

Inspiratory muscle training on lung function of male roller hockey players: a randomized controlled trial pilot study

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Abstract

Background: There is evidence that inspiratory muscle training (IMT) increases the athlete's performance by decreasing the work of the respiratory muscles during exercise. IMT has shown positive results in the pulmonary function of athletes, and it was hypothesized that 4 weeks of intervention could increase lung function at rest. Investigate the influence of IMT on lung function of male roller hockey players.

Methods: Eleven male roller hockey players were randomized and allocated in the experimental group (EG) or control group (CG). Forced expiratory volume in first second, forced vital capacity, and peak expiratory flow (PEF) were assessed with spirometry, in the beginning of the study and 4 weeks later. The EG (n=6) was submitted to an IMT using a threshold during 4 weeks, 3 times a week, 30 repetitions with 50% of maximal inspiratory pressure. The CG (n=5) was not submitted to any intervention.

Results: Baseline pulmonary variables, forced expiratory volume in first second, forced vital capacity, and PEF, sociodemographic, and anthropometric characteristics were not significantly different among EG and CG. Significant increase on PEF ($P=.033$) was found in the EG after IMT.

Conclusion: IMT with threshold seems to have a positive impact on PEF in roller hockey players. These findings may be corroborated by further controlled randomized studies.

Keywords: inspiratory muscle training, pulmonary function, roller hockey and spirometry

Introduction

Roller hockey is considered an intermittent sport, because there are oscillations between moments of high and moderate intensity. This sport requires good balance, coordination, and good neuromuscular control as the players need to combine manipulation of a stick to control the ball and the skating.^{1,2}

The load applied to the inspiratory muscles should be appropriate as the physiological responses to training are identical to any other skeletal muscle.^{3,4} There is great controversy about the inspiratory muscle training (IMT), suggesting that when 80% of maximal pressure inspiratory is used there is a risk of developing chronic inspiratory muscle fatigue.⁵ During exercise, it is known that 14% to 16% of the

cardiac output is redistributed from the active peripheral muscles to the IMT as increased inspiratory work increases noradrenaline, causing a decrease in blood flow in the active limbs.⁴

In the high-intensity exercise, the respiratory muscles consume about 10% to 15% of total VO_2 , and they become susceptible to fatigue. In healthy people, the inability to maintain high levels of ventilation is considered a limiting factor for maximal aerobic capacity.³ During fatigue, an exacerbation of the metaboreflex sympathetic system increases sympathetic afferent discharge.^{4,6}

The inspiratory metaboreflex is activated during exercise as the fatigue of the inspiratory muscles induces the accumulation of metabolites that increases the sympathetic activity and the vasoconstriction, reduces the oxygen transport and consequently, increases the fatigue of the active peripheral muscles. It is known the one way to attenuate this metaboreflex is through the development of inspiratory muscles, strengthening them with 2 different training methods: (i) aerobic training, by increasing oxidative capacity and resistance to diaphragmatic fatigue and (ii) IMT, for reducing blood lactate concentration.⁴

IMT has been shown to produce effects such as increased inspiratory muscle strength, diaphragm thickness, and pulmonary volumes measured by spirometry.⁷ In addition, it increases pulmonary oxygen uptake, decreases blood lactate concentrations, VO_2 , cardiac output, inspiratory muscle fatigue under normoxia and hypoxia conditions, and cardiovascular and respiratory work. Thus, there is evidence that IMT increases the athlete's performance as it decreases the work of the respiratory muscles during exercise, leading to higher oxygen availability to the active peripheral muscles.^{3,8,9} According to Downey et al's⁹ results, such as the increase of diaphragm thickness, begin to be evident after 4 weeks of intervention. In a study by Júnior et al,¹⁰

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it is concluded that the use of the threshold associated with IMT brings numerous benefits in terms of performance and breathing capacity in athletes.

IMT has already shown to have beneficial results in the pulmonary function of female basketball players,¹¹ soccer players,¹² cyclists,¹³ and swimmers.¹⁴

The evidence on the influence of IMT on intermittent sports is very small specially in roller hockey, given this, it was hypothesized that 4 weeks of intervention could increase lung function at rest. With this study, we aim to investigate the influence of IMT on lung function of male roller hockey players.

Materials and methods

Study design

This was a randomized controlled trial. For allocation of the groups, the athletes were randomly assigned to the experimental group (EG) or control group (CG) using sealed envelopes.

The study was approved by the Ethics Committee of Fernando Pessoa University. The ethical principles, norms, and international principles about preservation and respect of data follow the Declaration of Helsinki.

