Comparative study of the oxygen consumption and anaerobic threshold in a progressive exertion test in professional soccer and indoor soccer athletes

Ernesto Cesar Pinto Leal Junior[1], Fabiano de Barros Souza[2], Márcio Magini[3] and Rodrigo Álvaro Brandão Lopes Martins[4]

ABSTRACT

Oxygen consumption ($\dot{V}O_2$) has been very useful for the functional evaluation of athletes. Ergospirometry is a non-invasive procedure used to evaluate the physical performance or the functional ability of an individual, connecting the analysis of the inspired gases with the respiratory variables. This evaluation method is extremely important to sports, since it brings significant contribution in the verification of indices of cardiorespiratory aptitude, which is the case f the maximal oxygen consumption ($\dot{V}O_{2\,max}$) and the anaerobic threshold (AT). The present study had as objective to compare oxygen consumption and anaerobic threshold in professional soccer and indoor soccer athletes in a progressive test. 31 male individuals voluntarily participated in the test, being: 19 professional soccer athletes and 12 professional indoor soccer athletes. The athletes were submitted to a progressive cardiorespiratory evaluation protocol through the ergospirometric method, and the results were analyzed concerning their statistical difference through the t-Student test ($p < 0,05$). The average $\dot{V}O_{2\,peak}$ indices between the two groups did not present statistically significant difference ($p > 0,05$); however, there was statistically difference between the two groups concerning the anaerobic threshold (AT) ($p < 0,05$). Based on the results obtained in our study we concluded that even practicing sports with different characteristics, the athletes from both groups have similar indices of oxygen consumption. Nevertheless, the anaerobic threshold between the two groups did not present the same similarity, suggesting higher predominance of anaerobic metabolism during exercise in the indoor soccer athletes.

Keywords: Comparative analysis. Exertion physiology. Ergospirometry. $\dot{V}O_2$. Aerobic ability.

INTRODUCTION

Maximal oxygen consumption ($\dot{V}O_{2\,max.}$) may be defined as the highest volume of oxygen by time unit which an individual can hold, breathing atmospheric air during the exercise. It is reached when the maximal indices of cardiac debt and oxygen peripheral extraction are also reached, not surpassing even with increase in the muscular work load[(1)].

$\dot{V}O_{2\,max.}$ has been considered one of the parameters of great importance as performance predictor, since the human capacity to perform long and medium duration exercises depends mainly on the aerobic metabolism. Thus, it is a widely applied index in order to classify functional cardiorespiratory capacity, especially in athletes[(2-3)].

The anaerobic threshold is the transition of the aerobic to the anaerobic threshold; it is also an index that satisfactorily reflects the physical capacity, being applied both in clinical practice and in the evaluation and training of athletes[(4-5)].

The anaerobic threshold which when exclusively characterized concerning respiratory exchanges receives the name of 'ventilatory threshold', may be defined as the effort intensity above which the lactic acid production surpasses its own removal, causing hyperventilation[(6)].

Ergospirometry is a non-invasive procedure, used in order to evaluate physical performance or functional capacity of an individual, connecting exhaled gases analysis, respiratory variables and oxymetry[(7)].

Such method has been useful in the determination of factors connected with performance predicting factors, identification of exercise intolerance, metabolic transition determinants, clinical and therapeutic evaluation of several pathologies, exercise intensity prescription, respiratory and cardiovascular efficiency indices and energetic cost[(2,8)].

Several studies were conducted with the aim to evaluate physical conditioning of soccer athletes. Nonetheless, studies with the same aim are scarce involving indoor soccer athletes.

Once the two modalities are similar in their sportive gestures, with great discrepancy concerning the physical dimensions in which they are practiced, though, one may wonder about what would be the similarities and differences found in the respiratory variables and in the metabolism of their practitioners.

The present study had the aim to evaluate the physical conditioning of soccer and indoor soccer athletes, as well as to compare the Oxygen Consumption ($\dot{V}O_2$) and the Anaerobic Threshold (AT) of these athletes' groups.

