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EFFECTS OF INSPIRATORY MUSCLE TRAINING ON PHYSICAL PERFORMANCE DURING BACKPACK CARRYING

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ABSTRACT

Purpose: *Restricting chest movement when carrying a loaded backpack reduces efficiency and increases the work of the respiratory muscles. The aim of the present study was to investigate the effects of six weeks of inspiratory muscle training (IMT) on respiratory muscle strength and endurance and on physical performance when carrying a load* ***Methods:*** *Twenty male (age: 32.2 ± 3.4 years) members of the Special Operations Unit of the Slovenian Army volunteered to participate. The experimental group (n=10) trained their respiratory muscles for six weeks against an incremental inspiratory resistance with a breathing apparatus. The placebo group (n=10) performed the same IMT protocol but with a sham inspiratory resistance. Assessment of the subjects before and after IMT included measurements of the maximal inspiratory and expiratory pressures, heart rate measurements, and ratings of perceived physical and respiratory exertion before and after a 60-min walk test with a 25-kg backpack* ***Results:*** *After six weeks of IMT, the maximum inspiratory pressure measured before and after the 60-minute walk test increased significantly ($p < 0.001$) in the experimental group by 47 ± 13% and 58 ± 20%, respectively. Inspiratory fatigue was also significantly lower in the experimental group. No changes were observed in the heart rate and the rating of perceived exertion during the walking test. In the placebo group, no significant changes were observed in the measured parameters after IMT.*

Conclusion: *Six weeks of IMT with progressive breathing resistance improves strength and reduces fatigue of the respiratory muscles. Individuals who perform tasks that require them to carry a heavy backpack for extended periods of time may benefit from IMT.*

Keywords: *load-carrying, respiratory muscle fatigue, respiratory muscle training, thoracic motion restriction.*

UČINKI VADBE INSPIRATORNIH MIŠIC NA TELESNO ZMOGLJIVOST MED NOŠENJEM NAHRBTNIKA

IZVLEČEK

Cilj: *Omejitev gibanja prsnega koša med nošnjo obteženega nahrbtnika zmanjša učinkovitost in poveča delo dihalnih mišic. Cilj pričujoče študije je bil raziskati učinke šesttedenske vadbe inspiratornih mišic (VIM) na jakost in vzdržljivost dihalnih mišic ter telesno zmogljivost med prenašanjem bremena.*

Metode: *Prostovoljno je sodelovalo 20 moških (starost: 32,2 ± 3,4 let) pripadnikov Enote za specialno delovanje Slovenske vojske. Eksperimentalna skupina (n=10) je šest tednov neprekinjeno vadila proti naraščajočemu uporu pri vdihu s posebno dihalno napravo. Placebo skupina (n=10) je izvedla enak protokol VIM z napravo, vendar le z navideznim inspiratornim uporom. Začetno in končno testiranje preiskovancev je vključevalo meritve največjih inspiratornih in ekspiratornih tlakov, meritve frekvence srčnega utripa in oceno občutenja telesnega in dihalnega napora pred in po 60-minutnem testu hoje s 25-kg nahrbtnikom.*

Rezultati: *Po šesttedenski VIM se je največji inspiratorni tlak izmerjen pred in po testu hoje pomembno (P < 0,001) povečal v eksperimentalni skupini, in sicer za 47 ± 13 % pred testom in za 58 ± 20 % po testu. Značilno se je zmanjšala tudi inspiratorna utrujenost v eksperimentalni skupini. Odziv frekvence srčnega utripa in ocena občutenja napora med testom hoje se po VIM ni spremenila. V placebo skupini po VIM nismo opazili pomembnih sprememb v nobenem izmerjenem parametru.*

Zaključek: *Šesttedenska VIM s progresivnim inspiratornim uporom izboljša jakost inspiratornih mišic in zmanjša njihovo utrudljivost. Tovrstna dihalna vadba ima lahko pozitivne učinke za ljudi med opravljanjem nalog, ki zahtevajo dolgotrajno nošenje težkega nahrbtnika.*

