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ORIGINAL ARTICLE

CORRELATION BETWEEN MAXIMUM INSPIRATORY PRESSURE (MIP) AND PEAK OXYGEN UPTAKE (VO_2PEAK) IN FEMALE PROFESSIONAL SOCCER ATHLETES

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Exercise Test, Breathing Exercises, Athletic Performance, Soccer.

Objective: To evaluate the correlation between inspiratory muscle strength through maximum inspiratory pressure (MIP) and peak oxygen uptake (VO_2 peak) in female professional soccer athletes. **Study Design**: Prospective and cross-sectional study. **Methods:** 16 professional soccer players, female, aged between 18 to 40 (26 ± 4.3 years), underwent measurement of maximum inspiratory pressure (MIP:120.7 ± 16.9 cmH_2O) and performed the cardiopulmonary exercise test (CPET) in a treadmill, where the ventilatory and metabolic variables were measured. One of them was the VO_2 peak (44.30 ± 5.9 ml/kg/min.). The volunteers were assessed on the same day and time as follows: (1) assessment of inspiratory muscle strength; and, (2) incremental cardiopulmonary exercise testing up to maximum tolerance. The data were analyzed using the SPSS® version 13.0 statistical program, and Pearson's correlation was made between MIP and VO_2 peak. **Importance of the Study**: This study can reveal what kind of correlation exists between these important markers, helping in the development of new strategies for improving performance in sport. **Results:** The volunteers presented a MIP of 120.7 ± 16.9 cmH_2O, and in the CPET on a treadmill, they obtained a VO_2 peak of 44.30 ± 5.9 ml/kg/min. The statistical analysis showed an inverse association with $r = -0.14$ and $p = 0.612$ between MIP and VO_2 peak. **Conclusion:** There was an inversely proportional correlation between MIP and VO_2 peak; thus, this result leads us to believe that inspiratory muscle strength does not seem to influence VO_2 peak directly.

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INTRODUCTON

The search for new ventilatory muscle training (VMT) strategies to improve physical exercise has been the subject of the latest researches. Wich involves the administration of substances up to the new training protocols, intending to improve the parameters related to the performance of athletes and healthy subjects, at different ages and different types of activities,[1-9] seeking the performance enhancement[10,11,13]. Within this field of research, has been highlighted the studies that assess the interference of different ventilatory muscle training (VMT) protocols in physical exercise performance[10-17].

However, there is still no consensus about the direct relationship between respiratory muscle strength and better performance. In this sense, some studies have shown an association between inspiratory muscle strength and improved performance[10,-17]. In contrast, other studies have not found differences in performance, despite finding improvements in the performance of respiratory muscles[12,14]. Markov et al[15] found an enhancement in the result of the endurance test of cyclists after 15 weeks of VMT, without observing an increase in the cardiac ejection fraction. Volianitis et al.[17] found an increase in respiratory muscle strength, decreased fatigue, and an improvement in the results of the maximum load and endurance tests after 11 weeks of VMT in rowers. On the other hand, Willians et al[14] performed VMT for 4 weeks in runners and, despite the increase in respiratory muscle strength and endurance, they did not find any improvement in the results of the constant load test. This variation in results may be associated with the use of different training protocols and methods, generating different and difficult results to compare. Therefore, it is necessary to carry out further studies to understand whether there is, in fact, a relationship between inspiratory muscle strength and performance, which would subsidize the importance of inserting the inspiratory muscle training (IMT) in training protocols.

The cardiopulmonary exercise test (CPET), ergospirometry, or cardiorespiratory test is a non-invasive methodology for the global assessment of the integrity of cardiovascular, respiratory, peripheral muscle, neurophysiological, humoral and hematological adjustments of the human organism during the execution of physical exercise[18]. In practice, the great utility of CPET is the determination of functional capacity[18, 19, 20] and aerobic power by obtaining two most used functional limitation indices, which are: the peak oxygen uptake (VO_2 peak) and the maximum oxygen uptake (VO_2 max). In addition to revealing the anaerobic threshold or ventilatory anaerobic threshold (VAT) at maximum or submaximal levels of physical exercise[21]. Although the indications for this test are the most varied and increasing[19], we can see that its indication has been used in some clinical manifestations not fully explained by data from anamnesis, physical examination, imaging tests, pulmonary function test, and conventional electrocardiography[21]; as an example in finding and evaluating the etiological factor, and also the degree of effort intolerance[19]. It is worth noting that both athletes, as well as healthy individuals and patients, can benefit from CPET[19] regardless of the purpose for which the test is performed. However, for us, physiotherapists, it still has a particular purpose when it comes to the individualized prescription of physical exercises, physical reconditioning, and people with diseases, besides to justify the development of safer, comfortable, and reliable intervention protocols[19].

