inspiratory muscles. Indeed, these metabolites stimulate the afferent nerve fibers, which increase their firing frequency. This stimulation precipitates an increase in the strength of sympathetic neural outflow, which induces a generalized vasoconstriction, which affects the sports performance. To resume, the inspiratory muscle fatigue reduces active limbs blood flow and exacerbates fatigue in these limbs (Romer et al., 2006; Chang et al., 2021). Consequently, it may be supposed that RMT may improve performance. This hypothesis has been confirmed by McConnell and Lomax, 2006 who have suggested that inspiratory muscle training attenuates or delayed the vasomotor changes induced by the inspiratory muscle metaboreflex, which adaptation may produce an improvement of performance.

In recent decades many specialized devices for RMT devices have been created. The respiratory devices fall into two main categories: devices that impose a resistance training stimulus and those that impose an endurance-training stimulus (Menzes et al., 2018). On the other hand, the resistance-training devices fall into the following three main categories, based on how the load is generated: passive flow-resistance, dynamically adjusted flow resistance, and pressure threshold valve. Endurance training, also named as voluntary isocapnic hyperpnea training, is time consuming and extremely strenuous, requiring a very high level of user commitment, to achieve and sustain the prescribed training intensity (McConnell, 2013). In a detailed review of currently used respiratory muscle endurance training devices (Manzes et al., 2018) as suitable for adolescent athletes, the Spirotiger brand is discussed. Pure endurance training of the respiratory muscles is undertaken using a sustained, high-intensity hyperpnoea task, and has been used much less widely than resistance training. In healthy people, the training also improves the volume of air that can be respired during a brief maximal burst of hyperventilation, typically 15 seconds (an index of power output) (Illi et al, 2012). The latter finding is also consistent with improvements in peak velocity of muscle contraction, although there is no direct evidence of this to date. The aim of this study was to investigate the effects of an additional 4 weeks of respiratory muscle endurance training based on normocapnic hyperpnea on respiratory muscle function in young well-trained track and field athletes as part of their pre-competition period.

Material & methods

Participants. The study was conducted at the University Center for Functional Research in Sports and Kinesitherapy at South-West University "Neofit Rilski"-Blagoevgrad. Twenty-four junior, track and field athletes (age 15.1±1.4 years, height 169.3±6.0 cm, body mass 56.3±7.7 kg) participated in this study. Participants were randomly assigned into two groups: control group (CG, n=12, 4 males and 8 females) and RMT group (n=12, 4 males and 8 females). No history of pulmonary disease in the participants and acknowledged their good health condition to participate in the study. All participants are non-smokers (self-report), with no evidence of respiratory restrictions or obstruction on examination of the maximum flow-volume loops. All participants and their parents provided written informed consent for voluntary participation in the study. Before the study commenced, the participants were informed of the procedures and potential risks of the training. During the 1 month long experimental period, both groups continued their regular preseason athletic training program (long jump, sprints, middle- and long-distance events, race walking, and hurdling, long jump, triple jump, high jump, and pole vault). Regular athletic training sessions were performed three times per week under the supervision of the coach, who developed the following training program: 2 hours of athletic activities, including strength conditioning, drills for skill improvement, team games, and individual disciplines. The participants included in experimental group performed in addition RMT with a commercially available respiratory muscle trainer - Spirotiger Medical, (Idag AG, Volketswill, ZH, CHE). The athletes were instructed no practiced any physical activities during the study period other than those stated. The participants were instructed to adhere to their usual diet and to not engage in strenuous physical activity the day before testing. On the test day, the participants were asked to not eat for at least 2 h before testing. For each participant, testing was scheduled at a similar time of day to minimize the effects of diurnal fluctuation. The RMT for participants of the experimental group was performed before determination of investigated respiratory parameters. The assessment of respiratory muscle strength as well as dynamic pulmonary function were carried out at similar times of the day (morning) for both groups.