METHODOLOGY

31 male athletes, divided in two distinct groups were studied:

Soccer Group: consisted of 19 Professional Soccer Athletes from the Esporte Clube Taubaté Team, with mean age of 24,3 years (± 2,3), mean height of 178,8 cm (± 6,3) and mean body mass of 75,1 kg (± 7,5).

1. Mestre em Engenharia Biomédica. Doutorando em Ciências Cardiovasculares (UFRGS). Fisioterapeuta. Docente da Disciplina de Fisioterapia Desportiva do Centro Universitário La Salle (UNILASALLE), Canoas, RS. Docente da Disciplina de Monitoramento da Funcionalidade do Movimento Humano na Adolescência da Universidade de Caxias do Sul (UCS), Pesquisador do Laboratório do Movimento Humano (LMH) da Universidade de Caxias do Sul (UCS), Caxias do Sul, RS.
2. Mestre em Engenharia Biomédica. Educador Físico, Laboratório de Avaliação do Esforço Físico – LAEF, Universidade do Vale do Paraíba (UNIVAP), São José dos Campos, SP.
3. Doutor em Ciências. Físico, Laboratório de Matemática Aplicada, Instituto de Pesquisa e Desenvolvimento – IP&D, Universidade do Vale do Paraíba (UNIVAP), São José dos Campos, SP.
4. Doutor em Biologia Celular e Molecular, Biólogo, Laboratório de Farmacologia e Fototerapia da Inflamação, Departamento de Farmacologia, Instituto de Ciências Biomédicas, Universidade de São Paulo (USP), São Paulo, SP.

Received in 1/11/05. Final version received in 5/6/06. Approved in 24/8/06.

Correspondence to: Ernesto Cesar Pinto Leal Junior, Prof. MSc., FT, Rua Ernesto Alves, 1.919, apto. 74, Centro – 95020-360 – Caxias do Sul, RS. E-mail: ecplealj@ucs.br

Indoor Soccer Group: consisted of 12 Indoor Soccer Professional athletes from the Assem/FADENP Team of São José dos Campos, with mean age of 20,9 years (± 2,7), mean height of 176,0 cm (± 6,0) and mean body mass of 69,9 kg (± 5,9).

The individuals who fulfilled the following inclusion criteria participated in the study: a) do not present pneumopathy history in the last 12 months; b) do not present cardiopathy; c) perform training with minimum frequency of 5 times a week and 4 daily hours.

The study was submitted and approved by the Ethics and Research Committee (CEP) of the Vale do Paraíba University – UNIVAP. The individuals were informed on the study and a consent form was applied, according to the resolution 196/96 from the CNS.

The used material was namely: a Micromed Digital Electrocardiographer for the registration and analysis of the ECG during effort; a treadmill brand name Inbrasport, model Super ATL; a VO 2000 gases analyzer brand name Graphics, connected to a microcomputer, with the Elite software produced by Micromed; nasal clip; disposable electrodes; disposable shaving blades; disposable emery boards and alcohol at 70º.

The tests were conducted in the pre-season of the two studied groups in the Laboratory of Physical Effort Evaluation – LAEF, in the Health Sciences School – FCS of the Vale do Paraíba University – UNIVAP.

The tests were conducted in a controlled environment, at a temperature of 24ºC, and with Relative Air Humidity of 60%.

The evaluation protocol used was the progressive effort one, with constant inclination of 3%, and initial velocity of 4,0 km/h. There was a velocity increase of 1,0 km/h at every test minute until the fourth minute. After the fourth minute, the velocity increase was also of 1,0 km/h, occurring at every 2 (two) minutes of the test, though.

The duration of the tests was determined by the athlete's exhaustion. When he reached it, he signaled to the evaluator, who hence started the recovery phase with initial velocity of 5,0 km/h. There was a decrease of 1,0 km/h after the first minute kept until the end of the recovery, determined by the stabilization of the athlete's Cardiac Frequency.

The obtained data were then compared with the groups through their arithmetic mean, and later analyzed concerning their statistical difference through the non-paired t-Student test, with significance index of $p < 0,05$.