When the informed consent was given, the objectives and procedures of the study were communicated as well as the advantages and inherent risks. All the participants were informed that they could withdraw from the study at any moment. The trial was reported according to CONSORT guidelines.¹⁵

Participants

Participants were recruited from the roller hockey club. Only the male roller hockey players able to provide informed consent were included. Exclusion criteria consisted of athletes with smoking habits; athletes with any severe musculoskeletal, respiratory, cardiac, and/or neurological pathology; and athletes who did not complete all the procedure.

Intervention

Between September and October 2018, all the athletes were submitted to 4 weeks of protocol in the first third of the roller hockey season. They had the same work intensity, similar training protocols, and they returned to physical activity simultaneously. During this protocol, they were advised to maintain the training regimen and normal diet.

Participants' characteristics

All the participants completed a structured questionnaire on sociodemographic and anthropometric data, which included age; weight; height; body mass index; smoking habits; years of practice; training per week; duration of each training; weekly hour of training; and possible pathologies, respiratory, neurological, and/or cardiac.

Resting pulmonary function

The pulmonary volumes were measured in all participants: forced expiratory volume in first second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF) were assessed at baseline.⁷

The study followed the guidelines of American Thoracic Society and it was used a handheld spirometer (MicroLab, ML3300, MK6; Micro Medical Limited, Kent, UK). The test began by instructing the subject about the maneuvers. All the

participants performed 3 respiratory cycles, doing in each cycle a free maximum inspiration, followed by a maximum exhalation against a buccal placed between their lips. Everyone had the same posture during the test.^{7,16}

Inspiratory muscle training

The IMT was only performed in EG using an inspiratory pressure gadget of endurance, threshold (POWERBreathe IronMan Plus, Warwickshire, UK). The athlete should be able to open the valve by forced inspiration to mobilize maximum lung volume.^{5,17} The training load used in this study is equivalent to 50% of maximal inspiratory pressure (MIP). Athletes were instructed on the IMT and on the technique for using the threshold. In order to calculate the load, on the first day, the participants performed the training with the minimum of resistance, increasing the load in the second session, being the athletes only able to perform 30 respiratory cycles with the threshold, in a biped position. The calculation of the load was carried out through the threshold. The protocol was implemented for 4 weeks, 3 times per week, once per day.^{13,17,18}

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics vs. 25.0 (IBM Corp, Armonk, NY) considering a level of significance of 0.05 for all the inference tests. The statistical analysis started with the detection of possible outliers and with the test to the normality of the distribution of the quantitative variables (Kolmogorov-Smirnov test). The "Age," "Practice per week," and "hours per practice" variables were not normally distributed and are reported through median (interquartile range). The other variables are reported in the form of mean \pm standard deviation. The comparison of continuous data was made using the *T* Test for paired samples, whereas the comparison of the variables between the 2 groups was performed using the *T* Test for independent samples. The Wilcoxon-Mann-Whitney nonparametric test was used for the variables "Age," "Training per week," and "Training hours." The same test was used to compare the 2 groups. Statistically significant differences ($P < .05$) were noted with an asterisk (*).

Results

Participants

Thirteen male roller hockey players were analyzed, distributed, and allocated to the EG ($n=6$) or the CG ($n=7$). Two athletes were excluded due to withdrawal (Fig. 1). Baseline sociodemographic and anthropometric characteristics were not significantly different between groups. No significant differences were also found in baseline pulmonary volumes ($.249 \leq P \leq .476$) (Table 1).

Pulmonary function

Table 2 shows the comparison between baseline and final evaluation in the EG and in the CG. The results reveal that the PEF of EG is the only variable with a statistically significant increase ($P=.033$). The same was not observed in the other variables, FEV, FVC, and FEV1/FVC, in which the differences were not statistically significant in the EG ($.141 \leq P \leq .225$) or in the CG ($.129 \leq P \leq .785$). In the variables FEV1, FVC, and FEV1/FVC, we, however, observed an increasing tendency in the EG.

