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9 authors, including:

Eduardo Fontes
Universidade Federal do Rio Grande do Norte

Verusca Najara de Carvalho Cunha
Universidade Católica de Brasília

Guilherme Morais Puga
Universidade Federal de Uberlândia (UFU)

Herbert G Simões
Universidade Católica de Brasília

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Individual anaerobic threshold prediction through 1 km and 3 km running performance in young soccer players

[1*]Dr Carmen Sílvia Grubert Campbell, PhD, [2]Mr Kaori Célia Sakuma, B Phys Ed, [1]Mr Rafael Rodrigues da Cunha, B Phys Ed, [3]Dr Sérgio Rodrigues Moreira, PhD, [2]Dr Eduardo Bodnariuc Fontes, PhD, [1]Dr Ricardo Moreno Lima, PhD, [1]Ms Verusca Najara de Carvalho Cunha, MSc, [1]Mr Guilherme Morais Puga, MSc, [1]Dr Herbert Gustavo Simões, PhD,

[1] Graduate Program on Physical Activity and Health, Catholic University of Brasilia – UCB, Brasília / DF, Brazil.
[2]Department of Sports Science, University of Campinas, Campinas/SP, Brazil.
[3]Federal University of Vale do São Francisco, Brazil

***Corresponding author. Address at the end of text.**

Abstract

Background: Individual anaerobic threshold (IAT) is a valid method to evaluate aerobic capacity. However, IAT determination requires blood analysis and thus is less accessible for coaches and athletes. **Type of study:** Predictive validation. **Purpose**: To verify the validity of IAT prediction through 1 km and 3 km running performance in male youth soccer players. **Methods:** Participants (n=20; 15.4 ± 1.2 years; 170.1 ± 1.5 cm; 58.9 ± 5.8 kg) were divided into 2 groups (G1 and G2) who underwent running tests to identify IAT and the mean velocity for 1 km and 3 km performance (Vm_{1km} Vm_{3km}). For IAT determination volunteers performed 8 X 800m at incremental intensities of 80-103% Vm_{3km}. **Results:** Linear regression between IAT and running performances (Vm_{1km} and Vm_{3km}) obtained from G1 participants yielded predictive equations ([IAT_p^{1km} = (1.0009 * Vm_{1km}) – 80.798] and [IAT_p^{3km} = (0.8517 * Vm_{3km}) + 4.5408]) that were applied in G2 for validation purposes. The running velocities corresponding to IAT (205.8 ± 18.8m.min^{-1}) and IAT predicted from 1km (IAT_p^{1km} = 207.8 ± 10.1m.min^{-1}) and 3km (IAT_p^{3km} = 204.8 ± 7.4m.min^{-1}) did not differ from each other. **Conclusions:** The proposed equations were considered valid and could be used on exercise evaluation and prescription for young soccer players with similar physiological characteristics in this study's participants. **Keywords:** exercise; lactate; threshold; equations; fitness; soccer; teenagers

***Dr Carmen Sílvia Grubert Campbell**
She is a teacher, adviser and researcher for the Graduate Program on Physical Education and Health at the Catholic University of Brasília, Brazil. Her current research involves the effects of the type and intensity of exercise on the blood pressure and cognitive performance of children.

Mr Kaori Célia Sakuma
Mr Sakuma has a Physical Education degree from the University of Mogi das Cruzes, Brazil.
Email: kaorisakuma@gmail.com

Mr Rafael Rodrigues da Cunha, MSc
Mr da Cunha has an undergraduate degree in Physical Education and a Master's degree in Physical Education from the Catholic University of Brasília. His major research focus is on the effects of resistance exercise on muscle structure and function.
Email: rafilsksdf@gmail.com

Dr Sérgio Rodrigues Moreira, PhD
Dr Moreira has degrees in Physical Education from the Catholic University of Brasília (2006/2009). His main research focus is on fitness, as related to the lactate threshold and resistance exercise for type 2 diabetes.
Email: serginhocapo@gmail.com

Dr Eduardo Bodnariuc Fontes, PhD
Dr Fontes' main research is related to fitness, canoeing, electromyography and critical speed.
Email: eduardobfontes@gmail.com