Ključne besede: *prenašanje bremen, utrujenost dihalnih mišic, vadba dihalnih mišic, omejitev gibanja prsnega koša.*

INTRODUCTION

Carrying a load with a backpack is defined as the movement of a person with an additional mass on the trunk supported by shoulder straps (Knapik, Harman, Steelman & Graham, 2012). It is a common form of occupational physical activity, especially for soldiers, firefighters and rescue workers, as well as for various forms of sports and recreational activities. The load carried in a backpack restricts the movement of the chest and the amount of air a person can inhale, increasing the work of breathing (Dominelli, Sheel & Foster, 2012; Faghy & Brown, 2014b). In this case, the respiratory muscles are working outside the optimal limits of their length-tension curve (Romer & Polkey, 2008). Altered respiratory mechanics lead to accelerated fatigue of the respiratory muscles (Faghy & Brown, 2014a; Faghy & Brown, 2014b), which can reduce physical performance by reducing the blood flow to other skeletal muscles and increasing the perception of physical and respiratory effort (Dempsey, Romer, Rodman, Miller, & Smith, 2006; Harms, et al., 1997).

The actual effect of carrying an extra load in a backpack on respiratory muscle function under different working conditions has not been studied in detail. Butcher, Jones, Eves and Petersen (2006) reported a significant reduction in the maximum airway pressure in professional firefighters wearing a heavy backpack and a respiratory mask during both long-duration low-intensity physical activities and short-duration high-intensity physical activities. However, it is difficult to assess the individual effects of wearing a backpack and using a breathing mask because the mask itself increases the work of breathing (Eves, Jones & Petersen, 2005). In subjects of varying fitness levels, wearing a 25 kg backpack without a breathing mask has been shown to reduce the maximum inspiratory pressure (MIP) by 11% during 60 min walking (58% $\dot{V}O_{2max}$) on a treadmill and by a further 5% during subsequent high-intensity running (Faghy & Brown, 2014a; Faghy & Brown, 2014b; Faghy, Blacker & Brown, 2016).

The physical training of members of military special forces includes both low-intensity activities (e.g. military patrols) and high-intensity activities (e.g. military interventions and combat operations) while wearing a backpack, so it might be useful to include respiratory muscle training in their training routine. By using special training aids and training programs, one can strengthen the inspiratory or expiratory respiratory muscles in isolation or both at the same time. Inspiratory muscle training (IMT) adds resistance to the inspiratory flow and primarily strengthens the inspiratory muscles, especially the abdominal diaphragm, which creates an intrathoracic negative pressure during inspiration. IMT is commonly used to reduce respiratory effort during physical activity in elite athletes (HajGhanbari et al., 2013) and healthy individuals (Illi, Held, Frank & Spengler, 2012; Sales et al., 2016) as it significantly increases the strength of the inspiratory intercostal muscles, as well as the diaphragm (Verges, Lenherr, Haner, Schulz, & Spengler, 2007; Romer & Polkey, 2008). This has been shown to improve athletic performance (HajGhanbari et al., 2013), e.g. cycling (Romer, McConnell & Jones, 2002; Johnson, Sharpe & Brown, 2007; McConnell, 2011), running (Tong et al., 2008), swimming (Yañez-Sepulveda et al., 2021) and rowing (Griffiths & McConnell, 2007).

Respiratory muscle performance can be improved with various training protocols, most of which result in increased respiratory muscle strength and, to a lesser extent, improved muscle endurance (Fernández-Lázaro et al., 2021). IMT protocols vary and depend on the respiratory device used, the characteristics of the exerciser and the desired effects. In general, a minimum of four weeks of regular IMT, usually performed twice daily for at least 5 days per week at 50-70% of the maximum inspiratory pressure (MIP), is required for improvement in respiratory muscle strength (McConnell, 2013). Moderate- to high-intensity IMT (~60% MIP) can increase maximal contraction velocity and inspiratory muscle strength. Faghy & Brown (2016) reported that six weeks of IMT performed twice daily increased the maximal inspiratory pressure at rest by 31% and significantly attenuated the cardiovascular and perceptual responses to 60 minutes of walking with a 25-kg backpack at a steady pace, while improving performance by 8% during high-intensity timed runs. Because the relative intensity of their IMT protocol was kept constant at 50% of the maximal inspiratory muscle pressure, we hypothesize that even higher training effects can be achieved with a more progressive inspiratory resistance protocol. The progressivity of inspiratory resistance is likely to be of critical importance for training individuals with high levels of physical fitness, such as members of military special forces.