RESULTS

In the studied group of professional Soccer athletes, the mean $\dot{V}O_{2\ peak}$ was 4,20 l/min (± 0,31) in absolute indices and 54,8 ml/kg/min (± 4,02) in indices concerning the body mass; the mean Respiratory Anaerobic Threshold of the group occurred with an oxygen consumption of 3,46 l/min (± 0,35), with 14 minutes of test (± 1,67).

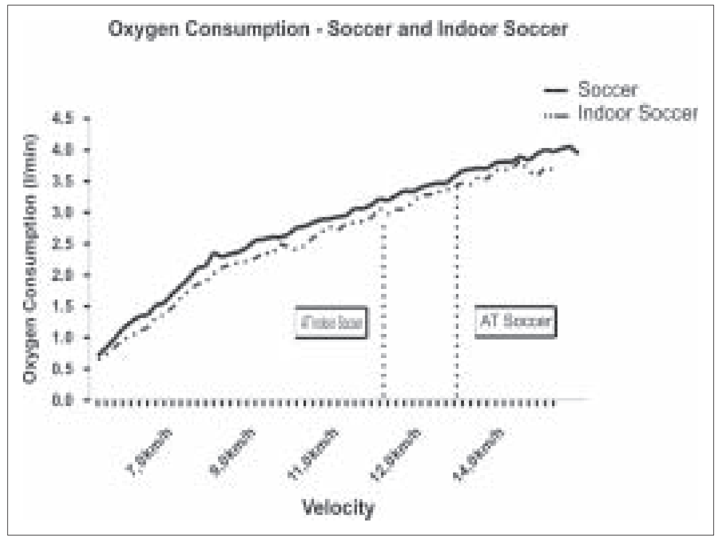
In the Indoor Soccer professional athletes, the mean $\dot{V}O_{2\ peak}$ was 3,89 l/min (± 0,43) in absolute indices and 55,7 ml/kg/min (± 3,70) in indices concerning the body mass; the mean Respiratory Anaerobic Threshold of the group occurred with an oxygen consumption of 2,97 l/min (± 0,44), with 11 minutes and 40 seconds of test (± 1,33) (table 1).

TABLE 1
Peak oxygen consumption and anaerobic threshold – soccer and indoor soccer groups

	Soccer	Indoor soccer	Statistical significance
$\dot{V}O_{2\ pico}$ (l/min)	4,20 (± 0,31)	3,89 (± 0,43)	$p > 0,05$
Anaerobic threshold (l/min)	3,46 (± 0,35)	2,97 (± 0,44)	$p < 0,05$*

* Statistically significant.

The mean curves of the Oxygen Consumption ($\dot{V}O_2$) and Anaerobic Threshold (AT) obtained in the two studied groups follow for better visualization of the data.



Graph 1 – *Oxygen consumption ($\dot{V}O_2$) of the two studied groups*

DISCUSSION

The peak Oxygen Consumption ($\dot{V}O_{2\ peak}$) obtained indices between the two studied groups: Soccer – 4,20 l/min in absolute indices and 54,8 ml/kg/min in indices concerning body mass; Indoor Soccer – 3,89 l/min (± 0,43) in absolute indices and 55,7 ml/kg/min (± 3,70) in indices concerning body mass, did not present statistically significant difference ($p > 0,05$).

Our data are close to the ones by Diaz (2003)[9], who conducted a study whose aim was to examine the trends of the cardiovascular and metabolic variables in 248 professional elite soccer players in a period of 27 years (1973-2000). The maximal oxygen consumption indices were 54 ml/kg/min in the 80's decade and 57 ml/kg/min in the 90's decade.

Al-Hazzaa *et al.* (2001)[10], conducted a cardiorespiratory evaluation with 23 players from the Saudi soccer team, where the cardiorespiratory parameters were evaluated with the ergospirometric method of open circuit, and the mean $\dot{V}O_{2\ max}$, absolute and concerning body mass indices obtained were respectively 4,16 l/min and 56,8 ml/kg/min, being these indices similar to the ones from our study. Moreover, according to the author, the $\dot{V}O_{2\ max}$ concerning body mass were lower than the indices reported in the literature according to the modality; however, such fact is explained due to the conduction of the tests being occurred in the pre-season.