Professor Ricardo Moreno Lima, PhD
Professor Lima received his PhD in Physical Education from the University of Maryland (United States) with a scholarship from CAPES. He is a professor in the Faculty of Physical Education at the University of Brasília (UNB). His main research covers genetics as applied to exercise, resistance training, exercise evaluation, muscle phenotypes, cardiovascular phenotypes and aging.
Email: ricardomoreno@unb.br

Ms Verusca Najara de Carvalho Cunha, MSc
Ms Cunha is a PhD student and teacher assistant at the Catholic University of Brasília. Her main research interest is on functional assessment and the effects of exercise on blood glucose and GLUT4 translocation in transgenic ob/ob mice.
Email: najavrusk@gmail.com

Mr Guilherme Morais Puga, MSc
Mr Puga is a PhD student at Paulista State University, Brazil.
Email: gmpuga@gmail.com

Dr Herbert Gustavo Simões, PhD
Dr Simões' main interest is in physiology, particularly with regard to the lactate threshold, resistance exercise, blood glucose and lactate minimum.
Email: hgsimoes@gmail.com

Introduction

Soccer is one of the most popular sports in the world, with more than 265 million players[1,2]. Successful performance in this modality depends upon physical, tactical, and technical factors[2,3]. Although the players' neuromuscular performance is a determinant of success in a soccer match[4] and the aerobic contribution to soccer relies on the player's position, overall, the match has predominantly an endurance component[4-8]. Thus establishing simple methods to evaluate the aerobic capacity may provide a useful tool to monitor athletes' fitness and prescribe individualised training, mainly for young athletes.

Among methods to determine aerobic capacity, the individual anaerobic threshold (IAT) has been suggested as a valid protocol that considers the kinetics of blood lactate during incremental testing and post-exercise recovery[9-12]. Despite the ongoing debate on terminology and/or the physiological background, IAT identifies an exercise intensity associated to maximal lactate steady state[12,13], which is useful for exercise prescription. However, the IAT determination for training programmes might be difficult, particularly for team sports, such as soccer, since it is time-demanding and invasive procedures (e.g. blood sampling) are required.

In order to improve the practical application of the aerobic capacity evaluation, several studies have proposed straightforward and reliable methods to predict the anaerobic threshold [14,18]. However, only a few studies were performed using field conditions with non-invasive procedures[15-17,21]. Furthermore, indirect methods for aerobic capacity assessment (i.e. IAT and Maximal Lactate Steady State intensities) have been proposed mainly for adults in running[15], [23,24], swimming[25,26], and cycling[27-29]. In this regard, the IAT prediction through simple and reliable methods with low time and cost demands in youth soccer players would help to identify individualised and safe training intensities and thus improve athletes' performance during a match. However, to the best of these authors' knowledge, no previous studies have attempted to identify predictive equations for IAT in young soccer players. Therefore, the aim of this study was to verify the validity of predictive equations to estimate the IAT in young soccer players based on their 1 km and 3 km running performances.

Methods

Study design

Two groups of soccer players (G1 and G2) performed two time-trials (1 km and 3 km), and IAT tests on a running track. The data from mean velocity at each time-trial (Vm_{1km} and Vm_{3km}, respectively) and the velocity corresponding to IAT tests for G1 were applied to linear regressions. These procedures generated two predictive equations of IAT (IAT_p^{1km} and IAT_p^{3km}, respectively) that were applied on G2 in order to compare the direct and indirect IAT measures. All the tests were performed on different days 48- to 72 hours apart. Subjects were instructed to avoid the ingestion of alcohol or any substance containing caffeine and to abstain from vigorous exercise for at least 48 hours before the trials. In addition, they were asked to have their last meal approximately 2 hours before the tests and to keep the same ingestion pattern in each testing session. The trials were performed in the morning (09-10h00) in temperatures around 24-26 ºC and 50% humidity. These variables were similar to their normal training conditions.

