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ORIGINAL ARTICLE

Correlation between Hoff test performance, body composition and aerobic and anaerobic fitness in professional soccer players

Alessandro Moura Zagatto · Willian Eiji Miyagi · Gabriel Motta Pinheiro Brisola · Fabio Milioni · Adelino Sanchez Ramos da Silva · Paulo Roberto Pereira Santiago · Marcelo Papoti

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Abstract

Purpose The purpose of the study was to investigate a possible association between the distance covered in the Hoff test with parameters of maximal oxygen uptake ($\dot{V}O_{2MAX}$), anaerobic threshold, anaerobic fitness, and body composition of professional adult soccer players.

Methods Twenty-five professional soccer players (20 ± 3 years) participated in the study. On different days the athletes performed: a graded incremental exercise test in a laboratory to measure $\dot{V}O_{2MAX}$; a specific soccer field test called the Hoff test; a running anaerobic sprint test (RAST); an incremental test on an oval circuit to determine the velocity relative to anaerobic threshold (V_{AnT}) and an estimation of body composition.

Results The average $\dot{V}O_{2MAX}$ corresponded to 4.1 ± 0.1 L min^{-1} (54.1 ± 1.2 mL kg^{-1} min^{-1}). The average distance covered during the Hoff test was 1,442.4 ± 30.0 m. The distance covered during the Hoff test showed significant correlations with absolute and expressed in an appropriated scale $\dot{V}O_{2MAX}$ ($r = 0.44$, $p = 0.02$; $r = 0.42$, $p = 0.02$, respectively) while no significant differences were found with body composition, V_{AnT} and RAST variables.

Conclusions The present study demonstrated that the distance covered during the Hoff test has weak correlation with $\dot{V}O_{2MAX}$ determined in treadmill running, and no correlation with V_{AnT}, body composition and RAST outcomes, probably due to the non-specificity of the proposed tests when associated with the Hoff test.

Keywords Aerobic power · Anaerobic power · Soccer evaluation · Specificity · Anthropometry

A. M. Zagatto (✉)
Department of Physical Education, Sao Paulo State University (UNESP), Av Engenheiro Luiz Edmundo Carrijo Coube, Vargem Limpa, Bauru, SP CEP 17033360, Brazil
e-mail: azagatto@yahoo.com.br

W. E. Miyagi · G. M. P. Brisola · F. Milioni
Post-Graduate Program in Sciences Motricity, Bioscience Institute, Sao Paulo State University (UNESP), Rio Claro, SP, Brazil

A. S. R. da Silva · P. R. P. Santiago · M. Papoti
School of Physical Education and Sports of Ribeirão Preto, University of São Paulo (USP), Ribeirão Preto, SP, Brazil

Introduction

Soccer is a highly complex sport, and to play soccer at a competitive level, the athletes need a good level of aerobic and anaerobic fitness, strength and flexibility [1]. The aerobic fitness level (i.e., maximal oxygen uptake—$\dot{V}O_{2MAX}$) in professional soccer is closely related to the distance covered at high intensity by elite players during an official match [2], in addition the total distance covered (about 10–12 km) is performed at a relative intensity of 75 % of the $\dot{V}O_{2MAX}$ [2, 3, 5], resulting in an aerobic contribution of about 90 % of the total energy cost of the game [2, 3]. This high aerobic demand in soccer is necessary both to provide power in an endurance event as well as to provide quick recovery after a high-intensity activity (i.e., anaerobic effort) [3–5]. Furthermore, the development of soccer players' aerobic fitness can elevate technical performance and promote greater contact with the ball during the game [5].

Although the aerobic metabolism has the predominant energy pathway contribution during a soccer match, the determinant actions are characterized by high-intensity efforts, and are sustained by anaerobic pathways [2, 6, 7]. The contribution of the anaerobic system during a match has been evidenced by the high values of peak blood lactate ($\approx$10 mmol L^{-1}) [2], decrease of muscle pH ($\approx$6.8) [8], distance covered at high intensity (1.1 km covered at a speed above 18 km h^{-1}) [9] and the number of intense actions during the game (between 150 and 250) [8].

