Comparison between invasive and non-invasive methods for the determination of the aerobic capacity of professional soccer players

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ABSTRACT

The anaerobic threshold (AT) may be determined by protocols that use fixed blood lactate concentration (OBLA – onset of blood lactate accumulation) and others that apply individualized procedures as the lactate minimum test (LACmin). The measuring of the aerobic capacity from AT demands the use of sophisticated equipment and high cost per athlete, which makes it limited. The 12-minutes Cooper test is applied as an alternative way. The main objective of the present study was to compare the exercise intensity of a 12-minute Cooper test with the velocities of AT determined by protocol adapted from Tegtbur test (Lac_{minat}) and OBLA in professionals soccer players. Sixteen athletes from the A3-São Paulo State Soccer league participated in this study. Each athlete was available in the three tests with a minimum and maximal interval of 48 and 72 hours, respectively. The results show that the intensities obtained in the Cooper test were different from the OBLA velocities (15.09 ± 0.94 and 14.28 ± 1.02, respectively) but were significantly correlated. Cooper and OBLA were not correlated with Lac_{minat}, but the velocities were similar to this protocol test. Thus, from regression analysis between Cooper and OBLA values, it was possible to determinate a correction equation that allows, through a non-invasive test (Cooper), obtaining the velocity corresponding to OBLA.

INTRODUCTION

The performance of a soccer player depends on a set of physical, technical, tactical and psychological characteristics that should be developed by specialized professionals. In the last years, much attention has been given to the development of the physical capacity of athletes, and in some cases, searching to supply deficiencies from the technical side.

The aerobic capacity stands out among the capacities used by a soccer player, which plays important role not only during the game, but also during the recovery period of athletes. Thus, with the objective of personalizing the training evaluation and prescription, many sports professionals have used physical evaluation invasive and non-invasive methods as instruments of practical applicability able to evaluate and to quantify the aerobic capacity of athletes.

There are some indexes that require invasive procedures for their measurement that are responsible for the evaluation and quantification of the aerobic capacity and allow specialized soccer professionals to follow up the sportive training. Among these, the lactacidemia response used to determine the Aerobic Threshold during

exercise is maybe the most accurate way to measure the aerobic capacity, once it presents corroborated sensibility to physical training, besides serving as predictor of the aerobic performance[1,2].

The Anaerobic Threshold (AT) is a parameter of aerobic fitness that was originally used to verify the aerobic capacity of cardiac patients[3]. Later, this clinical procedure became routine in large medical centers[4]. From the sportive point of view, the AT obtained through lactacidemia has been used in the prescription of exercise intensities for trainings[5], what has called the attention of exercise physiology researchers[6], who search to define protocols more and more applicable to the evaluation of the sportive yielding. The AT has been emphasized in the sportive training area, especially due to the fast adjustment of this parameter in relation to the training modifications and to the low correlation found between the quantification of the maximum oxygen intake ($\dot{V}O_2max$) and the prediction of aerobic performance in competitions[7,8]. Moreover, this is a more reliable method in relation to the ecologic validity of the test and that presents lower operational cost when compared to the $\dot{V}O_2max$. Despite being invasive, both the volume of blood collected (25 µl per sample) and the utilization of simple hygiene and asepsis procedures exclude any health risk from the lactacidemia test of appraisers and appraised, what usually leads to the acceptance from ethics research committees[2].

In relation to the protocols used to measure the intensity corresponding to the Anaerobic Threshold (iAT), there are protocols that use fixed blood lactate concentration and those that use variable concentrations in individualized protocols.

The gold standard protocol for the determination of iAT is the maximal lactate steady-state[9] (MLSS) that involves the performance of continuous physical activity with constant and random intensity during approximately 30 minutes with blood samples collection (25 µl) each 5 minutes. The appraised performs 4-6 sessions of different intensities with minimum intervals of 24 hours. After each session, the lactacidemia x time of exercise curve is plotted and the iAT is found in the maximum lactate concentration, where there is no increase equal or greater than 1 mmol/L[10,11] or 0.2-0.5 mmol/L[12,13] from the tenth to the thirtieth minute of exercise. Despite being a very accurate method, it becomes unfeasible in the sportive environment due to the high operational cost and to the long time spent by the athlete to perform the evaluations.

The OBLA[14] uses incremental loads with sufficient intervals for the collections of blood samples between loads. At the end of the test, a lactate blood concentration x load intensity graphic is plotted through interpolation, generally linear or exponential, and the iAT corresponding to 4 mmol/L is determined.

Tegtbur et al.[15] proposed an interesting methodology to identify the iAT, which consists of the initial execution of two consecutive anaerobic efforts (2 x 200 m or 300 + 200 m), determining a great elevation on the lactate blood concentration. After an inter-

val (8 min), a test with increasing intensities with runs of 800 m starts. With the performance of the first loads, the decrease on the lactate is observed up to the attainment of a minimum value (Lacmin) from which a new increase on the substrate concentration starts. This minimum value corresponds to the maximum intensity where a dynamic balance between production and removal of lactate in blood is observed.