Anthropometry, body mass analysis and examination of the cardiovascular and respiratory systems

Height was measured to the nearest 0.1 cm using a stadiometer (Kern MPE 250K100HM, Germany), and *body mass* (BM, kg) to the nearest 0.1 kg using an electronic balance scale (Kern MPE 250K100HM, Germany). The body impedance was measured in a standing position according to standardized protocol by bioimpedance analyzer (Jawon Medical IOI-353, Yuseong, South Korea; eight electrodes and pressing contacts). The following *parameters of body composition* were measured: body mass index (BMI, kg/m2), lean body mass (LBM, kg), soft lean mass (SLM, kg) and mass of body fat (MBF, kg). Measurement of the overall *chest expansion*: a tape is used to encircle the chest around the level of the nipple and measurements are taken at the end of a deep inhalation and exhalation. The state of the respiratory and cardiovascular system was determined with the so-called *Ruffier Squat Test*. The test involves the measurement of the heart rate before (HR0) and after a short loading (30 squats in 45 s), where HR1 and HR2 are measured 15 and 45 s after. The lower the Ruffier index (= (HR0+HR1+HR2) - 200 / 10) is, the better recovery is after physical exertion. The rating for the physical condition, according to the values of the Ruffier index, is: below 0 – very good; 0.1–5.0 – good; 5.1–10.0 – satisfactory; 10.1–15.0 – unsatisfactory; above 15.0 – pathological state of the cardiovascular system.

Breath-holding tests were used to assess the condition of respiratory musculature and respiratory function. Two breath-holding tests were employed: - voluntary inspiration apnea (VIA), in which after exhalation and maximal inspiration (total lung capacity level), the examined person conducts voluntary apnea, which duration is measured with stop watch in s; and - voluntary expiratory apnea (VEA), when after gasping and normal expiration (functional residual capacity level), the subject conducts voluntary apnea, which is also measured as duration in s.

Spirometry. Spirometric parameters, at rest and during forced exhalation were measured with a module of CPET system (COSMED, Italy). During testing, the participant is in sitting position, breathe 6-7 times wearing a nose clip and an individual mouthpiece placed in the turbine. Next, the subject inhales and exhales 2-3 times and take in the maximum possible amount of air, which, they exhale to the level of the reserve volume on exhalation. The dynamic lung volumes were measured by forced expiratory flow/volume. In this case the person inhales and exhales 1-2 times and then takes the maximal amount of air, which exhales as quickly as possible to the level of the reserve volume on exhalation. The test is repeated at least 3 times and the best result of the three trials was taken for statistical analysis. The following variables were determined for all participants before and after the study: VT- tidal volume; ERV- expiratory reserve volume, IRV- inspiratory reserve volume; VC- vital capacity; IC- inspiratory capacity, FVC- forced vital capacity, FEV1- forced expiratory volume in first second, PEF- peak expiratory flow, FEF 25-75 – forced expiratory flow at 25 and 75% of the pulmonary volume; MEF 25% - maximal expiratory flow 25%; MEF 50% - maximal expiratory flow 50%; and MEF 75% - maximal expiratory flow 75%.

Athletic training. The training was held 3 times per week (Monday, Wednesday and Friday) from 10-12 o'clock and included:

(a) 40 minutes' warm-up, which comprised: - 7-8 min of light running; - 10-15 min of general developmental exercises for the whole body and all joints; and - 10-15 min of specific running exercises (small running, high raised knees, accelerating running - 3, 4 times per 100 m). The purpose of the warm-up is to employ the body and prepare for the basic training and the specific discipline for training the specific qualities of the athletes.

(b) 45-60 minutes of basic training - according to the discipline of the athletes, such as: - Trap jumps; - Overcoming obstacles; - Crosses, long sections; - Sprints, speed endurance; - Triple jump; - Decathlon.

Respiratory Muscle Training: Immediately prior to RMT, instructional classes were held to ensure proper use of the hand held RMT device (Spirotiger) (Fig. 1). Spirotiger training was held three times a week on days when all competitors had training sessions. Breathing was performed within 10-15 min by all persons included in the RMT group, on a circular basis as part of their overall training for the day.

Table 1. Respiratory training protocol performed by each subject in respiratory muscle training group for each training day.

0 day	Theory, explanations, demonstration and 10 min training. Breathing coordination and selection of the breathing bag. (Fig 1, A);
1st day	Duration 8 min (1 min at a respiration rate of 20 acts /min, 2 min at a respiration rate of 24 acts /min, 2 min at 28 acts / min, 2 minutes at 30 acts / min, 1 min at 26 acts / min);
2nd day	Duration 10 min (1 min at a respiration rate of 24 acts/min, 2 min at a respiration rate of 28 acts/ min, 2 min at 30 acts / min, 2 min at 32 acts / min, 2 min at 34 acts / min 1 min at 26 acts / min);
3rd and 4th day	Duration 10 min (2 min at a respiration rate of 28 acts / min, 2 min at 30 acts / min, 2 min at 32 acts / min, 2 min at 34 acts / min, 2 min at 36 acts / min);
5th and 6th day	Duration 15 min (1 min at a respiratory rate of 28 acts / min, 4 min at 30 acts / min, 4 min at 32 acts / min, 3 min at 34 acts / min, 3 min at 36 acts / min);
6th -12th day	When the work with the device is mastered, the athletes become accustomed to the rhythm and depth of breathing and the volume of the bag. General developmental exercises were included without disturbing the training by stopping the device. Duration 15 min (2 min warm-up with 30 l /min, 3 min with 40 l/min for every five exercise, at the end 2 min free breathing at 35 l / min) (Fig. 1 B and C).