Due to the importance of the aerobic and anaerobic energy systems in soccer, a large number of tests have been used for monitoring and prescribing training during the competitive season [10]. Although many tests allow the successful determination of aerobic and anaerobic fitness, these do not often mimic the specific movements of soccer, therefore not reproducing faithfully the motor actions of the game, such as jumps, accelerations and decelerations, direction changes with and without controlling the ball [11], thereby resulting in a procedure with poor ecological validity.

Recently, the Hoff test has been proposed as a viable alternative for addressing some of the limitations described above for the evaluation of aerobic fitness in soccer [10, 12, 13]. Initially proposed by Hoff et al. [12] for aerobic training, in this protocol test, soccer players dribble a ball through the cones and hurdles that compose a field circuit. Kemi et al. [13], using this circuit as a soccer-specific aerobic evaluation with incremental velocities and a portable gas analyzer, demonstrated the validity for measuring $\dot{V}O_{2MAX}$.

Based on previous studies Chamari et al. [10] investigated the possibility of using the maximum distance in this test (i.e., 10 min maximum distance) as an easy way of measuring aerobic fitness and demonstrated that the Hoff test was significantly correlated with the $\dot{V}O_{2MAX}$ relative to body mass ($r = 0.68$, $p < 0.05$) in young European soccer players ($\approx$14 years); the same result found by Nassis et al. [14] in adult soccer players ($r = 0.49$, $p < 0.05$). The results of these studies [10, 14] show that the Hoff test could be used as an alternative method to estimate the $\dot{V}O_{2MAX}$ of soccer players in a protocol with greater proximity to the specifics of the sport.

Furthermore, Castagna et al. [15] showed a significant correlation between the distance covered in the Hoff test and the distance covered in sprints during a soccer match ($r = 0.70$, $p < 0.05$). However, in our recent study [16] no significant correlations between the values obtained in the Hoff test and the anaerobic threshold of young soccer players were observed, suggesting that further research on this subject is necessary.

For example, no study has associated the parameters from the Hoff test with variables which determine the success of the game, such as body composition [30] and anaerobic fitness [6]. Thus, the aim of the present study was to investigate possible associations between the distance covered in the Hoff test with parameters of aerobic and anaerobic fitness, and body composition of professional adult soccer players.

Materials and methods

Participants

The study included 25 professional players (age 20 ± 3 years, body mass 75.9 ± 1.6 kg, $\dot{V}O_{2MAX}$ 54.1 ± 1.2 mL kg^{-1} min^{-1}), belonging to a first division soccer team of the state of Mato Grosso do Sul, Brazil. These athletes had been engaged in regular training and competitions for at least 5 years and performed approximately 10 training sessions per week with an average duration of 2 h each. In the study only athletes who had no osteomyoarticular lesions and who were not taking anti-inflammatory drugs were included. The participants were informed about the risks and benefits of the procedures and participated in the tests only after signing a written informed consent. The experimental procedures used in the study, as well as the informed consent were approved by the Research Ethics Committee of the Sao Paulo State University (Protocol 54-210/2010).

Experimental procedures

Prior to the beginning of the tests, the body composition of the participants was measured. Following this, the participants underwent a maximal incremental test on a motorized treadmill (ProAction BH Fitness®, Las Palmas, Spain) to determine the $\dot{V}O_{2MAX}$ in a laboratory. From the second day, all tests were performed on a soccer field. On the second day, the participants performed a specific field test to determine the individual anaerobic threshold, and on the third day they underwent the running anaerobic sprint test (RAST) for the determination of anaerobic fitness. On the final day of evaluation, participants performed the Hoff test [12]. The Hoff circuit was incorporated into the daily warm-up for familiarization by the participants. All tests were separated by at least 24 h and performed at the beginning of the season, during the preparatory period.