The aim of our study was therefore to investigate the effects of six weeks of IMT with progressive breathing resistance in members of military special forces on respiratory muscle strength and endurance, heart rate response and the perception of effort when walking with a heavy backpack.

METHODS

We conducted a controlled prospective intervention study on a sample of members of the Special Unit of the Slovenian Army (SOU SA). The study was approved by the Medical Ethics Committee of the Republic of Slovenia (No. 0120-494/2017/7), the Ministry of Defence of the Republic of Slovenia and the General Staff of the Slovenian Army.

Study Sample

All the potential SOU SA candidates were first given important information regarding the purpose and procedure of the study. Twenty male (mean age: 32.2 ± 3.4 years, age range: 27-38 years) members of the SOU SA site completed a questionnaire on their general health and signed a declaration in which they volunteered to participate in the study. Exclusion criteria for the subjects were cardiovascular, respiratory or metabolic diseases, a history of peripheral or central thromboembolism, radiculopathy or other peripheral neurological disorders of the lower limbs.

Assessment of General Fitness

The assessment of general physical fitness was based on regular military tests performed by the subjects in the three months prior to the start of the study. The tests included two minutes of push-ups, two minutes of abdominal crunches and a fast run of 3200 meters. The result achieved by the subject in each test task was converted into points using a motor test scoring system defined by gender and age categories (Ivšek & Pograjc, 2014).

Study Design

The twenty subjects were randomly divided by lot into two groups of equal size. The experimental group (EG) performed a six-week IMT program with a breathing device that provided a progressive increase in inspiratory resistance. The placebo group (PG) performed the same program with a device that did not add inspiratory resistance but had a virtual resistance regulator installed. Both groups were tested before and after the completion of the six-week IMT program, as described below.

Tests and Measurements

All the tests and measurements were carried out in the sports hall of Vojašnica Edvarda Peperka, Moste-Polje Ljubljana. On the day of the test, the subjects ate a small meal two to three hours before the exercise and abstained from coffee or alcoholic beverages for at least 24 hours before the exercise. The subjects were familiarised with all the tests and measurement protocols before the first data collection.

Heart Rate and Aerobic Capacity

The subjects were placed in a stationary, semi-recumbent position on the examination table for 10 minutes and their heart rate was measured using a monitor with a chest strap (Polar M430 POLAR Electro, Europe AG, Val-de-Travers, Switzerland). The Polar Fitness Test™, which assesses a person's maximum oxygen consumption ($\dot{V}O_{2max}$) based on resting heart rate variability, gender, age, height, body weight and self- assessed physical activity level, was used to assess aerobic capacity.

Respiratory Muscle Strength and Fatigue

Measurements were taken using an inspiratory and expiratory MicroRPM® pressure measurement device (VYAIRE Medical Inc., Illinois, USA). Respiratory muscle strength was measured using the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) in cm H_2O (Faghy & Brown, 2016). The MIP measurement was derived from the residual volume (maximal expiration) and the MEP measurement of the total lung capacity (maximal inspiration). Each measurement was taken five times. The minimum and maximum values were excluded and the average of the remaining three measurements was calculated (McConnell, 2013). The respiratory muscle fatigue was determined from the difference (Δ) between the MIP and MEP values obtained before (pretest) and immediately after (posttest) the 60-minute walking test.