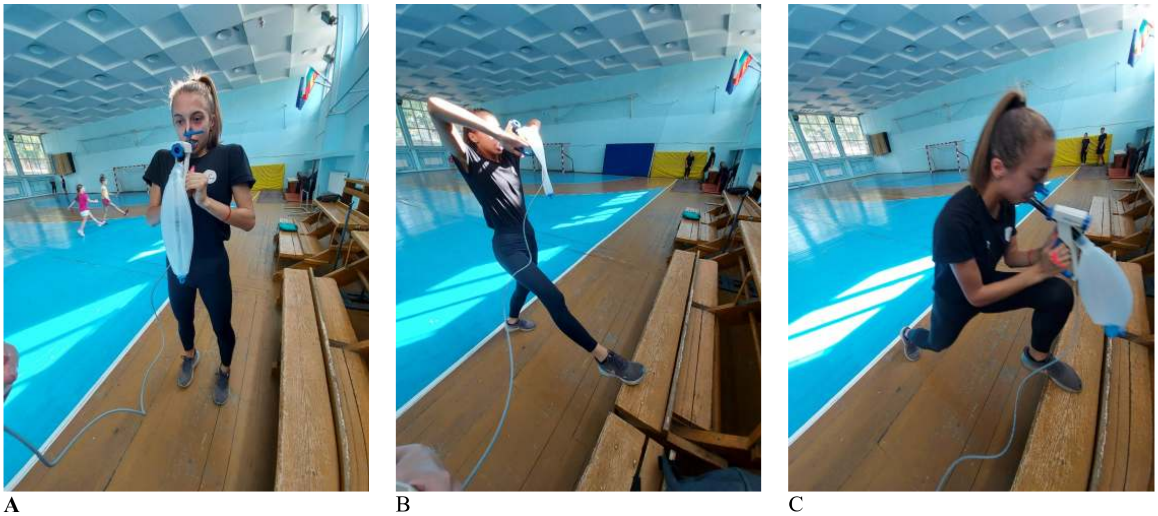

Fig. 1 Respiratory muscle training by using hand held respiratory muscle training device (Spirotiger) A) from starting position main stance and B), C) in combination with general developing exercises.

Data collection and analysis / Statistical analysis

Descriptive statistics was used for all data presented as mean±SD. Normality of the data distribution was analyzed with Kolmogorov-Smirnov test. Assessment of the differences in variables between two groups – control versus RMT group (two independent samples), was computed with Mann-Whitney U test. The statistical significance of post-training period changes in the both groups (pre- vs post-) was estimated with Wilcoxon test. Differences at a probability level of $p<0.05$ were considered significant. All statistical evaluations were performed using standard statistical software (GraphPad Prism 3.0).

Results

There were no significant differences ($p<0.05$) between anthropometric parameters in both groups (Table 2). We did not establish differences in the chest expansion, neighter in parameters investigated by Ruffier Squat test in pre-training period between the control and RMT group. We did not find differences in parameters of respiratory function, investigated by spirometry, in pre-testing period between the studied groups (Table 3). These results indicate homogeneity of the experimental groups.

Table 2. Anthropometric characteristics of young athletes.