Body composition

The total body weight was measured using a digital scale Tanita BF 683W® (Tanita, Tokyo, Japan). Body density was estimated using the method proposed by Guedes and Guedes [17] for young adults, using three skinfolds (i.e., triceps, suprailiac and abdominal) measured by a Lange® (Lange, Maryland, USA) skin folds compass. The percentage of body fat was estimated using the method proposed by Siri [18].

Graded exercise test for maximal oxygen uptake determination ($\dot{V}O_{2MAX}$)

The participants underwent a graded exercise test (GXT) on a motorized treadmill for the determination of $\dot{V}O_{2MAX}$. The initial intensity corresponded to 7.0 km h^{-1} and was increased by 1.5 km h^{-1} every 2 min, with treadmill inclination fixed at 1 %, until volitional exhaustion. Throughout the test, the heart rate (HR) was measured every 5 s by a Polar® (Polar, Kempele, Finland) heart rate monitor, while the oxygen consumption ($\dot{V}O_2$) was measured every three breaths using the gas analyzer VO2000® (Medgraphics, Minnesota, USA). The gas analyzer was calibrated before each test according to the manufacturer's recommendations. The $\dot{V}O_{2MAX}$ was assumed as the highest $\dot{V}O_2$ average obtained in the final 20 s of the exercise stage, when at least two of the follow criteria were met: (1) $\dot{V}O_2$ stabilization of the last two stages of exercise (range <2.1 mL kg^{-1} min^{-1}); (2) respiratory exchange ratio (RER) >1.1; (3) maximum HR (HR_{MAX}) >90 % of predicted maximum heart rate [19]. If two of the previously detailed criteria were not met, a new test was applied. The GXT was in accordance with Bentley et al. [19] and the $\dot{V}O_{2MAX}$ determination was adapted from Howley et al. [20].

The $\dot{V}O_{2MAX}$ was expressed in absolute values (L min^{-1}), relative to body mass (mL kg^{-1} min^{-1}) and at an appropriate scale (mL $kg^{-0.75}$ min^{-1}) [10, 12, 13, 20–24].

Individual anaerobic threshold determination (AnT)

To determine the velocity corresponding to AnT (V_{AnT}), a 400-m field track was marked with cones every 50 m. The participants underwent four 800-m submaximal efforts with intensities corresponding to 10.0, 12.0, 14.0 and 16.0 km h^{-1}, controlled by sound stimulus every 50 m. Between each effort, blood samples (25 µL) were collected from the earlobe using a calibrated and heparinized glass capillary, and stored in Eppendorf tubes containing 50 µL of sodium fluoride (NaF 1 %) for later analysis of blood lactate concentration [La^-] in an electrochemical lactimeter, YSI 1500 Sport (Yellow Spring Instruments, Ohio, USA). The HR and perceived exertion (RPE, Borg scale 6–20) were also measured according to the recommendations of Borg [25]. The points obtained from the relation of velocity versus [La^-] were fitted by exponential growth adjustment and the anaerobic threshold was assumed as the running velocity corresponding to a fixed [La^-] of 4 mmol L^{-1} [26].

Running anaerobic sprint test (RAST)

The RAST [27], which consists of six maximal 35 m all out sprints, interspaced by 10 s of passive recovery, was used for determination of anaerobic fitness. During the test, the running time was measured using a photocell system (CEFISE, São Paulo, Brazil), and prior to the start of the test, the participants were weighed, wearing clothes, to determine the total body weight and subsequent power calculation.

The power (P) of each sprint was obtained through the following equation:

$$P = \left(\mathrm{bw}/d^2\right)/t^3, \quad (1)$$

where bw is the body weight with clothes (kg) of each subject, d is the 35 m distance, and t is the time of each 35 m maximal effort [27].