In this context, it would be feasible to understand whether inspiratory muscle strength parameters would be related to VO2peak from CPET and would represent a good strategy for improving performance in rehabilitation protocols. Given the above, the objective of the study was to assess the correlation between inspiratory muscle strength through maximum inspiratory pressure (MIP) and peak oxygen uptake during exercise (VO_2 peak) in female professional soccer athletes.

METHODS

Study design and Sample

This is one prospective and cross-sectional study where, sixteen professional soccer athletes who regularly play for clubs in Rio de Janeiro were screened. The athletes obeyed the following inclusion criteria: being female, aged between 18 and 40 years old, apparently healthy according to clinical evaluation, who regularly trained with the respective team (five times a week, changing between tactical and physical training, in addition to games frequently on weekends). Players with a history of cardiovascular, respiratory, muscular, orthopedic, neurological, metabolic, or immunological diseases were excluded. The study was approved by the Comitê de Ética do Hospital Universitário Clementino Fraga Filho, under Resolution No. 466/2012 of research with human beings (nº 1138295). The volunteers signed the Informed Consent Form (ICF) to participate in the study.

Screening

The recruited volunteers went through the following assessment:

a) Clinical evaluation: The volunteers underwent to a clinical assessment performed by the doctor before their inclusion in the experimental protocol. The volunteers could be submitted to routine exams to help in the exclusion of diseases, such as laboratory exams (blood count, biochemistry, electrolytes) and electrocardiogram.

b) Physiotherapeutic evaluation: The volunteers underwent a detailed assessment (anamnesis and physical examination), in which personal and anthropometric data, medical diagnosis, vital signs, risk factors for coronary artery disease (history of smoking, family history of CAD, diabetes, morbid obesity, dyslipidemia, renal failure, systemic arterial hypertension, pulmonary hypertension, history of stroke, obstructive pulmonary disease, peripheral vascular disease, cerebral vascular disease), nutritional, body mass index (BMI) and water status were collected.

c) Lung Function: Aiming to verify whether the volunteers had preserved lung function. Spirometry was performed using the CPFS/D Medighafics® spirometer (Medical Graphics Corporation, St. Paul, MO, USA). The forced vital capacity test (FVC) was performed to determine the forced expiratory volume in the first second (FEV_1) and the FEV_1/FVC ratio. The reference values used were those of Knudson et al.[22]. They were expressed in BTPS conditions (Body Temperature Pressure Standard) and the technical procedures, acceptability and reproducibility criteria were performed according to the standards recommended by the American Thoracic Society (ATS)[23].

The evaluations were composed by:

a) Ventilatory Muscle Strength Test: The assessment of inspiratory muscle strength was always performed by the same evaluator, with the volunteer at rest, in a sitting position. A digital manovacuometer (MVD-300, Globalmed, Porto Alegre, Brazil) and a nasal clip were used, according to the Brazilian Guidelines for measuring maximum static respiratory pressures[24]. The maximum inspiratory pressure (MIP) was determined after maximum inspiratory effort, based on the residual volume, against a tube with an occluded distal end. For the test, a mouthpiece with a 2 mm orifice and a nose clip were used[24]. The values used in the definition of MIPs were those observed in the first second after the peak pressure. A maximum of five maneuvers was performed, with an interval of 30 seconds between maneuvers[25], with the highest reproducible values (difference <10%) found in at least three maneuvers. The normal values were based on the regression equation proposed by Neder et al.[26] for the Brazilian population. MIP values <70% of predicted were considered inspiratory muscle weakness[27].

b) Maximum or symptom-limited cardiopulmonary exercise testing: the CPET associated with ergometry system was performed, aiming to assess the functional capacity of the athletes before and after the VMT. And also to identify the presence of electrocardiographic and hemodynamics changes induced by exercise that could contraindicate their participation in the study. CPET was performed using the ramp-type protocol on a treadmill (Inbramed, Porto Alegre, Brazil). Initially, patients spent three minutes at rest standing on the mat; then, the warm-up period started for three minutes, walking at a speed of 5 km/h and without inclination. After this stage, the physical exercise protocol was started with 1km/h increments in speed every minute, and the inclination maintained at 1% (throughout the test) until physical exhaustion - that is, the volunteer's inability to perform the load imposed by the treadmill. The ergometry system controlled the load distribution. Finally, the post-test recovery period consisted of three minutes at submaximal speed (3 km/h) without inclination, followed by two minutes of rest sitting after the load was interrupted.