Twenty young regional soccer players took part in this study. All the subjects were randomly divided into two groups: G1 (n = 10; 14.9 ± 0.9 yrs.; 60.4 ± 6.9 kg; 170 ± 1.0 cm) and G2 (n = 10; 15.1 ± 1.0 yrs.; 60.2 ± 5.2 kg; 169 ± 1.0 cm). The study procedures were explained to the subjects and their parents, who read and signed an informed consent. The study had been approved by the Human Research Ethics Committee from the University of Mogi das Cruzes, SP, Brazil.

Determination of IAT and predictive equations

The 1 km and 3 km time-trials were performed on an official 400 m track, on separate days and random order. Both time-trials performances were registered by a single chronometer (Hs 50W, CASIO, Tokyo, Japan) and the mean velocity ($m.min^{-1}$) was calculated ($Vm_{1Km,}$ $Vm_{3km,}$ respectively). Strong verbal encouragement was provided to the participants during the time-trials to extract their best performance. Each participant had at least 1-2 previous familiarisation trials, on separate days, before the official tests.

The IAT test consisted of seven to eight incremental bouts of 800 m at intensities based on % of Vm_{3km} that corresponded to 80, 82, 84, 87, 89, 92, 94 respectively and the final stage between 100 to 103% of the Vm_{3km} test. The test would be finalised earlier at any point due volitional fatigue (i.e. did not complete the aimed velocity). The choice of selected incremental intensities as % of previous middle distance performance was done accordingly to previous studies [14-17,24,30]. The running velocity in each stage was controlled through sonorous stimulus at each 100 m. One minute of rest between each bout was given in the incremental test for heart rate and blood samples collection. After the last bout, blood sampling was done every two min during the nine minutes of post-test recovery period[14,22] (Figure 1). Blood lactate results were plotted against increasing intensity over time and IAT was identified as the running velocity corresponding to the inflection point of the blood lactate curve according to previous studies [14,17, 21, 31].

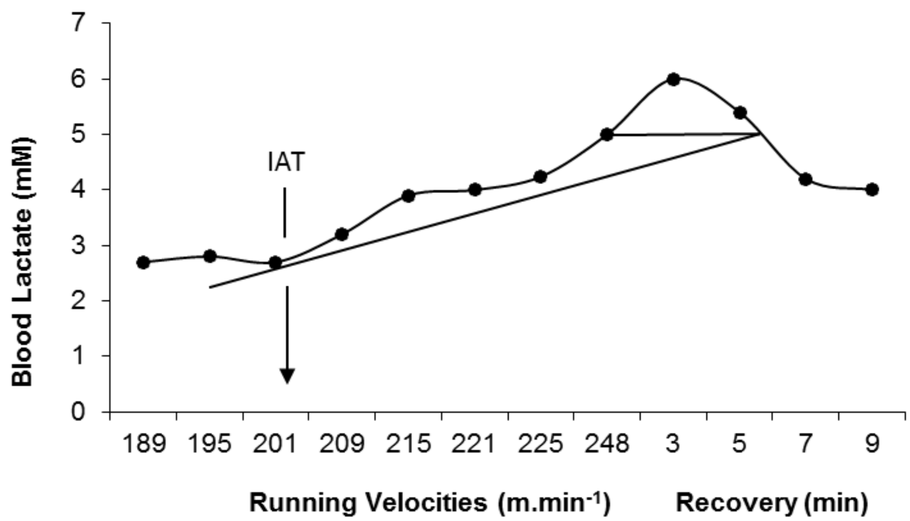

Figure 1: Individual Anaerobic Threshold (IAT) determination for a single participant

The predictive IAT equations were calculated through a linear regression between IAT and Vm_{1Km} (IAT_p^{1km}), and IAT and Vm_{3km} (IAT_p^{3km}) from G1 data (Figures 2 and 3).