Thus, the peak power (PP, the highest power value between the six efforts of 35 m) and mean power (MP, the mean power value between the six efforts of 35 m) were obtained. The same RAST variables were recorded relative to the athletes' body weight (i.e., PPR = PP/bw; MPR = MP/bw). The fatigue index [FI (%)] of the RAST was obtained through the following equation:

$$\mathrm{FI} = ((\mathrm{PP} - \mathrm{MinP}) \times 100)/\mathrm{PP}. \quad (2)$$

Hoff test

The Hoff test consisted of a maximal exercise with 10 min duration on a 290-m circuit, divided into three stages, comprising, respectively, the 49, 186 and 55 m distances. The entire circuit was performed with the participant controlling the ball. During the first stage the subjects covered 10 m controlling the ball in a straight line and forward dislocation, followed by 18 m of zig-zag dislocation within the cones placed every 2 m, simulating dribbling, ending in forward dislocation for 29 m, jumping three 30- to 35-cm-high hurdles every 7 m. For the second stage, after jumping the second hurdle, the participants performed a diagonal race to one cone placed 36 m away, and from that moment on, performed six extra diagonal dislocations in a path of 25 m each, giving a total of 186 m. During this stage, the participants completely circumvented the cones whilst controlling the ball. When arriving at the last cone, the third stage of the circuit was initiated and from that moment a 10-m distance was performed with a backwards race until the site marked by two cones. Subsequently, the athletes performed a forward race for 15 m, and finally, a 30-m distance to the end of the circuit (Fig. 1).

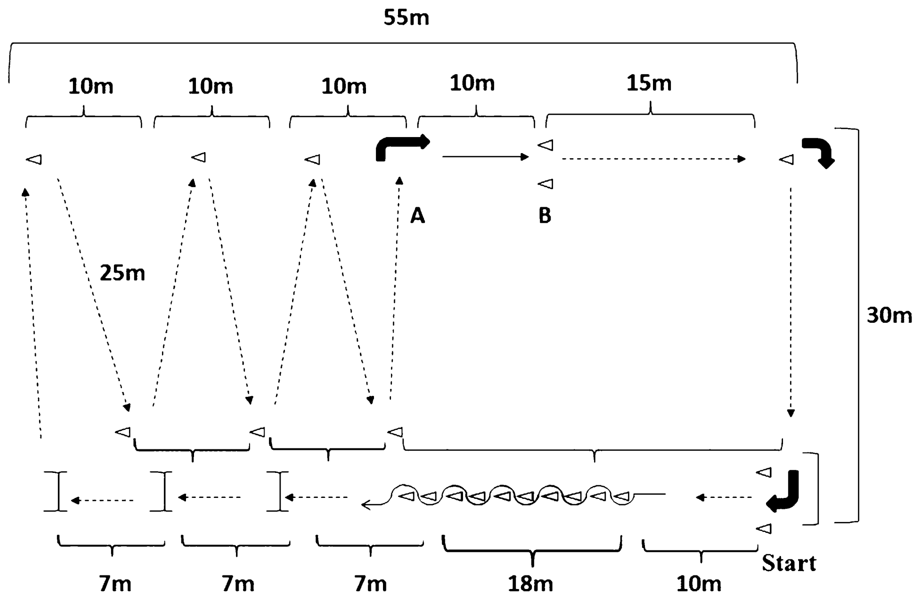

Fig. 1 Chart of Hoff test circuit. (- - -▶) Forward run. (——▶) Backward run. (◁◁◁) Dribble place. (⌶) 30–35 cm hurdles

Statistical analysis

Results are presented as mean ± standard error of the mean (SEM) and confidence interval of 95 % (95 % CI). Initially, the Shapiro–Wilk test was used to confirm the data normality. To verify the correlation between the results obtained in the Hoff test with the parameters used in the study (body composition, indices of aerobic and anaerobic fitness) the Pearson correlation test was used. The correlations were distributed according to r values, which were classified as very weak (0.0–0.2), weak (0.2–0.4), moderate (0.4–0.7), strong (0.7–0.9) and very strong (0.9–1.0) [28]. In all cases a significance level of 5 % ($p < 0.05$) was assumed. All data were analyzed using the software package SPSS Statistics 18.0 (SPSS Inc., Chicago, IL, USA).