Ventilatory and metabolic variables and HR were captured and recorded throughout the test period, as described below. Peripheral oxygen saturation SpO2 (Onyx 9500®) and ECG electrocardiogram (Wincardio USB) in leads MC5, DII, DIII, modified AVR, aVL, and aVF and from

V1 to V6 were continuously monitored throughout the experimental procedure. Blood pressure was checked at specific times in the protocol, taking care to avoid interference in the collection of variables. The tests were conducted by a team of researchers composed of physiotherapists and doctors, who were attentive to the signs and symptoms of inadequate response to exercise. Ventilatory and metabolic variables were obtained using a computerized system of ergospirometric analysis (VO_{2000} - Portable Medical Graphics Corporation®). The tidal volume was obtained through a high-flow Pitot pneumotachometer, connected to the device system and attached to a face mask - selected according to the volunteer's face size, to be appropriately adjusted, avoiding air leaks. After the mask placement period, a few minutes waited until the volunteers' ventilation remained stable. The equipment provided the values of O_2, CO_2, pulmonary ventilation (E), and Heart Rate (HR), in real-time.

Experimental procedure

The research was carried out in an air-conditioned laboratory with a temperature between 22ºC and 24ºC and relative humidity between 50% and 60% in the same period of the day (between 8 a.m. and 12 p.m.). The volunteers were familiarized with the experimental environment and with the researchers. For the day before and on the day of the test, each volunteer was instructed to avoid consumption of stimulating drinks, not to perform physical activity 24 hours before the tests, to have light meals, and to have an adequate night's sleep (at least 8 hours).

Statistical analysis

The data were analyzed using the SPSS® version 13.0 statistical program and submitted to the normality test (Shapiro-Wilk test) and homogeneity test (Levene test). According to the distribution of the variables, the measures of central tendency and dispersion used were mean and standard deviation (parametric). Pearson's correlation tests were performed for the MIP and VO_2peak indices, in which the classification was defined as 0-0.1 trivial; 0.1-0.3 small; 0.3-0.5 moderate; 0.5-0.7 strong; 0.7-0.9 very strong; and 0.9-1 perfect.[25] Statistical analyses were performed using the *SigmaPlot 11.0 for Windons* program, adopting a statistical significance of $p < 0.05$.

RESULTS

Sixteen volunteer professional soccer players were recruited and trained regularly in their club (five times a week with games often on weekends). Table 1 presents data such as age, anthropometric characteristics and shows the data extracted from the software connected to the gas analyzer used during the CPET of the volunteers, in which VO_2peak 44.30 ± 5.9 ml/kg/min was one of the main variables of interest for this study. The data obtained from inspiratory muscle strength through MIP was 120.7 ± 16.9 cmH_2O, and VO_2peak was 44.30 ± 5.9 ml/kg/min. In figure 1, the correlation between the MIP and the VO_2peak peak of the athletes was inversely proportional.

Table 1. General characteristics of subjects

Sample	N=16
Age (years)	26 ± 4,35
Height (cm)	163 ± 0,08
Body Mass (kg)	63,5 ± 7,45
BMI (kg/m^2)	23,8 ± 3
Skinfolds sites	
Triceps (mm)	13,4 ± 3,7
Supra-iliac (mm)	16,5 ± 5,7
Thigh (mm)	18,0 ± 5,9
Fat percentage	19,7 ± 4,6
Cardiopulmonary Testing	
Rest	
VO2 (ml/kg/min)	
VO2 (l/min)	
1st ventilatory threshold	
Load (km/h)	9,4 ± 1,5
Time (s)	598,7 ± 78,5
VO_2 (ml/kg/min)	32,3 ± 5,8
VO_2 (l/min)	2,0 ± 0,4
Peak	
Load (km/h)	14,6 ± 1,4
Time (s)	894,4 ± 90,7
VO_2 (ml/kg/min)	45,4 ± 7,3
VO_2 (l/min)	2,9 ± 0,4
BORG (0 to10)	3 ± 2,12

Data were expressed as mean and standard deviation.
BMI=body mass index; VO_2=oxygen consumption.

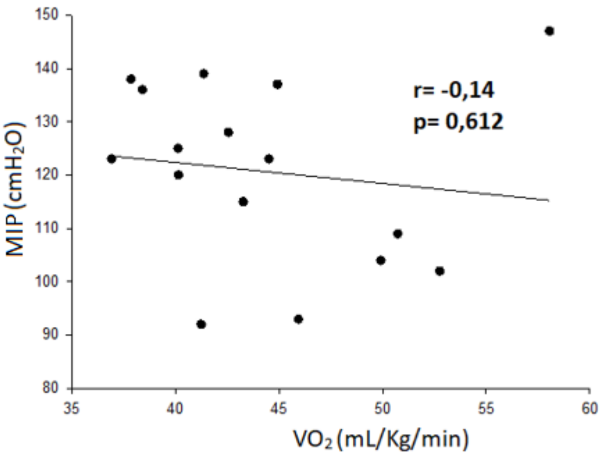

Figure 1: Pearson's correlation between peak oxygen consumption (VO2 peak) and maximum inspiratory pressure (MIP).