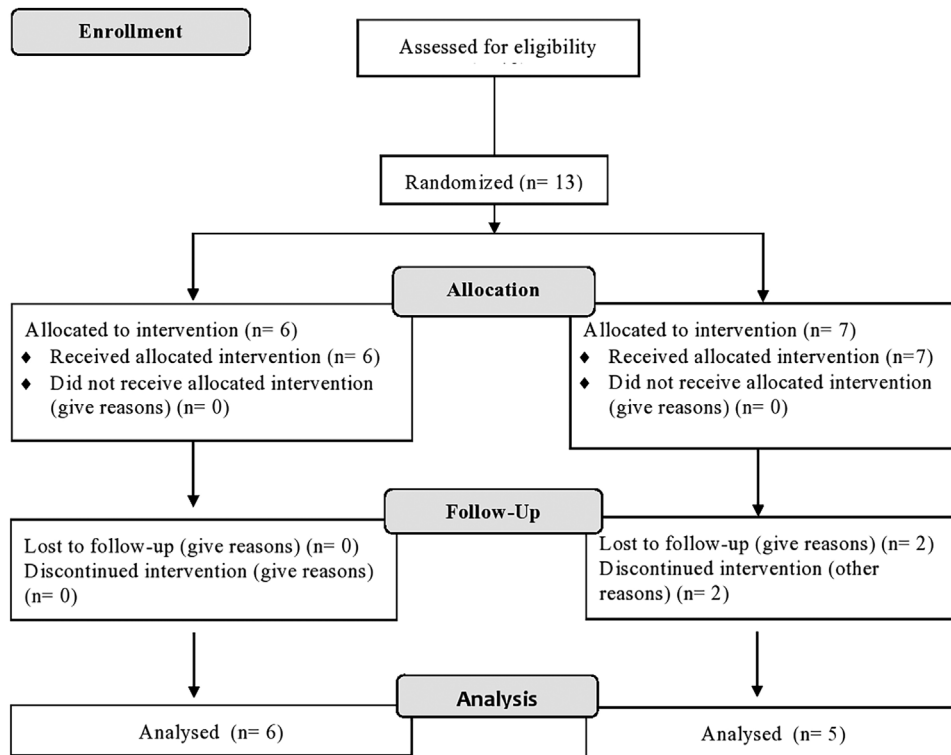


Figure 1. Flow diagram.

In Table 3, it is possible to observe that in the final evaluation there is a difference in the PEF, between the EG and the CG, although it is not conclusive ($P = .050$). In the variables FEV1 ($P = .406$), FVC ($P = .425$), and FEV1/FVC ($P = .724$) we did not find statistically significant differences between the EG and the CG.

Discussion

To the best of our knowledge this is the first randomized controlled trial that evaluated the influence of IMT on the lung function of roller hockey players.

Statistically significant differences were found in the PEF of the EG between the initial and final evaluation. PEF is important and

interferes with the athletes’ performance. According to Mohiuddin and Jaleeli,¹⁹ the higher the value PEF the better the players’ performance. The increase in this variable suggests, indirectly, that there was an improvement in the pulmonary elasticity, in the strength of the thoracic muscles and in the compliance of the chest wall and the lungs.^{19,20} A study by Kellens et al²¹ that applied IMT using a threshold in amateur athletes for 8 weeks observed significant increases in PEF after 4 weeks, as in our study. Studies conducted by Durante et al²² on a different population, concluded that after applying the IMT with a threshold for 6 weeks, an increase in strength inspiratory muscle lead to an increase in the velocity and expiratory flow, which consequently increased PEF. There are even some studies that have shown that at the end of 2 weeks of IMT, changes in the neural adaptation

Table 1
Characteristics of participants from both study groups (n = 11)

Variable	EG (n=6)	CG (n=5)	P
Age (yr)	22.5 (7.2)	19.0 (5.0)	.177
Weight (kg)	74.7 ± 3.7	74.8 ± 13.3	.984
Height (m)	1.77 ± 0.06	1.82 ± 0.08	.252
BMI (kg/m ²)	23.9 ± 1.4	22.5 ± 2.9	.382
Training per week	3.0 (1.0)	3 (0)	.361
Training hours (h)	4.5 (0.8)	4.5 (0)	.361
FEV1 (L)	4.54 ± 0.55	4.27 ± 0.30	.340
FVC (L)	5.27 ± 0.73	4.80 ± 0.47	.249
PEF (Ls ⁻¹)	8.56 ± 1.76	7.82 ± 1.49	.476
FEV1 / FVC (%)	86.4 ± 6.1	89.2 ± 5.4	.449

Mean ± standard derivation or median (interquartile range). BMI = body mass index, CG = control group, EG = experimental group, FEV1 = forced expiratory volume in first second, FEV1/FVC = Tiffeneau Index, FVC = forced vital capacity, PEF = peak expiratory flow. *Statistically significant ($P < .05$).