Walking Test with a Backpack

Before the 60-minute walking test, the subjects put on a military backpack (V2 Plus System, Tasmanian Tiger GmbH, Dasing, Germany) that was evenly filled with a 25-kg load. Each subject adjusted and fastened the straps of the backpack individually before performing the test. The subjects completed the 60-minute walking test on a leveled Technogym Skillrun™ treadmill (Technogym, Cesena, Italy). Before they started walking, subjective ratings of overall perceived exertion (RPE) were assessed using the 15-item RPE scale and respiratory effort was assessed using the CR10 RPE scale (Borg, 1982). The heart rate was measured and recorded continuously during the test. The test began with a three-minute warm-up period so that the subjects gradually reached a target speed of 6.5 km/h, which they then maintained for 60 minutes (Faghy et al., 2016). Every ten minutes, the subjects rated the overall physical effort and respiratory effort. After completing the test, the subjects removed their backpacks, cooled down by walking slowly on a treadmill for 5 minutes, and then rested under control for another 20 minutes.

Inspiratory Muscle Training Intervention

The experimental group (n=10; EG) exercised with the POWERbreathe® (medium resistance) inspiratory muscle strengthening device (Powerbreathe International Ltd., Southam, UK) with an initial resistance of 60% MIP. The placebo group (n=10; PG) performed the same IMT program using the same respirator with the internal inspiratory valve removed, minimizing the respiratory resistance. Every two weeks, the subjects' MIP was measured again and inspiratory resistance was adjusted accordingly with an additional 10% increase to reach the final training target of 80% MIP. The MIP was reassessed in PG at the same time points and the breathing resistance was adjusted virtually. All subjects performed 30 consecutive maximal breaths twice daily. Each maximal inspiration was followed by an active forced expiration to expiratory residual volume (McConnell, 2011). Both groups kept an exercise diary that encouraged them to perform IMT regularly; compliance with the program was checked weekly by the investigators

The POWERbreathe® respirator works on the principle of suprathreshold inspiratory loading. This requires the subject to generate an inspiratory pressure that exceeds the pressure threshold set on the device in order to open the inspiratory valve. The inspiratory threshold is increased by tensioning the spring attached to the air valve of the device. The advantage of suprathreshold loading is that the increase in inspiratory resistance does not affect the actual airflow through the unit. Furthermore, the load resistance can be assessed objectively (McConnell 2011; McConnell, 2013).

Statistical Analysis and Data Processing

The normality of the data distribution was analyzed using the Shapiro-Wilk test, which showed the adequacy of the parametric tests. The effect of training was assessed by comparing the mean values of heart rate and maximum respiratory pressures measured at rest prior to the 60-minute walk test (pretest), before and after the six-week IMT period. The effect of IMT on fatigue during walking was assessed by comparing the heart rate and RPE at the end of the walking (posttest) and Δ MIP and Δ MEP. The means were compared using the independent samples t-test and the two-way factorial ANOVA (group × time) with repeated measures for the time factor. If the factor interaction was statistically significant, a pairwise comparison was performed using Tukey's HSD post-hoc test. The threshold for statistical significance was set at $p < 0.05$ for all analyses. Results are presented as means ± standard deviations unless otherwise stated.

RESULTS

Subjects from EG and PG did not differ significantly in age, anthropometric characteristics, general physical fitness, and aerobic capacity. The detailed analysis of group characteristics is shown in Table 1.

Table 1: Comparison of the basic subjects' characteristics across groups.

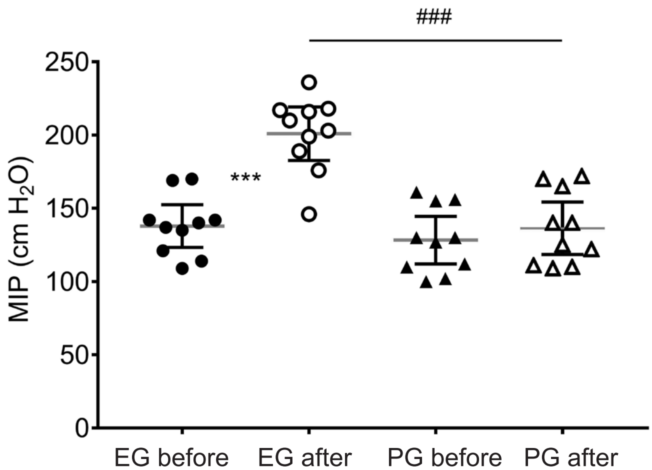
	EG	PG	p-value
Age (years)	33.3 ± 4.1	31.2 ± 2.8	0.258
Body height (cm)	180.6 ± 7.4	179.3 ± 4.5	0.641
Body weight (kg)	85.7 ± 5.6	82.7 ± 5.6	0.246
BMI (kg/m^2)	26.4 ± 2.3	25.6 ± 2.8	0.396
3200 m run (min)	13.3 ± 1.1	13.2 ± 1.1	0.843
Abdominal crunches (no./2 min)	87.3 ± 9.3	86.4 ± 9.0	0.843
Push-ups (no./2 min)	81.5 ± 7.2	79.4 ± 8.1	0.547
$\dot{V}O_{2max}$ (ml/kg/min)	47.8 ± 3.08	49.3 ± 2. 79	0.485

