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Maximal inspiratory pressure is influenced by intensity of the warm-up protocol

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ABSTRACT

The aim of the study was to compare the effect of inspiratory muscle warm-up protocols with different intensities and breathing repetitions on maximal inspiratory pressure (MIP). Ten healthy and recreationally active men (183.3 ± 5.5 cm, 83.7 ± 7.8 kg, 26.4 ± 4.1 years) completed four different inspiratory muscle (IM) warm-up protocols (2 × 30 inspirations at 40% MIP, 2 × 12 inspirations at 60% MIP, 2 × 6 inspirations at 80% MIP, 2 × 30 inspirations at 15% MIP) on separate, randomly assigned visits. Pre-post values of MIP using MicroRPM (Micro Medical, Kent, UK) showed a significant increase in the mean values after the IM warm-up (POWERbreathe® K1, Warwickshire, UK) with 40% MIP and 60% MIP warm-up protocols, when MIP increased by 7 cm H_2O (95% CI: 0.10. . .13.89) ($p = 0.047$) and by 6.4 cm H_2O (95% CI: 2.98. . .13.83) ($p = 0.027$), respectively. In conclusion, a higher intensity inspiratory muscle warm-up protocol (2 × 12 breaths at 60% of MIP) can increase IM strength.

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1. Introduction

Inspiratory muscle (IM) fatigue can have a negative effect on athletic performance and can occur after prolonged submaximal and short-term maximal exercise (Inbar et al., 2000; Johnson et al., 1993). One of the proposed mechanism how IM can limit exercise tolerance is through metaboreflex which reduces blood flow and limits locomotor muscle function (Wüthrich et al., 2015). To postpone the effect of IM fatigue, a specific and effective IM training and warm-up has been introduced; first in chronic obstructive pulmonary disease patients and subsequently also in athletes (Gosselink et al., 2011). In a recent systematic review IM training has been shown as an effective supplement to training for positive gains in athletic performance (Illi et al., 2012). However, the effects of an acute bout of inspiratory muscle warm-up on athletic performance have received less attention and results are controversial. Only handful of studies have investigated effects of IM warm-up on maximal inspiratory pressure (MIP) and on athletic performance (Arend et al., 2015; Brown et al., 2014; Johnson et al., 2014; Lin et al., 2007; Tong and Fu, 2006; Volianitis et al., 2001a,b, 1999). In several papers there has been a good correlation between changes in MIP and changes in exercise performance following the IM warm-up (e.g. Griffiths and McConnell, 2007; Lomax et al., 2011). The applied intensity of IM warm-up in previous research has been relatively low: either 40% of MIP or 15% of MIP for sham (placebo) protocols with two sets of 30 inspirations in both cases. In contrast, moderate to high intensities have been used for whole body warm-up prior to regular sporting activities which have been related to better results in athletic performance (Zois et al., 2013, 2015). Higher intensity warm-up results also in shorter time needed for warming up before training or competition (Saez Saez de Villarreal et al., 2007).

Based on the previous studies we hypothesized that IM would react to stimuli the same way as other skeletal muscles (Kraemer et al., 2002) thus a higher intensity of IM warm-up would better prepare the respiratory system than the previously used two sets of 30 repetitions at 40% MIP. A higher intensity of IM warm-up would mimic the higher respiratory loads that occur during sporting activities. The aim of our study was to compare the effect of different IM warm-up protocols on changes in MIP.

2. Materials and methods

2.1. Subjects

Ten healthy non-smoking male adults (mean age 26.4 ± 4.1; height 183.3 ± 5.5; weight 83.7 ± 7.8; BMI 25.0 ± 2.9) with no cardiopulmonary diseases and with normal lung function volunteered

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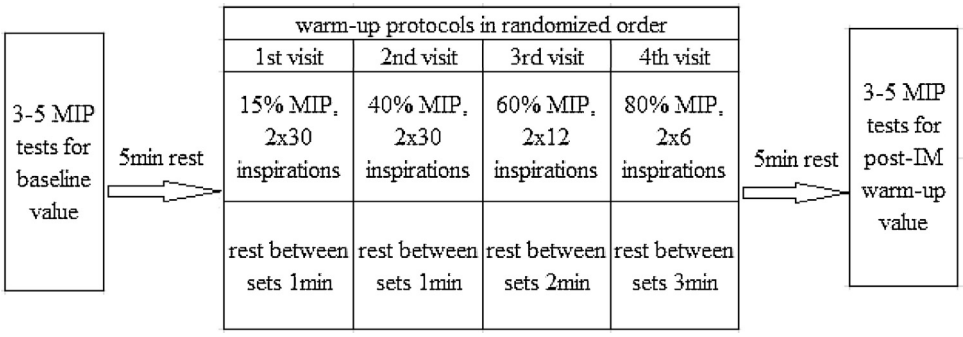