Table 2
Pulmonary function volumes comparison between baseline and final intervention in the experimental group (n=6) and in the control group (n=5)

Variable	Group	Baseline	Final	P
FEV1 (L)	EG	4.54 ± 0.55	4.66 ± 0.48	.141
	CG	4.27 ± 0.30	4.43 ± 0.38	.170
FVC (L)	EG	5.27 ± 0.73	5.35 ± 0.62	.274
	CG	4.80 ± 0.47	5.01 ± 0.73	.225
PEF (L/s)	EG	8.56 ± 1.76	10.52 ± 1.47	.033*
	CG	7.82 ± 1.40	8.78 ± 0.96	.129
FEV1/FVC (%)	EG	86.4 ± 6.1	87.3 ± 4.9	.276
	CG	89.2 ± 5.4	88.6 ± 7.3	.785

Mean ± standard derivation or median (interquartile range). CG = control group, EG = experimental group, FEV1 = forced expiratory volume in first second, FVC = forced vital capacity, FEV1/FVC = Tiffeneau Index, PEF = peak expiratory flow. *Statistically significant ($P < .05$).

Table 3
Pulmonary function volumes comparison at final evaluation between experimental group (n=6) and control group (n=5)

Variable	EG (n=6)	CG (n=5)	P
FEV1 (L)	4.66±0.48	4.43±0.38	.406
FVC (L)	5.35±0.62	5.01±0.73	.425
PEF (L/s)	10.52±1.47	8.78±0.96	.050
FEV1 / FVC (%)	87.3±4.9	88.6±7.3	.724

Mean ± standard derivation or median (interquartile range).

CG = control group, EG = experimental group, FEV1 = forced expiratory volume in first second, FVC = forced vital capacity, FEV1/FVC = Tiffeneau Index, PEF = peak expiratory flow.

*Statistically significant ($P < .05$).

process are already occurring as well as an improvement of synergic muscle coordination.⁵

The increase of FEV1 is centered on decreased airway resistance and increased lung elasticity. In addition, it is believed that there is an awareness of the respiratory pattern by the participants.^{17,23} A systematic review with meta-analysis evaluated 21 randomized controlled trials and observed that there was a nonsignificant increase in FEV1 after IMT, as in this study.²⁴

Relative to FVC, the increase in inspiratory muscle strength promotes pulmonary compliance. Therefore, the tidal volume increases, which causes a greater expansion of the lung inducing increases in FVC.²³ After IMT, the increase in tidal volume may be related to the increase in the thickness of the diaphragm. Has referred above it is believed that there are neural changes such as a better coordination of the synergistic muscles and a more effective activation of the principles inspiratory muscles, which in turn together with increased diaphragm thickness results in decreased locomotor muscle fatigue because the accessory inspiratory muscles are less recruited.^{17,25}

Our results are supported by some recent studies, such as a randomized trial that applied the respiratory muscle training in swimmers for 1 month, using the threshold IMT and the threshold positive expiratory pressure, each with 30% MIP and the maximum expiratory pressure, performing 10 repetitions for each where no significant results in FEV1 and FVC, after IMT were observed.²⁶ The study by Júnior et al²⁷ that applied IMT in rugby players for 3 weeks with 80% MIP, doing 30 Repetition Maximum (RM), also did not report significant increases in FEV1 and FVC. Nevertheless the 2 studies reported significant increases in respiratory muscle strength and in athletes' performance.

Although there are no studies about IMT in roller hockey, IMT studies have been published in various intermittent sports and all reported significant increases in lung function, such as that by Vasconcelos et al¹¹ with female basketball players [4 weeks of IMT (50% MIP, 30 RM)], that of Romer et al¹³ with cyclists for [6 weeks IMT (50% MIP, 30 RM)], the Nicks et al¹² study with soccer players [12 weeks (30 RM, 80% MIP)], the Tong et al²⁸ study with rowers [6 weeks (30 RM, 50% MIP)], and the Hartz et al²⁹ study with handball players (12 weeks, 2 times a day, 30 RM, with 50% until 70% of MIP).

Limitations

The limitations of this study are the small sample size and the inability to measure the inspiratory vital capacity, the MIP, and the maximum expiratory pressure through the spirometer. A future randomized controlled trial with athletes of this modality should involve a larger sample, with more follow-up and with the

measurement of the above-mentioned parameters, as well as the athletes' performance analysis.

Conclusion

According to the results obtained, the threshold IMT seems to have a positive influence on PEF of roller hockey players after 4 weeks of intervention.

Acknowledgments

None.

Conflicts of interest

The authors declare no conflicts of interest.

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