The iAT identification, regardless the protocol used, basically allows conducting the performance prediction in events with characteristics predominantly aerobic, and prescribes and follows the long-term effects of the sportive training.

Although widely used by high-level sportive teams that many times have an exercise physiologist among the technical staff, the aerobic capacity measurement through AT by means of the methods mentioned requires the availability of sophisticated equipments besides the high operational cost per athlete, making its utilization limited. As alternative, one of the most employed non-invasive tests in the sportive environment is the 12-minute test proposed by Cooper that consists of running the longest distance as possible within this time interval.

OBJECTIVE

The objective of this study was to compare the exercise intensity obtained through the 12-min Cooper test with intensities corresponding to the AT obtained through the protocol adapted from Tegtbur et al.[15] (Lac_{minat}) and through the OBLA (4 mmol/L) in professional soccer players.

MATERIAL AND METHODS

Participants

Sixteen male soccer players from the A3-São Paulo State Soccer league, who were competing in the State of São Paulo Cup during the second semester of 2003 participated in this study. The athletes and technical staff were previously informed in relation to procedures to be employed and signed a free and cleared consent term previously approved by the Ethics Research Committee of the Biosciences Institute – São Paulo State University "Júlio de Mesquita Filho", campus of Rio Claro. Age and biometric characteristics of participants are described in table 1.

TABLE 1
Age and biometric characteristics of stature, weight, body mass index (BMI) and fat percentage of 16 athletes from the A3-Sao Paulo State Soccer league

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/cm²)	Fat%
Average	24	177.5	73.5	23.36	10.3
SD	2.1	6.0	6.9	2.13	3.9

Determination of velocities (km.h-1) in Cooper, Lac_{minat} and OBLA tests

The tests were performed in official running track and the analyses of blood samples were carried out in the Biodynamic Laboratory – São Paulo State University "Júlio de Mesquita Filho", campus of Rio Claro. Each athlete was evaluated in the three protocols with minimum interval of 48 hours and maximum interval of 72 hours. A random sequence was adopted for the performance of tests and the subjects performed no familiarization exercises with the experimental protocol. Before the beginning of protocols, the athletes performed a 10-minute warm up exercise followed by passive interruption of 5 minutes with stretching with the objective of preparing the athlete for the performance of the test.

For the determination of the intensity (km.h-1) corresponding to the 12-min Cooper test, the athletes ran during 12 minutes and the distance was recorded with the objective of calculating the average velocity (km.h-1) of each individual.

The intensity (km.h-1) corresponding to the Lac_{minat} was determined based on the performance of 5 maximum efforts of 30 meters with 1 min of interval between each repetition for the hyperlactacidemia induction. After the performance of the 5th effort of 30 meters, 25 µl of arterial blood were collected from the earlobe at the 1st, 3rd and 5th recovery minutes. From the 6th minute on, the athletes started the progressive test composed of 4 submaximal efforts of 800 meters with intensities corresponding to 13.8; 15.7; 17.1 and 18 km.h-1, which were controlled by sound stimulus each 100 meters. Between series of 800 meters, 45-second intervals were given for the blood collection. The iAT was considered as the running velocity corresponding to the lowest blood lactate concentration obtained through the derivative zero of the second-degree polynomial equation of the lactacidemia vs. running velocity curve.

In the determination of the intensity (km.h-1) corresponding to OBLA, the athletes were submitted to 4 submaximal efforts of 800 meters with intensities corresponding to 13.8; 15.7; 17.1 and 18.0 km.h-1, which were controlled by sound stimulus each 100 meters. Between series of 800 meters, 45-second intervals were given for the blood collection. The iAT was considered as the running velocity corresponding to the blood lactate concentration of 4 mmol/L, being obtained through exponential interpolation of the lactacidemia vs. velocity curve.

Unlike the determination of intensities corresponding to the Cooper and OBLA tests in which all athletes participated, in the Lac_{minat} test, only 8 athletes participated. This occurred because 2 athletes were injured during the performance of the 5 submaximal efforts and the rest of them were saved, once they were recovering from bruises.

Blood collection and analysis

25 µl of arterial blood were collected from the earlobe using heparinized and calibrated glass capillaries. The blood collected was placed in Eppendorf tubes (1.5 mL) containing 50 µl of sodium fluoride (NaF – 1%) for later determination of the blood lactate concentration in Electrochemical Lactimeter Yellow Spring Instruments (YSI), model 1500 Sport. The lactate concentration values were expressed as mmol/L.