DISCUSSION

The main findings of the study revealed that the volunteers of professional soccer athletes had a VO_2peak inversely proportional to MIP. Additionally, it appears that this group had a low VO_2peak for professional athletes, but this was also observed in other work with soccer athletes[28].

Concerning the lung function of the athletes, none of them presented rates compatible with obstructive or restrictive disease, which does not influence the measurement and the result of the inspiratory muscle strength caused by these limitations. In addition, the volunteers were familiarized with the evaluation procedures of the ventilatory part before the final measurement.

Archiza et al.,[28] also found that the VO2 max of two groups of women (age from 20.2 ± 2.0 to 22.0 ± 3.9 years) professional soccer athletes was also apparently low in the two groups studied (38.8 ± 2.9 and 40.8 ± 4.2), respectively.

Naso et al.,[29] found in this study that respiratory variables related to lung function and inspiratory muscle strength correlate with functional variables in patients with heart failure (HF). MIP correlated with the six-minute walk test (6MWT) (r = 0.543 and p<0.001), with functional capacity (FC) (r = -0.566 and p<0.001) and with the score of the functional capacity domain of the quality of life questionnaire, Short Form Health Survey (SF-36) (r = 0.459 and p = 0.002). The same occurs with FVC and the 6MWT variables (r = 0.501 and p = 0.001), FC (r = -0.477 and p = 0.001) and SF-36 (r = 0.314 and p= 0.043). The FEV_1 correlated with the 6MWT (r = 0.514 and p <0.001) and with the FC (r = -0.383 and p = 0.012).

Tong et al.,[30] analyzed the influence of the CORE muscles (CM) on the performance of recreational long-distance runners, and this study shows interesting numbers because they are non-athletes. They did not verify the correlation between MIP (-151.3 ± 18.2 cmH_2O) and a high VO_2 (65.0 ± 4.7ml/kg/min.). In this study, the authors demonstrated that the intense run to exhaustion induces fatigue in the CM in endurance runners.

The occurrence of CM fatigue during running exercise can be partially attributed to the increased respiratory effort induced by exercise. Besides, the reduction in CM function with fatigue in runners can limit their ability to perform an intense run. Although they have directly demonstrated the limitations of CM function in the performance of endurance runners, current findings describing the occurrence of CM fatigue during intense running and its negative influence on runners' endurance capacity provide a strong justification for the essential role of training this musculature for a possible improvement in the performance of runners. Also, there is evidence available of the dual role of inspiratory muscles in breathing and central stabilization during intense running. The present study suggests that VMT incorporated into a specific core training regime potentially increases the effectiveness of central training in a practical way to deal with the challenge faced during intense exercise.

Gonzales and Williams[31] previously analyzed the volunteers' MIP and VO_2max, then studied the effects of performing a training session with 80% of the maximum workload on the cycle ergometer on the MIP. As a result, there was a decrease in MIP in the post-exercise period. The fact that draws attention in this study was that men and women had a very similar MIP and without statistical difference and men, as is already widespread in the literature, show a higher VO_2 than women. This finding reinforces our study in the sense that MIP has no correlation with VO_2.

Da Silva et al..[32] studied 27 girls (age: 13.1 ± 1.01 years and BMI 17.65 ± 3.11kg/m^2) distributed in 2 different groups, where 14 were volleyball athletes (GA), and 13 were sedentary (GS). MIP, MEP, and VO_2 estimated using the Margaria formula for time trial racing on the 1600m track were collected and analyzed. When MEP data were correlated with the estimated VO_2 max, in GA, a correlation was observed between these variables. This may have occurred due to the possible synergism between the abdominal muscles and the diaphragm during inspiration. In this phase of ventilation, the abdominal muscles are tensioned in order to generate an apposition zone, improving respiratory mechanics during inspiration, possibly increasing the supply of O_2 to the tissues and consequently increasing the individual's aerobic capacity (VO_2 max). However, when correlating MIP with VO_2 max estimated in GA, there was no correlation between them. This may have occurred because the diaphragm did not increase its muscle strength. This muscle probably had only an increase in muscular endurance, which was not enough to directly influence the increase in aerobic capacity (VO_2 max).

STUDY LIMITATIONS

We must consider that the VO_2 data were analyzed in the peak condition of the exercise and not in the maximum consumption since not all the criteria recommended in the literature were verified to affirm the VO_2 max. Another point worth mentioning is the number of professional soccer athletes per team who received the same training conditions. This makes the sample appear smaller than necessary for a reliable sample calculation.

CONCLUSION

According to the findings of this study, there seems to be an inversely proportional correlation between MIP and VO2peak for these professional soccer players, which leads us to believe that inspiratory muscle strength does not seem to influence VO2peak significantly. It is believed, therefore, that their functional capacity is independent of the maximum inspiratory strength, which may be attributed to the other systems that participate in metabolism and, consequently, in physical exercise.

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