Results

The total distance covered and the average velocity corresponding to the Hoff test were 1,442.4 ± 30.0 m (95 % CI 1,382.4–1,510.2 m) and 8.6 ± 0.4 km h^{-1} (95 % CI 95 % 8.3–9.0 km h^{-1}), respectively.

The values of total body weight, lean weight, body fat and percentage body fat mass of the participants are shown in Table 1. No correlations between the values of total body weight, lean weight, body fat and percentage body fat mass and the distance covered in the Hoff test were found (Table 1).

The mean PP, MP and FI (RAST variables) are presented in Table 2. No significant correlations were founded between the distance covered in the Hoff test and the RAST variables (Table 2).

The $\dot{V}O_{2MAX}$ (absolute, relative to body mass in appropriate scale and relative to body mass), maximal heart rate (HR_{MAX}), velocity relative to AnT (V_{AnT}), heart rate relative to AnT (HR_{AnT}), rate of perceived exertion relative to AnT (RPE_{AnT}) and respective coefficients of Pearson's

Table 1 Total body, lean weight, body fat, percentage of body fat mass and correlation coefficients with performance in the Hoff test

$N = 25$	Mean ± SEM (CI 95 %)	Hoff test distance covered (r)
Total body weight (kg)	75.9 ± 1.6 (72.5–79.1)	0.07
Lean mass (kg)	66.7 ± 1.2 (64.1–69.2)	0.16
Body fat mass (kg)	9.2 ± 0.8 (7.4–10.9)	−0.01
Percentage of body fat mass (%)	11.8 ± 1.0 (9.8–13.8)	0.18

Table 2 RAST variables and coefficient correlation with performance in the Hoff test

$N = 25$	Mean ± SEM (CI 95 %)	Hoff test distance covered (r)
PP (W)	919.4 ± 31.1 (853.9–984.8)	−0.09
PP (W kg^{-1})	12.1 ± 0.3 (11.4–12.7)	0.17
MP (W)	753.1 ± 23.5 (703.6–802.5)	−0.04
MP (W kg^{-1})	9.9 ± 0.2 (9.4–10.4)	−0.12
FI (%)	34.4 ± 1.1 (31.9–36.7)	−0.32

PP peak power, *MP* mean power, *FI* index of fatigue

Table 3 Physiological variables and coefficient correlation with performance in the Hoff test

$N = 25$	Mean ± SEM (CI 95 %)	Hoff test distance covered (r)
$\dot{V}O_{2MAX}$ (L min^{-1})	4.1 ± 0.1 (3.8–4.2)	0.44*
$\dot{V}O_{2MAX}$ (mL $kg^{-0.75}$ min^{-1})	158.1 ± 2.9 (152.0–164.2)	0.42*
$\dot{V}O_{2MAX}$ (mL kg^{-1} min^{-1})	54.1 ± 1.2 (51.7–56.5)	0.33
HR_{MAX} (bpm)	188.2 ± 1.8 (184.5–191.8)	0.39
V_{AnT} (km h^{-1})	13.0 ± 0.3 (12.4–13.5)	0.40
HR_{AnT} (bpm)	173.8 ± 2.0 (169.3–178.1)	0.30
RPE_{AnT}	10.3 ± 0.4 (9.2–11.3)	0.32

$\dot{V}O_{2MAX}$ maximal oxygen uptake, HR_{MAX} maximal heart rate, V_{AnT} anaerobic threshold velocity, HR_{AnT} heart rate corresponding to anaerobic threshold, RPE_{AnT} perceived exertion corresponding to anaerobic threshold

* $p < 0.05$

correlations with the distance covered in the Hoff test are shown in Table 3.

Significant correlations were found between the absolute $\dot{V}O_{2MAX}$ ($r = 0.44$) and $\dot{V}O_{2MAX}$ relative to body mass in an appropriate scale ($r = 0.42$) and the distance covered in the Hoff test (Fig. 2).