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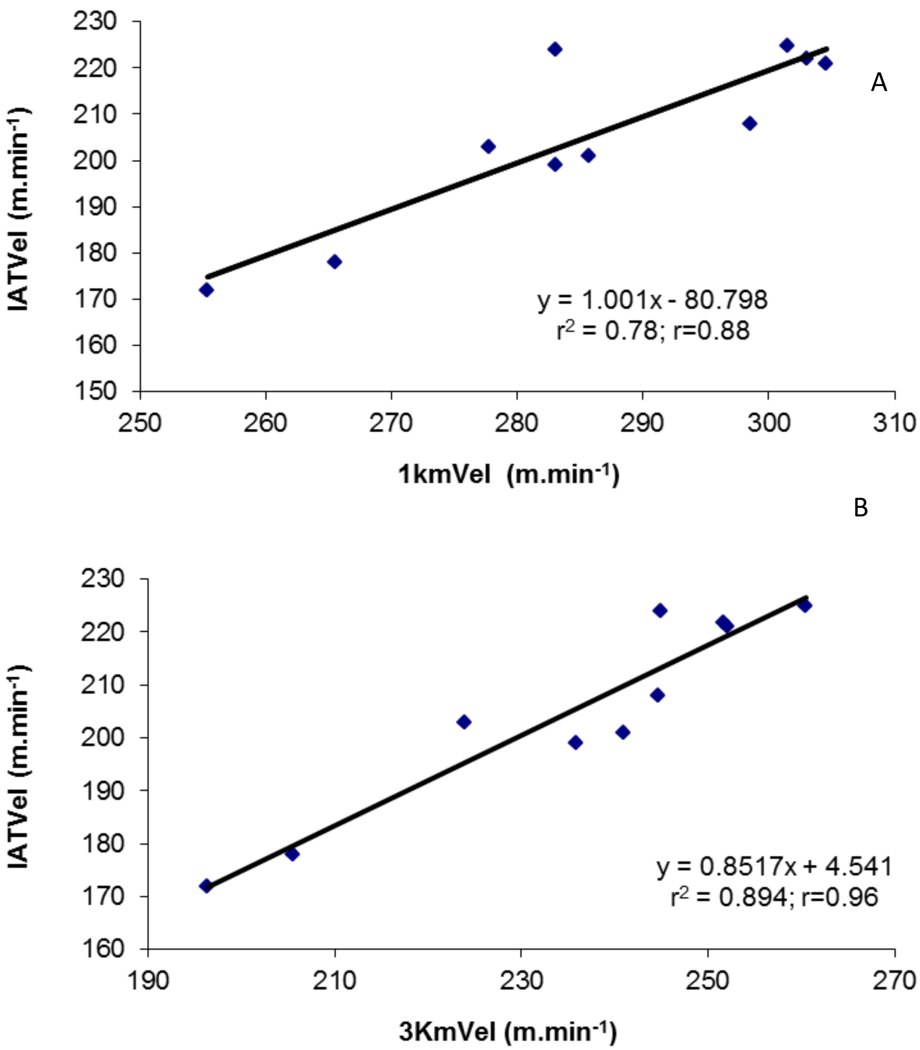

Figure 2: Linear regression between running velocities of 1 km time-trial and IAT (A) and between 3 km time-trial and IAT (B) for G1 (n=10)

Blood collection and heart rate measurements

Blood samples (25 µl) were taken from the ear lobe by means of calibrated capillary tubes, and stored in 1.5 ml Eppendorf microtubes containing 50 µL of NaF 1%. The lactate analyses were conducted by an electroenzimatic method (YSI 2300-S, Yellow Springs Instruments, Yellow Springs, OH, USA). Heart rate was measured through a Polar Sport Tester Monitor (Polar Inc. Finland).

Statistical analyses

Data are presented as mean and standard deviation. Independent *t* tests were applied to compare the G1 and G2 results. Repeated measures ANOVA with Tukey test as a post hoc were used to compare the results obtained through the two predictive equations and real IAT estimation for participants of G2. Pearson's product-moment correlation was used to verify the relationship between IAT and IAT_p^{1km}, as well as IAT and IAT_p^{3km} results. The limits of agreements between the velocities were analysed using the Bland and Altman procedure[32]. The significance level was set at $P < 0.05$.

Results

Mean time and running velocity from the 1 km and 3 km time-trials, as well as the IAT results determined from the G1 and G2, are shown in Table 1. No differences were observed between G1 and G2 for any of the examined variables. The relationship between the IAT velocity and running performances (Vm_{1km} and Vm_{3km}) from the G1 are shown in Figures 2 and 3 along with the predictive equations, respectively. High correlations were observed between IAT velocity and both 1km (r=0.88) and 3km (r=0.96) running performances for G1.