Statistical analysis

According to the Shapiro-Wilk's W test, the set of data presented normal distribution and the homogeneity was corroborated through the Levine's test. Thus, the one-way ANOVA test was used followed by the post-hoc Newman-Keuls test, whenever necessary, with the objective of comparing the exercise intensities obtained in Cooper, Lac_{minat} and OBLA tests. The Pearson correlation analysis was applied between tests. All data were expressed as average ± standard deviation. The significance level of $p \leq 0.05$ was adopted for all analyses performed.

RESULTS

Figure 1 represents the comparison between exercise intensities (km.h-1) obtained in the non-invasive and invasive methods of aerobic capacity determination.

According to figure 1, it is possible verifying that the iAT determined through the Lac_{minat} test (15.11 ± 0.54 km.h-1) presented no significant difference with the iAT determined through OBLA (14.28 ± 1.02 km.h-1) neither with the velocity corresponding to the Cooper test (15.09 ± 0.94 km.h-1). The velocities determined through OBLA and Cooper test presented significant differences.
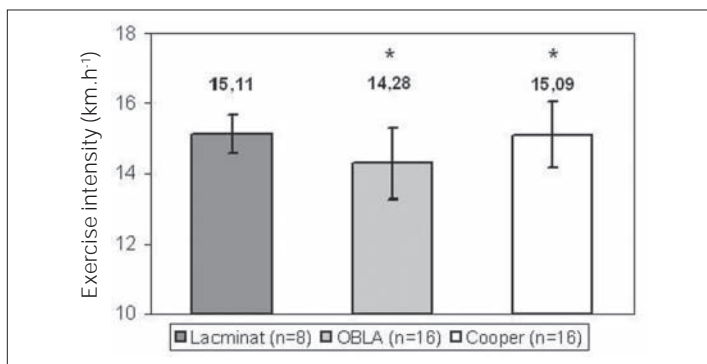
Fig. 1 – *Comparison between invasive and non-invasive methods to determine the aerobic capacity of athletes from the A3-São Paulo State Soccer league*
* Significant difference for p ≤ 0.05 after one-way ANOVA test followed by *post hoc* Newman-Keuls test

Table 2 shows the Pearson correlation analysis between intensities (km.h⁻¹) corresponding to non-invasive and invasive methods of aerobic capacity measurement. According to table 2, one could verify that only exercise intensities obtained through Cooper test and OBLA presented significant correlation (r = 0.76, p < 0.01).

TABLE 2
Pearson correlation values between exercise intensities (km.h⁻¹) obtained through Cooper test, Lac_minat and OBLA (4mmol/L) of athletes from the A3-São Paulo State Soccer league

	Cooper x Lac_minat (n = 8)	Cooper x OBLA (n = 16)	Lac_minat x OBLA (n = 8)
r	0.23	0.76*	0.35
p	0.58	0.01*	0.38

* Values significantly correlated for p ≤ 0.05

Figure 2 represents the regression analysis between exercise intensities corresponding to Cooper test and OBLA and provides a correction equation (Equation 1) capable to estimate AT determined through OBLA by means of the Cooper test.
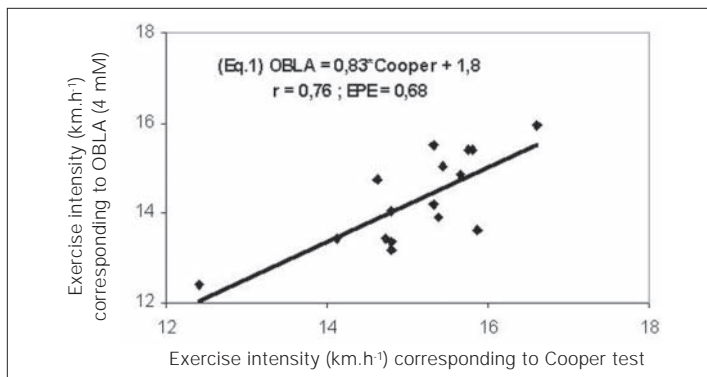

Fig. 2 – *Linear regression analysis between exercise intensity values (km.h⁻¹) corresponding to Cooper test and OBLA (4mmol/L) of 16 athletes from the A3-São Paulo State Soccer league*
Equation 1 (Eq. 1) allows the attainment of intensity (km.h⁻¹) corresponding to OBLA through the Cooper test.
ESE: Estimation Standard Error

DISCUSSION

The Lacmin was proposed with the objective of identifying the maximum exercise intensity in which a balance between the lactate production and removal rates occurs in blood. The Lacmin protocol may be divided into three stages: in the first stage the sub-

jects are submitted to supramaximal efforts in order to reach the hyperlactacidemia; the second stage is composed of a period, usually of 8 minutes, of passive recovery; and in the third stage the subjects perform an incremental test[10].

