Respiratory Physiology & Neurobiology 230 (2016) 68–72

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

Short communication

Maximal inspiratory mouth pressure in Japanese elite male athletes

Toshiyuki Ohya*, Masahiro Hagiwara, Kentaro Chino, Yasuhiro Suzuki

Japan Institute of Sports Science, 3-15-1 Nishigaoka, Kita-ku, Tokyo 115-0056, Japan

ARTICLE INFO

Article history:
Received 24 April 2016
Received in revised form 9 May 2016
Accepted 10 May 2016
Available online 12 May 2016

Keywords:
Respiratory muscle
PImax
Pulmonary function
Inspiratory muscle training

ABSTRACT

Maximal inspiratory mouth pressure (MIP) is a common measurement of inspiratory muscle strength, which is often used in a variety of exercises to evaluate the effects of inspiratory muscle training. An understanding of elite athletes' MIP characteristics is needed to guide sport-specific inspiratory muscle training programs. The purpose of this study was to investigate and better understand the MIP characteristics of elite athletes from a variety of sports. A total of 301 Japanese elite male athletes participated in this study. MIP was assessed using a portable autospirometer with a handheld mouth pressure meter. Athletes with higher body mass tended to have stronger MIP values, in absolute terms. In relative terms, however, athletes who regularly experienced exercise-induced inspiratory muscle fatigue tended to have stronger MIP values. Our findings suggest that athletes could benefit from prescribed, sport-specific, inspiratory muscle training or warm-ups.

1. Introduction

Maximal inspiratory mouth pressure (MIP) is commonly used to measure inspiratory muscle strength; it reflects the combined force-generating capacity of the inspiratory muscles during a brief, quasi-static contraction. Because MIP measurements are taken using volitional, non-invasive techniques, which are better tolerated by participants than balloon catheter systems, the index often uses a variety of exercises to evaluate the effects of inspiratory muscle training or warm-ups (HajGhanbari et al., 2013).

Inspiratory muscle training is classified into two major categories: inspiratory muscle strength training and inspiratory muscle endurance training. Inspiratory muscle strength training is performed by breathing against an external inspiratory load. This load is often adjusted with reference to MIP (HajGhanbari et al., 2013). Inspiratory muscle training requires participants to achieve a threshold pressure to open the valve of an inspiratory muscle training device (e.g., the POWER breathe inspiratory muscle trainer) to provide an inflow of air (HajGhanbari et al., 2013). Substantial respiratory strength is needed to achieve and maintain the target threshold pressure, which ranges between 50% and 80% of MIP (HajGhanbari et al., 2013). Inspiratory muscle warm-up is typically performed at 40% of MIP (Ohya et al., 2015; Volianitis et al., 2001), and has been found to improve inspiratory muscle function (Ohya et al., 2015) and exercise performance (Volianitis et al., 2001). However, the optimal inspiratory muscle training or warm-up loads for athletes, based on their specific sports, remain unclear.

The characteristics of MIP have already been reported in both young (Leech et al., 1983), and older adults (Summerhill et al., 2007). To our knowledge, no study has quantified and reported the MIPs of elite athletes across a variety of sports. An understanding of the characteristics of elite athletes' MIPs is needed to guide inspiratory muscle training programs relative to specific sports. The purpose of this study was to understand the MIP characteristics at rest in a variety of sport-specific elite athletes.

2. Methods

2.1. Participants

Participants in this study were 301 Japanese elite male athletes and 28 normal healthy males. Table 1 shows the age, height, and body mass of the participants. All the athletes were recruited following medical and/or fitness checks conducted in the Japan Institute of Sports Sciences. Written consent to participate was obtained from all participants after informing them of the purpose of the experiment, the procedure, and the possible risks. This study was approved by the Human Subjects Committee at the Japan Institute of Sports Sciences.

* Corresponding author at: Department of Sports Science, Japan Institute of Sports Sciences, Tokyo 115-0056, Japan.
E-mail address: toshiyuki.ohya@jpnsport.go.jp (T. Ohya).

http://dx.doi.org/10.1016/j.resp.2016.05.004

Table 1
Characteristics of Japanese elite male athletes and healthy males.

	alpine skiing (n = 5)	badminton (n = 19)	basketball (n = 14)	canoe (n = 9)	cross-country skiing (n = 9)	cycling (road) (n = 11)	cycling (track) (n = 12)	fencing (n = 8)	freestyle skiing (n = 5)	hockey (n = 19)
age (years)	22.8 ± 2.2	24.8 ± 4.0	22.9 ± 2.0	24.7 ± 2.8	22.8 ± 2.5	20.8 ± 0.9	24.8 ± 4.5	24.3 ± 3.5	24.0 ± 3.1	25.3 ± 3.9
height (cm)	172.8 ± 4.8	174.1 ± 4.4	186.8 ± 10.0	175.5 ± 4.0	173.0 ± 4.4	171.1 ± 5.9	175.7 ± 4.6	176.4 ± 5.1	169.6 ± 6.3	174.5 ± 3.4
body mass (kg)	76.5 ± 5.4	71.6 ± 5.7	86.4 ± 14.5	82.8 ± 6.5	70.4 ± 4.7	60.6 ± 5.3	75.3 ± 6.3	72.0 ± 6.6	68.6 ± 6.8	71.6 ± 6.3