EG – experimental group; PG – placebo group; BMI – body mass index; 2max – maximal pulmonary oxygen consumption

Respiratory Muscle Strength

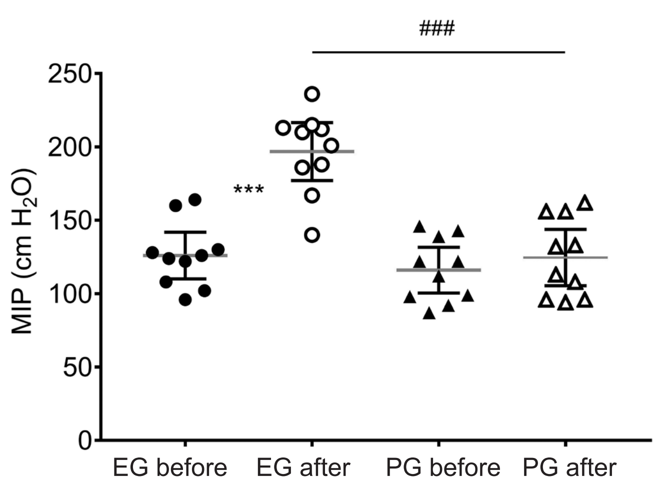
The interaction of factors during the six-week IMT was significant ($p < 0.001$) for the pretest MIP. The pretest MIP increased significantly ($p < 0.001$) in the EG by 63 ± 15 cm H_2O (47 ± 13%) after training. There was no significant change ($p = 0.162$) in the pretest MIP in the PG after training. The pretest MIP was significantly higher ($p < 0.001$) in the EG after training (Figure 1).

The interaction of factors during the six weeks of IMT was significant ($p < 0.001$) for the posttest MIP. The posttest MIP increased significantly ($p < 0.001$) in the EG by 71 ± 20 cm H_2O (58 ± 20%) after training. There was no significant change ($p = 0.306$) in the posttest MIP in the PG after training. The posttest MIP was significantly higher ($p < 0.001$) in the EG after training (Figure 2)



*** indicates the pretest to posttest difference in the EG at p < 0.001. ### indicates the difference between the groups at p < 0.001.

Figure 1: Comparison of the mean (standard deviation) maximum inspiratory pressure (MIP) measured before the 60-minute walk test between the experimental group (EG) and the placebo group (PG) before and after the inspiratory muscle training program.



*** indicates the pretest to posttest difference in the EG at p < 0.001. ### indicates the difference between the groups at p < 0.001.

Figure 2: Comparison of the mean values (standard deviation) of the maximum inspiratory pressure (MIP) measured after the 60-minute walk test between the experimental group (EG) and the placebo group (PG) before and after the inspiratory muscle training program.

The interaction of factors during six weeks of IMT was not significant for the pretest MIP ($p = 0.556$) and the posttest MIP ($p = 0.279$) (Figures 3 and 4).