Table 1: Performance times (T1 km and T3 km), mean running velocity of the 1 and 3 km time-trial (Vm^{1km} and Vm^{3km}), individual anaerobic threshold (IAT), the relative velocity (%) in which IAT occurred (IATv-%Vm 1 and 3 km) and heart rate associated to IAT (HR IAT) for G1 and G2 (n = 20)

	T1km (min:s)	**T3km (min:s)**	**Vm^{1km} ($m.min^{-1}$)**	**Vm^{3km} ($m.min^{-1}$)**	**IATvel ($m.min^{-1}$)**	**IAT**vel **(%Vm1km)**	**IAT**vel **(%Vm3km)**	**HR IAT (bpm)**
G1 (n=10)	3:30 ±0:12	12:32 ±1:15	285.8 ±16.6	235.6 ±20.9	205.2 ±18.8	71.7 ±3.6	87.1 ±2.6	184.1 ±5.1
G2 (n=10)	3:28 ±0:07	12:31 ±0:18	288.4 ±10.1	235.2 ±8.7	205.8 ±11.7	71.4 ±3.0	87.5 ±2.2	184.5 ±5.9

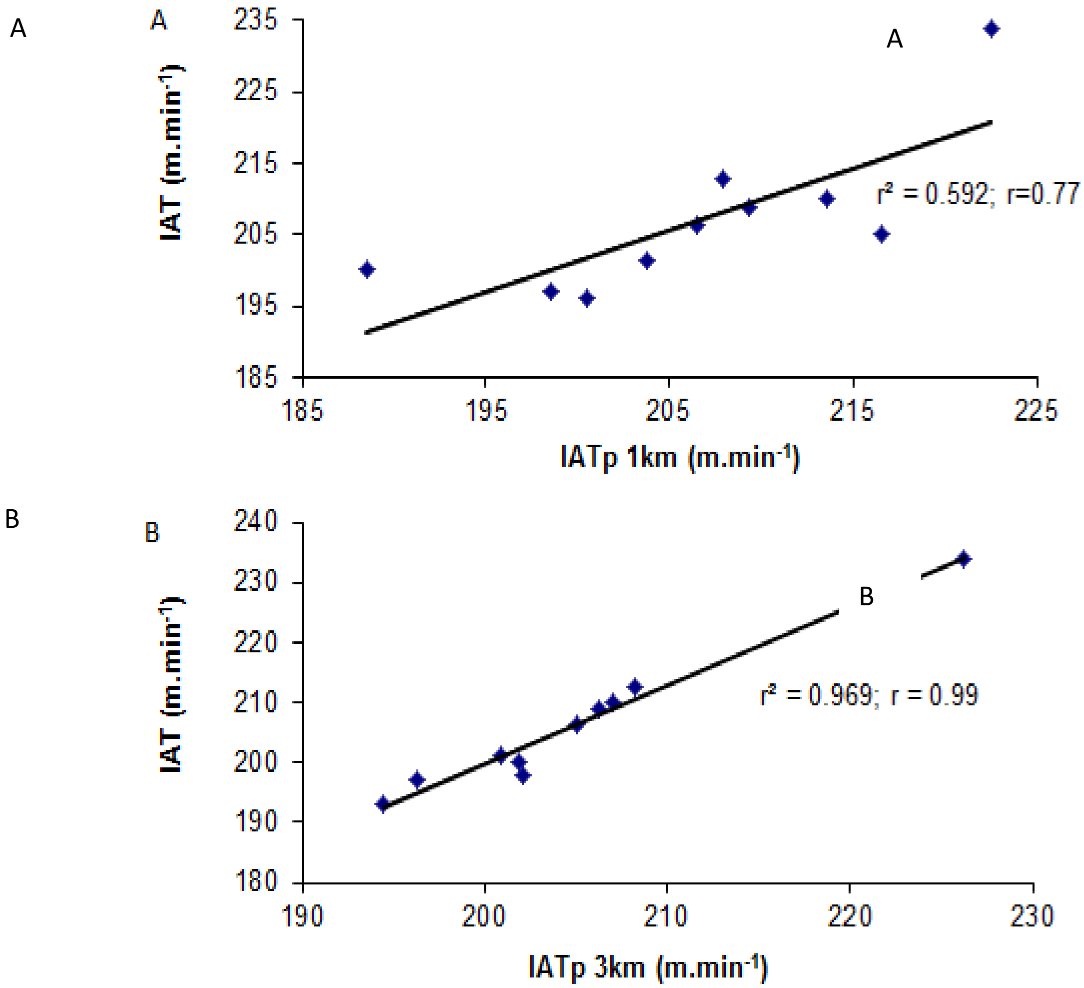

Figure 3: Relationship between IAT to IATp1km (A) and IATp3km (B) for G2 participants (n=10)

Table 2 shows the results for the IAT determined directly for G1 and G2, as well as the IAT_p^{1km} and IAT_p^{3km} predicted for G2.

Table 2: Individual anaerobic threshold velocity (IATvel) from G1 (n = 10) and G2 (n = 10), and the predicted IAT for G2 from 1 km and 3 km time-trials performances (IAT_p^{1km} and IAT_p^{3km}, respectively)

IATvel ($m.min^{-1}$) G1	**IATvel ($m.min^{-1}$) G2**	**IAT_p^{1km} ($m.min^{-1}$) G1**	**IAT_p^{3km} ($m.min^{-1}$) G2**
205.2 ± 18.8	205.8 ± 11.7	207.8 ± 10.1	204.8 ± 7.4

A significant correlation between IAT and IAT_p^{1km} (r = 0.77; $P < 0.05$) and between IAT and IAT_p^{3km} (r = 0.99; $P < 0.05$) for G1 was observed. The results of the Bland-Altman analysis (BIAS ±95%) Limit of Agreement (LoA) between the IAT and IAT_p^{1km} and between IAT and IAT_p^{3km} for G2 data are presented in Figures 4A and 4B.
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The bias was -2.0 ± 18.5 and 1.0 ± 10.9 $m.min^{-1}$ respectively, and the LoA ranged between 16.5 (+1.96 SD) and -20,5 (-1.96 SD) for the former, and 11.9 (+1.96 SD) and -9.9 (-1.96 SD) for the later. Both analyses showed good agreement between the variables