Parameters	**Control group n=12**	**RMT group n=12**	***p***
Age (years)	15.4 ± 1.8	15.8 ± 1.4	0.3425
Height (cm)	167 ± 6.0	169 ± 7.3	0.2177
Body mass (kg)	56.3 ± 11.3	54.7 ± 7.7	0.3645
Lean body mass (kg)	46.2 ± 8.2	46.5 ± 7.0	0.3833
Mass of body fat (kg)	10.8 ± 4.0	9.2 ± 4.5	0.1695
Percent Body Fat (%)	18.8 ± 5.0	16.2 ± 7.2	0.2548
Soft lean masa (kg)	42.2 ± 8.2	43.2 ± 6.6	0.2655
Body mass index (kg/m^2)	19.7 ± 2.6	18.9 ± 2.5	0.2265

We established a statistically significant increase of time at breath-holding tests only in the RMT group: breath holding time of the full VIA at the beginning of the study was 73.5±14.9 s and at the end of the post training period it was 89.7±18.3 s ($p<0.01$); breath holding time of the full VEA at the beginning was 45.3±13.1 s and at the end it was 51.7±11.0 s. The respiratory VIA and VEA in CG did not change during experimental period: breath holding time of the full VIA at the beginning of the study was 57.6±10.3 s and at the end it was 60.2±10.4 s; breath holding time of the full VEA at the beginning was 38.9±8.7 s and at the end it was 41±9.1 s. The results of the chest expansion showed no significant increase in centimeters during inhalation and exhalation in both control (in inhalation about 89.6±4.5 cm and exhalation about 81.3±4.2 cm) and RMT groups (in inhalation about 90.6±7.0 cm and exhalation about 84.6±7.4 cm), after the four weeks training period.

The values of Ruffier index show good cardiovascular endurance and good rate in the groups. In CG at the beginning of the study it was 6.2±1.2 and after the 4-week period it becomes 4.3±0.6. In RMT group Ruffier index decreased statistically significantly from 5.7±0.9 during the start of experiments to 3.9±0.5 ($p<0.01$) at the end of the study. The decrease of values of the index was found in both groups, but it was more pronounced in RMT group compared to the control group. According to the rating the satisfactory physical condition of the athletes was changed to good physical condition. The athlethes in the RMT group reported a slower onset of fatigue when performing the track and field exercises.

Four weeks after the targeted training, at the end of the study, we established significant changes in static volumes and capacity mainly in RMT group (Table 3). Vital capacity increased significantly ($p<0.05$) in RMT group by 20% as a result of an increase of TV by 24 % and IRV by 60%. Expiratory reserve volume did not change. In dynamic characteristic of respiratory function, we established statistically significant differences in RMT group in PEF, FEV/VCmax, and MEF75%, which increased with 37%, 11.7% and 36.6%, respectively, ($p<0.05$).

Table 3. Pulmonary function data in pre- and post-training period in control group and respiratory muscle training (RMT) group

VARIABLES	**CONTROL GROUP**		**RMT GROUP**	
	Pre-	**Post-**	**Pre-**	**Post-**
RESTING SPIROMETRY				
TV (l)	1.3±0.4	1.3±0.2	1.2±0.3	1.4±0.2$^{\#*}$
IRV (l)	1.4±1.2	1.6±1.1	1.5±0.7	2.4±1.3$^{\#}$
ERV (l)	1.3±0.8	1.3±1.1	1.5±1.1	1.4±0.8
VC (l)	3.9±0.8	4.1±1.0	4.1±0.9	4.7±1.0$^{\#}$
IC (l)	2.6±1.0	2.9±1.0	2.7±0.7	3.9±1.4$^{\#*}$
FORCED EXHALATION SPIROMETRY				
FVC (l)	3.4±1.0	3.8±0.9	3.6±0.8	3.7±0.7
FEV 1 (l)	3.0±1.0	3.4±0.9	3.1±1.0	3.7±1.7
FEV1/FVC% (%)	87.8±13.3	91.8±7.7	84.1±27.5	91.2±6.3
FEV1/VCmax (%)	76.4±14.8	89.7±7.9$^{\#}$	73.8±25.8	89.9±6.2$^{\#}$
PEF (l/s)	4.5±1.7	5.3±1.4	5.6±1.5	7.8±1.8$^{\#*}$
FEF 25-75 (l/s)	3.4±2.5	4.0±1.2	4.3±1.5	4.9±1.4
MEF 25% (l/s)	2.6±1.1	3.0±0.9	3.2±1.3	3.2±1.1
MEF 50% (l/s)	3.6±1.5	4.0±1.3	4.5±1.7	5.3±1.4$^{\#*}$
MEF 75% (l/s)	4.1±1.7	4.9±1.3	5.1±1.5	7.0±1.6$^{\#*}$

Designations: TV- tidal volume, IRV- inspiratory reserve volume, ERV- expiratory reserve volume, VC- vital capacity, IC- inspiratory capacity, FVC- forced vital capacity, FEV1- forced expiratory volume in first second, PEF- peak expiratory flow, FEF 25-75 – Forced expiratory flow at 25 and 75% of the pulmonary volume; MEF 25% - maximal expiratory flow 25%; MEF 50% - maximal expiratory flow 50%; MEF 75% - maximal expiratory flow 75%;