Nonetheless, these indices are different from the ones found by Tumilty (1993)[11], where the soccer athletes have an average of maximal oxygen consumption of 60 ml/kg/min.

The indices of our study also differ from the ones obtained by Raven *et al.* (1976)[12], who conducted a study with the aim to evaluate a professional soccer team from the American league (NASL) concerning their physiological function. Eighteen players were evaluated concerning their cardiorespiratory function; exercise endurance and body composition, besides having their motor abilities measured at the end of the season. The maximal oxygen consumption ($\dot{V}O_{2\ max.}$) was of 58,4 ml/kg/min.

With the aim to compare the maximal oxygen consumption ($\dot{V}O_{2\ max.}$) in a field test specific to soccer and a conventional spirometric test, Kemi *et al.* (2003)[13] obtained similar indices of $\dot{V}O_{2\ max.}$ between the specific tests performed on field (5,0 l/min) and the spirometry in laboratory (5,1 l/min), differently from the results found in our study.

Our results are also different from the ones obtained by Casajus (2001)[14], in a Spanish professional soccer team with 15 athletes at the beginning and the end of the season. Concerning the maximal oxygen consumption, the author observed that there was no significant difference between the tests conducted at the beginning of the season (65,5 ml/kg/min) and the end of it (66,4 ml/kg/min).

Chin *et al.* (1992)[15], reported an oxygen consumption of 59,1 ml/kg/min in 24 professional soccer athletes from Hong Kong. These results were also different from the ones obtained in our study.

Our indices also differ from the ones from Silva *et al.* (1999)[16], who evaluated 18 professional soccer players through a maximal test on treadmill, using a scaled and continuous protocol and obtaining $\dot{V}O_{2\ peak}$ of 63,75 ml/kg/min (± 4,93).

The studied Indoor Soccer group reached the Anaerobic threshold (AT) in a time shorter in relation to the Soccer group studied, being this difference statistically significant ($p < 0,05$), even having the two studied groups similar indices of $\dot{V}O_2$. Such fact could suggest a greater aerobic predominance in Soccer when compared with Indoor Soccer[17].

However, the Indoor Soccer athletes remained longer in anaerobic exercise comparing to the Soccer athletes group, which could be explained by the better anaerobic conditioning of these athletes and by a smaller local vascular compression played by the muscles during the activity. The compression is determined by an optimization of the motor units recruiting in the anaerobic metabolism, caused by the adaptation to the modality training[18-19]. Such fact would facilitate the removal of the lactic acid through the circulatory way and consequently decrease the second source of CO_2 production which occurs above the anaerobic threshold, called non-metabolic CO_2 (resulting from the lactate buffering, which occurs in higher exercise levels)[3,20].

Another fact that could explain the longer presence of the Indoor Soccer athletes in the anaerobic exercise would be the "running savings" mechanism, in which the individual has the energetic use optimized. It would occur due to the kind of training to which these athletes are submitted, which is similar to a training with intervals[19,21-22].

CONCLUSION

We were able to conclude through the analysis of the obtained results that the athletes evaluated in the two groups have aerobic capacity coherent to the one reported in the literature for athletes in pre-season.

The two groups are similar in absolute and relative indices in the peak Oxygen Consumption indices; however, the Soccer athletes reached the Anaerobic Threshold later compared with the Indoor Soccer athletes.

Nevertheless, the Indoor Soccer athletes despite reaching the Anaerobic Threshold earlier, remained in anaerobic metabolism for longer than the Soccer athletes studied, which suggests an anaerobic activity predominance in Indoor Soccer compared with Soccer and consequently, a better adaptation on the side of these athletes to the anaerobic exercise, as well as a better adaptation of the Soccer athletes to the aerobic exercise.

Further studies are needed in order to mathematically analyze the behavior of the studied curves, as well as the influence of the Anaerobic Threshold in their behavior, so that the shown differences in the present study are elucidated.

All the authors declared there is not any potential conflict of interests regarding this article.