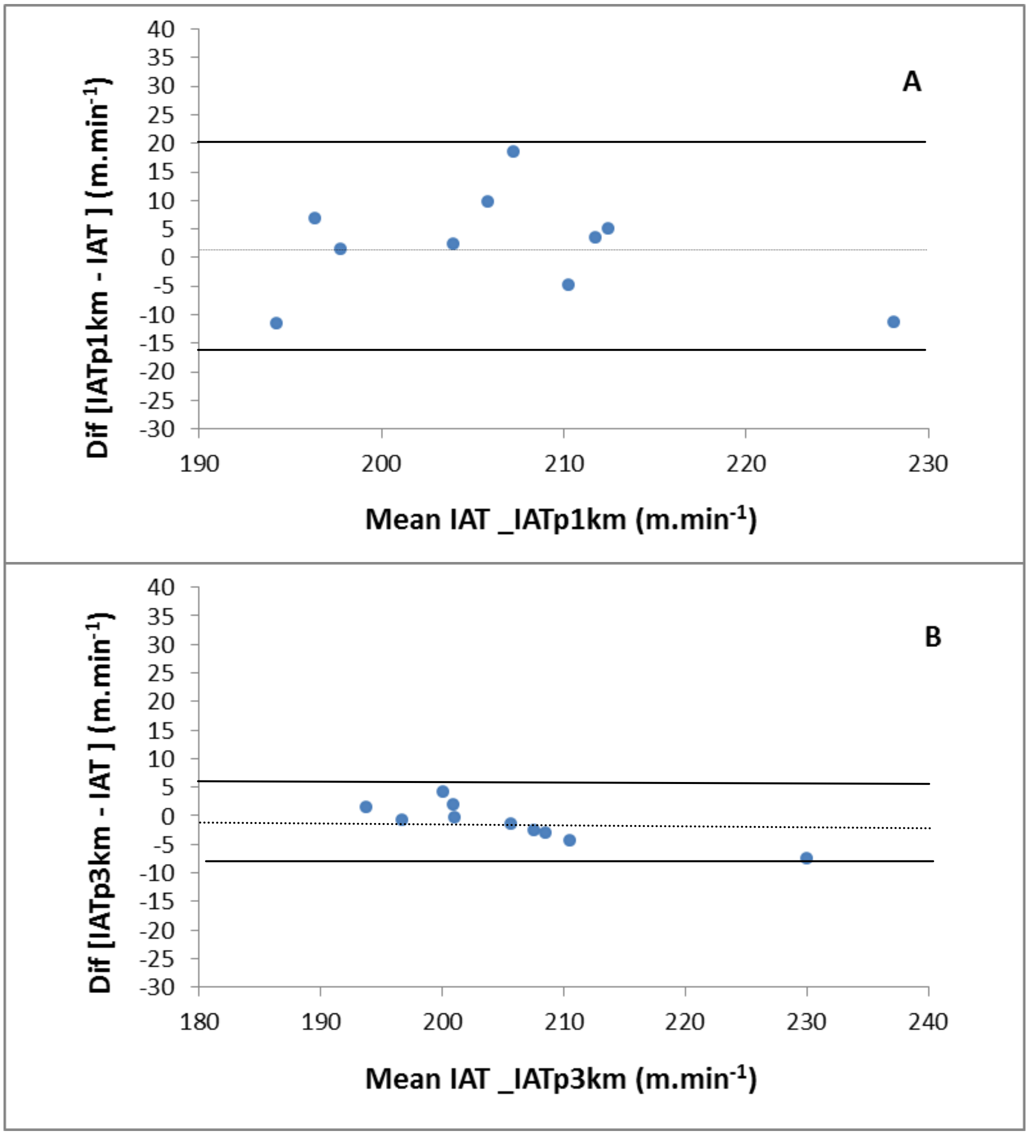

Figure 4: Bias ± 95% of LoA assessed by Bland-Altman analysis between IAT and IAT_p^{1km} *(A), and IAT and* IAT_p^{3km} *(B), for the cross validation group (G2)*

Discussion

The main findings of the present study were that the IAT can be estimated from predictive equations using the 1 km and 3 km running time-trials performances in young soccer players. The cross validation of proposed equations confirmed their validity on IAT prediction (Table 2 and Figure 4).

The IAT was initially proposed by Stegmann, Kindermann and Schnabel[11]. This procedure uses blood lactate responses during and after an incremental test (Figure 1), which identifies the individual responses of blood lactate kinetics for a given subject. The validity of this method was confirmed in studies with track and field athletes and recreationally active non-athletes[12,13,14,17,21]. Coen et al[12] demonstrated the reproducibility of the IAT on running under different field protocols and methods. Moreover, the IAT has been considered a reliable protocol that identifies exercise intensity in which a blood lactate steady state and the acid-base balance may be observed[13,14,16,20]. To the best of these authors' knowledge, the present study is the first to determine IAT in young soccer players as well as to propose predictive equations to estimate this aerobic parameter on a running track.