Many studies were conducted with the objective of verifying if alterations on one or more stages could affect the iAT determined through Lacmin. Smith *et al.*[16] analyzing trained cyclists, demonstrated that the determination of iAT through the Lacmin test does not depend on the protocol used in order to reach hyperlactacidemia. However, Carter *et al.*[10] verified that the variations on the initial intensities in the Lacmin incremental test affect the intensity corresponding to Lacmin.

According to Higino and Denadai[17], no significant difference between iAT determined through Lacmin was observed when the recovery time between supramaximal efforts and the beginning of the incremental test was increased. However, these authors did not observe blood lactate steady-state for none of the Lacmin intensities during continuous test and concluded that at the experimental conditions used, the Lacmin test did not seem to be valid for the identification of the maximal lactate steady-state intensity in most athletes.

Although the MLSS is considered as the gold standard method to evaluate the endurance capacity, there is a divergence in the specialized literature in relation to the definition of this phenomenon and its utilization protocol. For instance, Haverty *et al.*[13] defined the intensity corresponding to MLSS as the highest running velocity in which the blood lactate presented no elevation above 0.2 mmol/L between the tenth and the twentieth minutes of a 20-minutes test. However, this time period does not seem to be sufficient to consolidate the lactacidemia steady state[12]. Heck *et al.*[11] used MLSS as the maximum running velocity that produces an increase below 1 mmol/L during the last 20 minutes of a 25-minute test.

Jones and Dust[18] used 13 runners and did not observe significant differences between velocities (km.h⁻¹) obtained through Lacmin (14.9 ± 0.2) and through Lactate Threshold (15.1 ± 0.3), considered as the first inflection of the lactate vs. velocity curve. However, the Lacmin velocity was lower when compared with the OBLA velocity (16.1 ± 0.2) and the MLSS velocity (15.7 ± 0.2). The correlation between velocities determined through Lacmin and MLSS was lower (r = 0.61) than that obtained between velocities determined through MLSS and OBLA (r = 0.93). Moreover, the average velocity in the 8 km performance (16.0 ± 0.3) presented no significant difference in relation to velocities determined through MLSS and OBLA, but was significantly higher than velocity determined through Lacmin.

According to Simōes *et al.*[19], no significant difference was observed between velocity determined through Lacmin (17.11 ± 1.18) and that obtained through OBLA (17.33 ± 1.20) for 12 male runners.

Our results, therefore, are not in agreement with results found by Jones and Dust[18] and corroborate with findings of Simōes *et al.*[19], once we did not verify differences between exercise intensities determined through Lac_minat (15.11 ± 0.54) and those obtained through OBLA (14.28 ± 1.02 km.h⁻¹) either.

When studies conducted on the same topic are compared, we should be aware that different protocols are many times used for the determination of the same variable. Besides, when the same sportive modality is analyzed, the ecologic validity should be taken into consideration, in other words, if trainings and competitions take place in running tracks, the tests should be performed in the same environment rather than in laboratories.

In the studies mentioned above, the three protocols used to determine the velocity corresponding to Lacmin were distinct, but running was the exercise involved in all of them. From the three protocols mentioned, two of them were conducted in running track, while Jones and Dust[18] used the treadmill. We understand that

we have found distinct results, once we believe that the tests are protocol-dependent. In sports, it is important to define protocols capable to be replicated in order to represent reference data.

Our main objective was to verify differences between one non-invasive test and two invasive tests capable to measure the aerobic capacity. The determination of the intensity corresponding to the Anaerobic Threshold through two distinct tests occurred due to the difference between the tests' methodology. The OBLA uses the fixed concentration of 4 mmol/L to determine iAT, while the Lac_{minat} is an individualized procedure that uses variable blood lactate concentrations in order to define iAT. It is worth emphasizing that most Brazilian Soccer Professional Teams have no specialized labour, substructure or financial conditions to perform the measurement of the aerobic capacity of their athletes by means of methods that require the determination of AT through blood lactate response during exercise. Thus, the results found in the present study are quire relevant, once they serve as practical tool for the technical staff to estimate AT through a test of easy applicability and low operational cost, in other words, the Cooper test.

On the other hand, this study presents some limitations, for example, the number of athletes who participated in the Lac_{minat} test is lower than the number of athletes who participated in the Cooper tests and OBLA, the low correlation found between Cooper x Lac_{minat} (r = 0.23; p = 0.58) and Lac_{minat} x OBLA (r = 0.35; p = 0.38) may be explained due to the excessive variability of data within a small sample (n = 8).

According to data presented, one may determine a correction equation (Eq.1: OBLA = 0.83 * Cooper + 1.8; ESE = 0.68) that allows the attainment of the intensity corresponding to the AT determined through OBLA in professional soccer players by means of the Cooper test, serving as practical tool for teams that cannot afford determining AT through lactacidemia.

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

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