REFERENCES

1. Taylor HL, Buskirk E, Henschel A. Maximal oxygen intake as an objective measure of cardiorespiratory performance. J Appl Physiol. 1955;8:73-80.
2. Silva PRS, Romano A, Yazbek Jr P, Cordeiro JR, Battistella LR. Ergoespirometria computadorizada ou calorimetria indireta: um método não invasivo de crescente valorização na avaliação cardiorrespiratória ao exercício. Rev Bras Med Esporte. 1998;4:147-58.
3. Barros Neto TL, Tebexreni AS, Tambeiro VL. Aplicações práticas da ergoespirometria no atleta. Rev Soc Cardiol Estado de São Paulo. 2001;11:695-705.
4. Barros Neto TL, Russo AK, Da Silva AC, Picarro IC, Griggio MA, Tarasantchi J. Potassium-induced ventilatory reflexes originating from the dog hindlimb during rest and passive exercise. Braz J Med Biol Res. 1981;14:285-90.
5. Hollmann W. Historical remarks on the development of the aerobic-anaerobic threshold up to 1966. Int J Sports Med. 1985;6:109-16.
6. Wassermann K, McIlroy MB. Detecting the threshold of anaerobic metabolism in cardiac patients during exercise. Am J Cardiol. 1964;14:844-52.
7. Serra S. Considerações sobre ergoespirometria. Arq Bras Cardiol. 1997;68:301-4.
8. Denis C, Dozmois D, Lacour JR. Endurance training, $\dot{V}O_2$ max., and OBLA: a longitudinal study of two different groups. Int J Sports Med. 1984;5:167-73.
9. Diaz FJ. Changes of physical and functional characteristics in soccer players. Rev Invest Clin. 2003;55:528-34.
10. Al-Hazzaa HM, Almuzaini KS, Al-Refaee SA, Sulaiman MA, Dafterdar MY, Al-Ghamedi A, et al. Aerobic and anaerobic power characteristics of Saudi elite soccer players. J Sports Med Phys Fitness. 2001;41:54-61.
11. Tumilty D. Physiological characteristics of elite soccer players. Sports Med. 1993; 16:80-96.
12. Raven PB, Gettman LR, Pollock ML, Cooper KH. A physiological evaluation of professional soccer players. Br J Sports Med. 1976;10:209-16.
13. Kemi OJ, Hoff J, Engen LC, Helgerud J, Wisloff U. Soccer specific testing of maximal oxygen uptake. J Sports Med Phys Fitness. 2003;43:139-44.
14. Casajus JA. Seasonal variation in fitness variables in professional soccer players. J Sports Med Phys Fitness. 2001;41:463-9.
15. Chin MK, Lo YS, Li CT, So CH. Physiological profiles of Hong Kong elite soccer players. Br J Sports Med. 1992;26:262-6.
16. Silva PRS, Romano A, Teixeira AAA, Visconti AM, Roxo CDMN, Machado GS, et al. A importância do limiar anaeróbico e do consumo máximo de oxigênio ($\dot{V}O_2$ máx.) em jogadores de futebol. Rev Bras Med Esporte. 1999;5:225-32.
17. McArdle WD, Katch FI, Katch VL. Fundamentos de fisiologia do exercício. 2nd ed. Rio de Janeiro: Guanabara Koogan, 2002.
18. Behm DG, Sale DG. Velocity specificity of resistance training. Sports Med. 1993; 15:374-88.
19. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. Sports Med. 2005;35:501-36.
20. Beaver WL, Wasserman K, Whipp BJ. On-line computer analysis and breath-by-breath graphical display of exercise function tests. J Appl Physiol. 1973;34:128-32.
21. Helgerud J, Engen LC, Wisloff U, Hoff J. Aerobic endurance training improves soccer performance. Med Sci Sports Exerc. 2001;33:1923-31.
22. Chamari K, Hachana Y, Kouach F, Jeddi R, Moussa-Chamari I, Wisloff U. Endurance training and testing with the ball in young elite soccer players. Br J Sports Med. 2005;39:24-8.