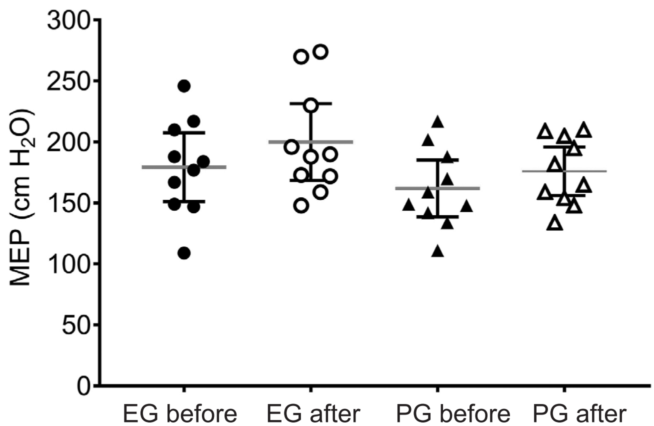


Figure 3: Comparison of the mean (standard deviation) maximum expiratory pressure (MEP) measured before the 60-minute walk test between the experimental group (EG) and the placebo group (PG) before and after the inspiratory respiratory muscle training program.

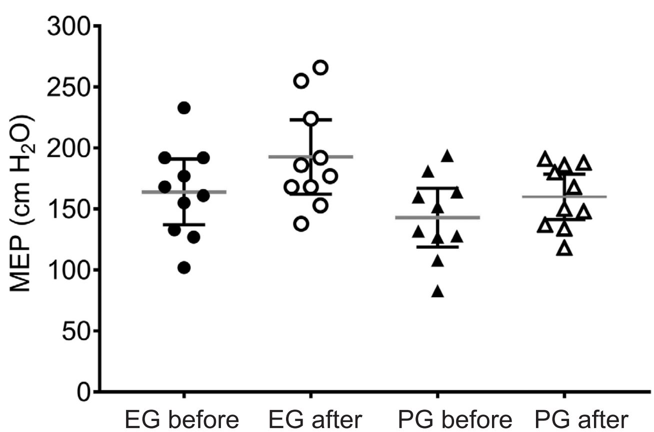


Figure 4: Comparison of the mean (standard deviation) maximum expiratory pressure (MEP) measured after the 60-minute walk test, between the experimental group (EG) and the placebo group (PG) before and after the inspiratory respiratory muscle training program.

Respiratory Muscle Fatigue

The interaction of factors during the six-week IMT was also significant ($p < 0.001$) for Δ MIP during the 60-minute walk test. The Δ MIP decreased ($p < 0.01$) from -12 ± 4 cmH_2O before the training to -4 ± 4 cmH_2O afterward. In contrast, the Δ MIP in PG before (-12 ± 3 cmH_2O) and after (-12 ± 4 cmH_2O) the training was no different ($p = 0.991$). The Δ MIP after IMT was significantly lower in EG ($p < 0.001$).

The interaction of the factors for Δ MEP during the 60-min walk test was also significant ($p < 0.01$). The Δ MEP decreased from -15 ± 5 cmH_2O before the training to -7 ± 5 cmH_2O afterward. In contrast, the Δ MIP in the PG before (-19 ± 7 cmH_2O) and after (-16 ± 4 cmH_2O) the training was no different ($p = 0.549$). The Δ MEP after IMT was significantly lower in EG ($p < 0.01$).

Heart Rate and Perceived Exertion

The interaction of the factors during the six-week IMT was not significant for the heart rate ($p = 0.215$), respiratory effort ($p = 0.327$), and overall body exertion ($p = 0.644$) (Figure 5).