Fig. 1. Study design in brief. After familiarization with the testing procedures the subjects performed MIP testing and started with IM warm-up protocols in a randomized order, MIP was measured again after the warm-up.

to participate. Subjects were required to be between 18 and 50 years old and healthy in order to be included. The exclusion criteria were obesity (BMI ≥ 30), previous history of respiratory or neuromuscular disease, smoking and pulmonary or upper respiratory tract infection two weeks prior to or during the study period. The purpose of the study and procedures were explained to the subjects after which the subjects signed the informed consent form. The study protocol obtained approval from the Research Ethics Committee of the University of Tartu and the study was conducted according to the Declaration of Helsinki.

2.2. Procedures

Subjects performed four inspiratory muscle warm-up protocols under similar conditions during the same time in the afternoon, in a randomized order. During all occasions, the subjects had to perform MIP testing first (Fig. 1). Based on this measurement the subsequent individual load for warm-up was calculated. The MIP testing was also conducted 5 min after the completion of the warm-up protocol, so each of the subjects acted as their own controls. Testing sessions were separated by a minimum of one week to minimize the training effect. On test days, no alcohol, coffee or caffeinated drinks were allowed before starting the test. The subjects were also asked not to participate in any strenuous exercise during the previous 24 h preceding the tests.

2.3. Maximal inspiratory pressure measurements

Subjects were not previously familiar with the MIP testing and during the familiarization sessions they were thoroughly introduced to the Mueller maneuver. MIP was performed as a maximal isometric inspiratory maneuver from residual volume and it was registered according to the present ATS/ERS statement on respiratory muscle testing (2002) using a mouth pressure meter MicroRPM (Micro Medical, Kent, UK). All MIP measurements were done with the subject in a seated position looking straight ahead and wearing a nose clip. The subjects had to perform five to seven MIP tests to minimize the learning effect before starting the study. Verbal encouragement during MIP testing was given to assist the subjects in performing maximally.

After the familiarization process for MIP testing, a five minutes rest was provided and baseline MIP measurement started again from residual volume. In order to obtain the highest MIP value, all subjects performed a minimum of three and a maximum of seven attempts to obtain three values with differences not higher than 5%. The highest value of three acceptable MIP results (maximal mean pressure held for 1 s) was used to calculate the load for inspiratory muscle warm-up before every intervention. Rest intervals of 1 min were allowed in-between MIP trials.

2.4. Inspiratory muscle warm-up at different intensities

A commercially available handheld inspiratory muscle training device (POWERbreathe® K1, POWERbreathe International Ltd, Warwickshire, UK) was used for the IM warm-up in a seated position. A nose clip was worn during the IM warm-up sessions to avoid nasal air leak. Subjects performed the warm-up protocols 5 min after completion of the MIP testing. Four different intensities (15%, 40%, 60%, and 80% MIP) were used in a randomized order to avoid the effect of testing order and the subjects were their own controls. The same Powerbreathe® device was used for each session and the load was set up individually to a specific individual load calculated from baseline MIP. Since the K-1 series optimizes the resistance during the first two breaths and then incrementally applys it, we did not count the first two breaths during the protocols. During all IM warm-up protocols, breathing frequency was paced by the K-1 device with an audible beep. Time between the inspiration was 4.5 s. Subjects were asked to inhale as quickly and deeply as possible. During all warm-up protocols the performed load was also calculated by multiplying the number of repetitions with defined individual intensity of MIP.

2.5. Statistical analysis

All data analyses were conducted using version 21 of Statistical Package for Social Sciences (SPSS Inc, Chicago, Illinois, USA). Descriptive parameters (mean ± SD) were calculated and significant differences were identified. All data were checked for normality and a paired samples *t*-test was used to analyze pre- and post-test data. The level of significance was set at $p < 0.05$.

3. Results

Table 1 presents the mean MIP values before and after different intensity IM warm-up protocols. The recorded MIP was significantly higher after acute IM warm-up using 40% of MIP ($p = 0.047$) and 60% of MIP intensity ($p = 0.027$). The performed load during warm-up sessions was significantly higher for the 40% and 60% MIP test compared to the 15% and 80% MIP test ($p < 0.05$). Performed load was also higher for the 60% MIP compared to the 40% MIP test ($p = 0.003$) while no differences were seen in the 15% MIP test compared to the 80% MIP test ($p = 0.39$).

The average MIP value was 5.1% and 4.7% higher after the 40% and 60% of MIP intensity warm-ups, respectively (Fig. 2).

4. Discussion

The aim of the current study was to assess the acute effect of different IM warm-up intensities on MIP. The main result was that the 40% and 60% MIP warm-up protocols resulted in significant

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