Several studies have shown the relationship between endurance capacity and exercise performance of different populations. Tanaka[22] verified a high correlation between the running velocity, corresponding to the lactate threshold, and the 5 min running performance in young subjects. Weltman et al[23] evidenced a high correlation between the fixed lactate concentrations of 2.0, 2.5 and 4.0 mM and the 3200 m running performance in women. Furthermore, Simões et al[31] analysing long-distance runners, also reported a significant correlation between the IAT and the 3 km time-trial performance ($r = 0.92$; $P < 0.05$). The findings were similar to this study's data when IAT was associated with the 3 km performance from G1 ($r = 0.96$; $P < 0.05$), but only a moderated correlation between IAT and 1 km time-trial performance was found ($r = 0.77$; $P < 0.05$). The Bland and Altman[32] plots confirmed an agreement between IAT and IAT_p^{1km} (Figure 4A), as well as IAT and IAT_p^{3km} parameters (Figure 4B) as determined for G2 participants. However, a better agreement between IAT and $IATp^{3km}$ was observed, and may be due the higher aerobic contribution for energy production during 3 km running in comparison to 1 km. In this way, in spite of our findings provided evidence that both equations (i.e. IAT_p^{1km} and IAT_p^{3km}) would be used, when applied in young soccer players with similar physiological characteristics to our participants, the IAT would be better predicted through 3 km time-trial performance. While the relationship between IAT and 1km time trial was only moderate; the IAT_p^{3km} presented a better agreement and higher correlation with the IAT when compared to the IAT_p^{1km}. So these data suggest that 3 km time-trial performance is more reliable than 1 km to predict IAT.