** Statistically significant difference ($p <0.05$) as compared to control group (Mann Whitney test)*

 # Statistically significant difference ($p <0.05$) as compared pre- indices in the groups (Wilcoxon)

Discussion

The present study examined the role of targeted respiratory muscle training and its impact on lung function and respiratory parameters. Various studies have shown that respiratory muscle training leads to different, often contradictory, results in athletes' different sports disciplines. Mickleborough et al. (2010) found that 6 weeks of inspiratory muscle resistance training (IMT) in runners resulted in significant increases in strength, endurance, maximal power, and inspiratory muscle work capacity by influencing the breathing mechanics and improving oxygen consumption, ventilation, heart rate, blood lactate concentration, perceptual response during continuous exercise. Boutellier et al. (1992) and Romer et al. (2006) reported that four weeks of respiratory muscle training improved cycling performance. The results in both studies showed the same trend as in other research, that RMT attenuates the perceptual response to maximal incremental exercise (Chang et al., 2021). Mackala et al. in 2019, Lemaitre et al. (2013) and the results they provide showed that RMT had a positive effect on athletic performance. On the other hand Pine et al. (2005), RMT didn't affect running sprints. Similar results were found by Kilding et al. (2010), who reported that respiratory muscle endurance training improved ventilatory power and endurance but did not alter VO2max or swimming endurance among swimmers. They found small positive effect in club-level trained swimmers in events shorter than 400 m. Track and field is sport that includes both aerobic and anaerobic exercise event and includes different types of sports disciplines, making it difficult to differentiate between the effects of respiratory training and cardiorespiratory endurance

The body composition of young athletes is influenced by their growth and maturity status. LBM especially SLM is obviously important to performance and is closely related to height; as such, it is related to the growth and maturity status of young athletes. On the other hand, MBF and PBF are more variable. They are influenced by normal growth and maturation, diet, and systematic training. MBF is the component of body composition that is common to all models and receives most consideration in studies of athletes. Excessive fatness tends to exert a negative influence on performances, especially those that require the movement or projection of the body through space, that is, running, jumping, vaulting, and so on, in contrast to those that require projection of objects, that is, shot put, discus, javelin, and so on, or moving another person, as in wrestling. In CG the mean of PFM was 18.8±5.0% while for RMT the values were 16.2±1.2%, as they fully correspond to the values in athletes who are between 14-20%. BMI is not a precise index for determining obesity and overweight, which was also observed in our studied groups - CG has BMI=19.7±2.6 kg/m^2 and RMT has BMI=18.9±2.5 kg/m^2. Body composition assessment can be of value in monitoring potential effects of training programs and health of young athletes.

The breath-holding tests and Ruffier test used in the study showed better results in the RMT group compared to CG. The obtained results confirm data from previous studies (Mackała et al., 2019) on the effects of respiratory training and more specifically the use of a device such as the Spirotiger to improve endurance in athletes. The test involves measuring the heart rate before and after a short, moderate-intensity exercise, which is a sign of aerobic endurance. After the respiratory training, the Ruffier index was found to be lower, which showed a better recovery and respectively slower onset of fatigue after training exercises in the RMT group. In our opinion, increasing the period of respiratory training would differentiate more clearly the distinctions between the two groups, regarding all measured parameters and especially the Ruffier index. Chest measurement showed no difference between the two groups after 4 weeks of targeted respiratory muscle training compared to the control group, which shows that as a result of the RMT training no significant changes have yet occurred in the respiratory muscles and chest capacity. The applied tests together with resting and forced exhalation spirometry parameters aimed to show the changes in the two studied groups and the advantage of targeted endurance respiratory training as part of the athletes' training program. Through these tests, a statistically significant improvement in cardiorespiratory functions was found in the RMT group, for only 12 workouts.