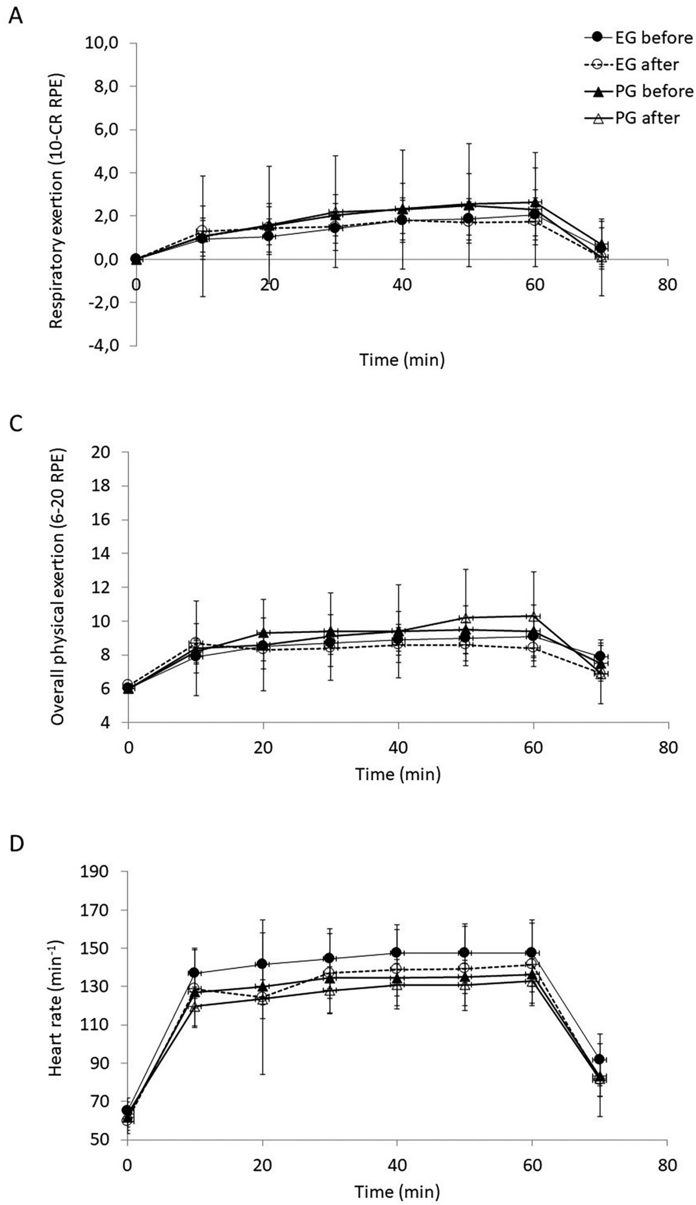


Figure 5. The mean (standard deviation) heart rate response (A) and ratings of overall body effort (B) and respiratory effort (C) during the 60-minute walk test before and after the six-week program of inspiratory muscle training for the experimental (EG) and placebo groups (PG).

DISCUSSION

The main objective of the present study was to evaluate the effects of six weeks of IMT with progressive inspiratory resistance in members of military special forces on respiratory muscle strength and endurance, heart rate response and the perception of exertion when walking with a heavy backpack. The results show that the experimental group increased inspiratory muscle strength (MIP) by 47% as a result of the training, while there was no effect on the expiratory muscle strength (MEP). In addition, a significant reduction in inspiratory and expiratory fatigue during the 60-minute walk test with a 25-kg backpack was found in the experimental group, but this was not reflected in the RPE or HR values during the test. In contrast, there was no significant improvement in any of the measured physiological parameters in the placebo group. Thus, our results fully confirm the findings of the meta-analysis on the effects of IMT in various types of athletes (Karsten, Ribeiro, Esquivel & Matte, 2018) and highlight the importance of the progressivity and specificity of breathing resistance for optimal training adaptation (McConnell, 2011).

A direct comparison with the results of the methodologically most similar study by Faghy and Brown (2016) confirms our initial assumption that progressive inspiratory resistance further enhances the effects of IMT. Indeed, Faghy and Brown (2016) achieved a 31% increase in MIP in the pretest and 19% in the posttest after six weeks of IMT in moderately physically fit healthy subjects, while our study achieved a 47% increase in MIP in the pretest and as much as 58% in the posttest in very physically fit subjects during the same training period. The training effect was substantially higher in our subjects despite their higher baseline level of physical fitness.