Middle distance performances have been used for aerobic capacity evaluation in previous studies. Simões et al[31] demonstrated that IAT of long-distance runners ranged between 91 and 93% of the mean velocity in 3 km time-trial. Swensen et al.[28] reported the maximal lactate steady state in cyclists being reached between 85 and 94% of the mean velocity at 5 km time trial. In the present study, the IAT was observed at ~71.4 and ~87.5% of mean velocity from 1 km and 3 km time trial respectively, evidencing the close association between middle-distance performance and IAT.

One limitation of the present study was that maximal lactate steady state was not determined in the subjects. However, previous studies[12,13,31] showed the reliability of the IAT to predict this parameter, suggesting that proposed predictive equations could identify running velocities that would be sustained over the long term without blood lactate accumulation. However, future studies should confirm this hypothesis.

In the present study, these authors evidenced that IAT may be accurately identified in field conditions (even directly or indirectly) for young soccer players. However, it was observed that IAT prediction in the 3 km performance was more reliable than 1 km performance. These results have practical applicability once the direct IAT determination is an invasive method and requires blood analysis, which is expensive and relies on trained expertise to perform the measurements. On the other hand, the predictive equations suggested in this study can be easily applied to several players at the same time and consequently are more applicable for coaches, trainers and players. More studies are needed to evaluate the use of the proposed equations for training purposes and to evaluate the sensibility of these equations to identify training-induced adaptations.

Practical applications

The predictive equations for 1 km and 3 km running performances were as follows:
[IAT_p^{1km} = (1.0009 * Vm1km) – 80.798]
[IAT_p^{3km} = (0.8517 * Vm3km) + 4.5408]
p.s. running velocities in $m.min^{-1}$

These equations enable coaches to evaluate and monitor soccer athletes over preparation period (i.e.. pre-season), since this reliable procedure is less time and cost demanding. Establishing individual and specific training intensities among the players may optimize the training sessions and improve performance. The results of the present study could be applied in several ways. For example, after a 1 km or 3 km performance test, the IAT velocity would be estimated (IAT_p^{1km} or IAT_p^{3km}) and then running training sessions could be prescribed on individual basis for young soccer players as follows:

- Moderate-intensity running: 30 to 35 minutes at a velocity below IAT_p (e.g. 90 to 95% IAT_p);
- Moderate to high-intensity running: 20 to 25 minutes at the IAT_p velocity or slightly above but not higher than 3% above IAT_p;
- High-intensity running: 10 to 15 minutes of exercise at a velocity ~ 3 to 5% above IAT_p.
- Alternatively, high-intensity running sessions, at a velocity approximately 10 to 15% above IAT_p could also be conducted to improve performance. In this situation, the utilization of 2 to 4 bouts of 4 to 5 minutes exercise with ~4 to 8 minutes rest intervals could be useful with the purpose of reaching VO_2max during exercise sessions.

Finally, for aerobic improvement, usually 3 to 5 aerobic training sessions per week are recommended, with only 1 to 2 sessions being done at intensity above IAT_p. These last high or very high-intensity exercise sessions can then be alternated with moderate-intensity exercise sessions (e.g. 5 to 10% below IAT_p).

Address for correspondence:

Dr Carmen Sílvia Grubert Campbell, Catholic University of Brasília, Graduate Program on Physical Activity and Health, QS07 LT 01 s/n EPCT Águas Claras G112, ZIP code 72.022-900 – Taguatinga – DF, Brazil
Tel.: +(55 61) 33569204/ 33569350
Email: campbellcsg@gmail.com

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