Previously, a systematic review suggested that 4 to 12 weeks may be a proper duration for respiratory muscle training (HajGhanbari et al., 2013; Mackala et al., 2019; Lemaitre et al., 2013; Chang et al., 2021). In our study, we observed significant improvements only after 4 weeks of RMT. In a study from 2021 Chang, et al., track the effect of 4 weeks of inspiratory training in 800 meter runners. They found that the limbs' blood flow significantly decreased from 19.91±11.65% to 9.63±7.62% after the IMT training program, while the control group increased from 5.33±7.45% to 13.50±7.48%. The authors explain the results obtained with the vertical movement of the diaphragm during this resisted training for respiratory muscles and may promote the perfusion of blood flow to the limbs, which reduces the influence of metabaroreflex phenomenon. This implies that the training of incremental RMT intensity attenuated metaboreflex phenomenon and reduced lower limb blood flow change rate in runners (Chang et al., 2021). Working in the mode of isocapnic hyperpnea allows to train the endurance of the fibers of the respiratory muscles. It can increase the frequency and depth of breathing without the need for physical exertion. In the mode of isocapnic hyperpnea, it is possible to take deep and explosive breaths without developing signs of hyperventilation by increasing the partial pressure of O_2 and decreasing the partial pressure of CO_2 in a controlled manner (McConnell, 2013). The workout improves the strengthening of the diaphragm, abdominal muscles, chest, pectoral muscles, neck muscles and spine. Acute prior inspiratory muscle activity has been shown to increase inspiratory muscle strength and athletic performance and to decrease perception of effort in exercise hyperpnea and estimation of the magnitude of inspiratory loads (Ross et al. 2007). In RMT group we established an increase of VC as a result of an increase of TV as well as an increase of IRV. We also established an increase of IC. These results suggested effect of RMT mainly on inspiratory function of lung. Normal calm breathing is mainly related to the contraction of the diaphragm. The primary inspiratory muscles are the diaphragm and external intercostals. Relaxed normal expiration is a passive process, happening because of the elastic recoil of the lungs and surface tension. However, a few muscles help in forceful expiration and include the internal intercostals, intercostalis intimi, subcostals and the abdominal muscles. The strenght of these muscles significantly affects lung function, which in the RMT group has a greater increase in spirometric indicators compared to the control group Functional adaptations after RMT show improvements in strength, speed, power, endurance, peak inspiratory flow rate, maximal inspiratory volume, and other spirometric parameters (McConnell, 2013). Pulmonary function was most commonly assessed via spirometry. This physiological test assesses the competency with which an individual inspires or expires volumes of air as a function of time by requiring the subject to perform a series of forced vital capacity (FVC) manoeuvres into a mouthpiece; it is a valuable tool for screening general respiratory health as well as for the training level of the athletes. Peak expiratory flow (PEF), plays an important role in the assessment of pulmonary function. A measurement PEF is especially useful for assessing bulbar-innervated, inspiratory, and expiratory muscle function. The PEF ranges from 500 to 700 l/min for men and from 380 to 500 l/min for women, and from 150 to 840 l/min for children and adolescents, with variations due to age, race, and sex (Mohiuddin et al., 2013). In our studied groups, the dynamics of this indicator, as well as MEF 50% and 75%, were statistically significantly increased only in the RMT group as a result of targeted breathing training. Maximal expiratory flow at 25 and

75% of the pulmonary volume (MEF25-75%) might be considered as a marker of early airway obstruction. MEF25-75% impairment might suggest earlier asthma recognition in symptomatic subjects even in the absence of other abnormal spirometry values. The normal range for MEF25–75 at age 5 to 6 years is 20%, corresponding to 60 to 140% predicted, and by age 50, the FEF25–75 has widened to 30%, a normal range of 40 to 160%. Better results were observed in the RMT group with values increasing by nearly 2 l/s compared to CG where the change was less than 1 l/s. The presented results show that, in addition to the inspiratory function, expiratory parameters are also affected by isocapnic hyperpnea, which gives an advantage to the respiratory muscle endurance devices over other devices. It is clear from the above that RMT allows intense and specific training of the respiratory muscles, without overloading the cardiovascular and musculoskeletal system, improving endurance and having a positive effect on lung function.

Conclusions

In conclusion, the study showed that targeted respiratory endurance training of respiratory muscles by 4 weeks with the help of a specialized device (Spirotiger) generated an improvement in lung function and spirometric indicators in adolescent track and field athletes. The use of this type of progressive training, through isocapnic hyperpnea, in addition to the pre-competition training of athletes, improved the function of the inspiratory and expiratory muscles, while also reduced the feeling of fatigue and led to greater endurance of the cardiorespiratory system. Respiratory muscle training can therefore be considered a worthwhile ergogenic aid for young track-and-field athletics.

Conflicts of interest There have been no conflict of interest situations in the course of the research and the publication of the manuscript.

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