IMT also had a positive effect on the endurance of the respiratory muscles of the experimental group. The initial inspiratory and, interestingly, expiratory fatigue induced by the 60-minute walk test were reduced by 8 cmH_2O. However, these changes were too small to reduce the subjective ratings of whole-body exertion or respiratory effort. Considering that the weight of a backpack is critical to respiratory fatigue under given exercise conditions, the weight of the backpack in our study appears to have been too low to cause noticeable respiratory fatigue and impair physical performance. Indeed, Dominelli, Sheel and Foster (2012) have shown that a backpack weighing less than 35 kg has no effect on respiratory mechanics and thus on the demand for respiratory effort during short periods of walking. Consistent with this, Shei, Chapman, Gruber & Mickleborough (2017) reported that six weeks of flow-resistive IMT improved physical performance in recreational athletes but did not attenuate diaphragmatic fatigue during constant-load running to volitional exhaustion with a 10-kg backpack. Indeed, Faghy and Brown (2014a; 2014b) have shown that prolonged low-intensity physical activity with a backpack weighing less than 25 kg does not cause premature fatigue of the inspiratory respiratory muscles, although it does cause certain changes in the cardiovascular and metabolic responses and perceived physical exertion. They also highlight other factors that may mitigate premature inspiratory respiratory muscle fatigue, namely previous regular exercise, male gender, higher body mass, higher skeletal muscle strength and higher aerobic capacity (Faghy & Brown, 2014a; Faghy & Brown, 2014b). All of these factors were present in our subjects, which most likely contributed to the low perceived respiratory muscle fatigue during the 60-minute walking test. Respiratory muscle fatigue due to the altered movement mechanics and excessive load on the chest when carrying a heavy backpack is clearly progressive (Butcher, et al., 2006; Faghy & Brown, 2014a; Faghy & Brown 2014b), so training-induced increases in respiratory muscle strength cannot completely prevent it. Wearing a backpack also requires a greater activity of the abdominal diaphragm to stabilize the thoracolumbar spine, which further accelerates diaphragm fatigue and worsens the mechanics and economy of breathing. It is therefore not surprising that IMT can also improve postural control when carrying loads and consequently reduce lower back pain (Janssens et al., 2015).

The main limitation of our study protocol was that it failed to produce detectable changes in the heart rate and ratings of perceived physical and respiratory exertion between the experimental and placebo groups. The most likely reason for this is that the intensity of the 60-minute walk test or the weight of the backpack was too low for the given population sample. To effectively stress the respiratory muscles, subjects must be exposed to a combination of prolonged moderate- to high-intensity physical activity while carrying a backpack weighing at least 25 kg. A two-stage testing protocol, such as that used by Faghy and Brown (2016), or a multi-stage protocol with progressive walking speeds and treadmill incline, such as that used by Armstrong, Ward, Lomax, Tipton, and House (2019), would most likely be more appropriate

The recommended intensity of IMT is between 50 and 70 per cent of the MIP, exercise duration is up to 30 breathing cycles and exercise frequency is twice daily, every day per week (McConnell, 2013). To optimize the training protocol for the needs of our study, we considered the basic principles of physical training: progressive overload and specificity. The progressivity of exercise overload is primarily achieved through incremental intensity (resistance), but increasing the time and frequency of exercise can have an additional effect. In our study, we only ensured the progressivity of the overload during the six-week training period by increasing intensity, i.e. by increasing the inspiratory resistance threshold on the respirator by 10% every two weeks. It could be that an additional modulation of the breathing exercise time, i.e. the number of breathing cycles, would further improve the training effect, especially the endurance of the inspiratory muscles. This should be tested in future studies. On the other hand, an additional increase in daily exercise frequency would not be feasible in our subjects, as performing IMT twice a day, seven days a week, was already at the upper limit of their busy daily schedule.

CONCLUSION

The aim of this study was to determine whether six weeks of IMT could increase the strength and endurance of the respiratory muscles, thereby delaying their fatigue when carrying a backpack during physical activity. The IMT protocol used in previous studies was improved on by progressively increasing the inspiratory resistance to ensure a more optimal overload of the respiratory muscles. Our results show that MIT significantly increases inspiratory strength and reduces muscle fatigue during a 60-minute walk with a 25-kg backpack. However, the positive changes in inspiratory pressure were not reflected in the perception of whole-body exertion and respiratory effort or in cardiovascular responses. Various groups of physically demanding occupations (e.g. military, firefighters, rescue workers, etc.), as well as people engaged in recreational activities that involve carrying heavy backpacks (hikers, alpinists, skiers, etc.), could benefit from MIT.

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