	hurdles (n = 13)	jumping (n = 10)	long-distance running (n = 7)	middle-distance running (n = 7)	nordic combined (n = 7)	rowing (n = 20)	rugby (n = 24)	sailing (n = 9)	short-track speed skating (n = 12)	snowboarding (n = 8)
age (years)	23.9 ± 2.7	24.9 ± 2.9	24.1 ± 2.7	24.1 ± 3.2	24.3 ± 4.0	23.6 ± 3.9	27.6 ± 4.3	28.4 ± 4.6	22.5 ± 2.2	24.3 ± 4.2
height (cm)	181.0 ± 4.9	179.0 ± 5.1	169.7 ± 5.6	174.4 ± 3.4	173.9 ± 4.4	178.1 ± 3.6	181.8 ± 8.1	178.2 ± 9.5	170.3 ± 6.1	173.5 ± 4.8
body mass (kg)	71.7 ± 6.7	67.8 ± 6.0	56.2 ± 4.0	63.6 ± 5.0	65.3 ± 6.2	72.3 ± 3.2	101.0 ± 13.1	71.5 ± 9.7	65.1 ± 6.8	71.3 ± 9.5

	speed skating (n = 5)	swimming (n = 12)	triathlon (n = 12)	walking (n = 8)	water polo (n = 7)	weight lifting (n = 9)	wrestling (light) (n = 7)	wrestling (middle) (n = 7)	wrestling (heavy) (n = 6)	healthy male (n = 28)
age (years)	26.0 ± 4.6	22.1 ± 2.0	26.5 ± 5.3	26.0 ± 3.9	25.7 ± 1.1	23.4 ± 2.7	22.9 ± 2.7	22.3 ± 3.2	24.0 ± 2.5	24.4 ± 4.2
height (cm)	171.6 ± 4.3	180.2 ± 5.0	172.3 ± 4.1	175.3 ± 6.5	182.7 ± 4.7	169.8 ± 10.1	163.4 ± 3.8	175.3 ± 3.5	178.4 ± 7.0	171.5 ± 5.8
body mass (kg)	71.6 ± 6.0	75.8 ± 7.9	64.7 ± 4.8	60.7 ± 4.5	83.0 ± 9.9	88.5 ± 29.8	63.9 ± 3.8	79.3 ± 5.2	111.8 ± 10.7	64.5 ± 8.7

2.2. *MIP measurement*

MIP was assessed according to published guidelines (American Thoracic Society/European Respiratory Society, 2002), using a portable autospirometer (AS-507; Minato Medical Science, Osaka, Japan) with a handheld mouth pressure meter (AAM377; Minato Medical Science) (Ohya et al., 2016). All measurements were made while the participant sat with their nose occluded. Participants were instructed to breathe out to residual volume and then inhale as hard and as quickly as possible to total lung capacity and sustain this inspiration for at least 1 s. Measurements were repeated until a minimum of five and a maximum of seven technically satisfactory measurements were obtained; the greatest of the three measurements that had less than 10% between-measurement variability was defined as the maximum (McConnell, 2007).

2.3. *Statistical analysis*

Values are expressed as means ± standard deviation (SD). Statistical analyses were performed using SPSS for Windows, Version 19.0 (IBM Corp., Armonk, NY, USA). Correlations between the MIP value and height and body mass of each athlete were determined and tested for significance using the Pearson product-moment correlation. Significance was set at $P < 0.05$.

3. Results

Fig. 1 shows the MIP values of Japanese elite male athletes; the mean was 132.8 ± 17.3 cm H_2O. Fig. 2 shows the athletes' MIP values relative to their body mass; the mean was 1.85 ± 0.21 cm $H_2O\,kg^{-1}$. A strong correlation ($r = 0.59$, $P < 0.001$) was observed between mean MIP values and mean body mass of athletes from each sport, but no correlation was found between mean MIP values and mean height ($r = 0.11$, $P > 0.05$).

4. Discussion

This is the first study to investigate the MIP characteristics of Japanese elite male athletes. In absolute terms, the MIP values of athletes with higher body mass tended to be stronger (Fig. 1). Hautman et al. (Hautmann et al., 2000) reported that MIP was strongly correlated with body mass in healthy males. In another study, body mass was found to affect lung function (Schoenberg et al., 1978); the authors suggested that the improved lung function associated with body mass was attributable to the increased muscle bulk (Schoenberg et al., 1978).

Previous studies have reported that inspiratory muscle fatigue (IMF) occurs after swimming (Brown and Kilding, 2011), short-duration high-intensity exercise (Ohya et al., 2016), and long-duration exercise (Ross et al., 2008). In relative terms, athletes whose sport typically demands exercise-induced IMF (e.g., middle-distance runners, triathletes, swimmers and long-distance runners in this study; Fig. 2) tend to have stronger MIP values than other athletes. For example, swimmers are required to precisely coordinate their frequency of breathing and tidal volume with stroke mechanics, which results in a different breathing pattern compared with on-land exercise (Rodríguez, 2000). Coupled with the increased hydrostatic pressure on the chest, and the potential effect of body position on breathing, these factors individually and collectively likely result in an increased load on the respiratory system (Cordain and Stager, 1988). Furthermore, in a previous study of highly trained female middle-distance runners, we demonstrated that IMF occurred after a 400-m and 800-m running test (Ohya et al., 2016). Running requires additional work from the inspiratory muscles; therefore, runners might be more susceptible to IMF