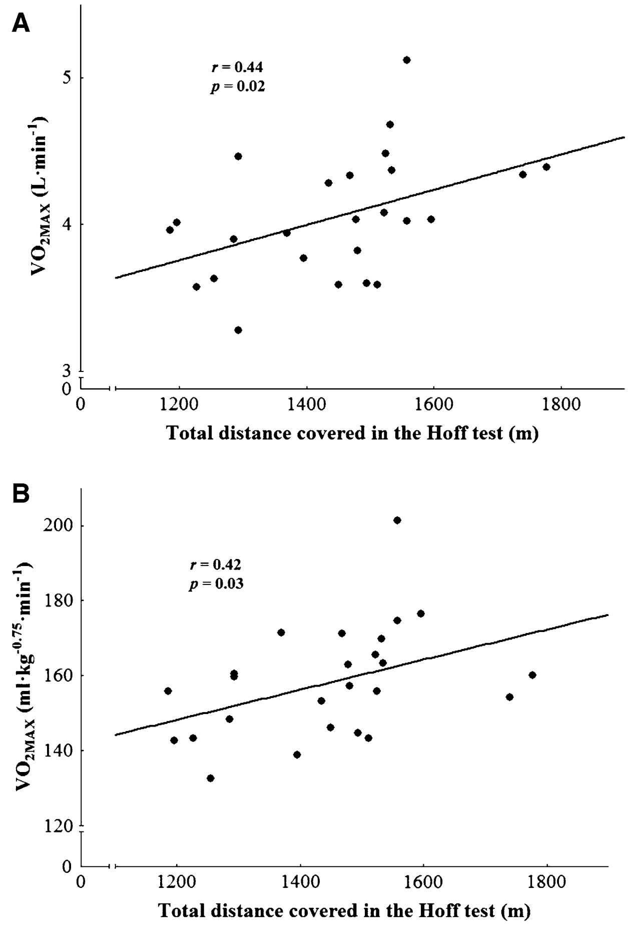

Fig. 2 Product-moment Pearson's correlation between the absolute values (**a**) and appropriately scaled (mL $kg^{-0.75}$ min^{-1}) (**b**) with the maximum distance covered in the Hoff test

Discussion

The present study aimed to verify possible associations between the total distance covered in the Hoff test and variables of aerobic and anaerobic fitness and body composition in professional soccer players. The main finding of this study was the moderate correlation between the total distance covered in the Hoff test and the $\dot{V}O_{2MAX}$ in absolute values and relative body mass (Table 3). However, no significant correlation was found between performance in the Hoff test and body composition variables, anaerobic fitness or, surprisingly, the anaerobic threshold (aerobic fitness).

In an earlier study, Hoff et al. [12] suggested that the proposed field circuit, besides being a specific protocol for aerobic power evaluation of soccer players, could also be used as a training method in order to increase $\dot{V}O_{2MAX}$. However, in the current study, only moderate correlations were observed between the total distance covered in the Hoff test and $\dot{V}O_{2MAX}$ both in absolute values ($r = 0.44$, $p = 0.02$) and relative to body weight ($r = 0.42$, $p = 0.02$). In addition, these values could explain only 19.36 and 17.64 %, respectively, of the observed variations in the distances covered in the Hoff test.

Although Kemi et al. [13] did not verify differences in $\dot{V}O_{2MAX}$ values measured in the laboratory and in the Hoff test, the moderate association values found may reflect the non-specificity of the protocol used for the $\dot{V}O_{2MAX}$ determination, and it is possible that higher values of coefficient correlation would have been verified if the determination of this variable had been performed using a portable spirometer in the Hoff test, this being a limitation of the present study.

Another possible explanation for the moderate correlation between the total distance covered in the Hoff test and the laboratory $\dot{V}O_{2MAX}$, is the low average $\dot{V}O_{2MAX}$ value found in the sample of this study. In a similar analysis Chamari et al. [10] verified a significant correlation between total distance covered in the Hoff test and laboratory $\dot{V}O_{2MAX}$ ($r = 0.68$) in young soccer players (i.e., under 15 years) with an average $\dot{V}O_{2MAX}$ of 65.3 ± 5.0 mL kg^{-1} min^{-1}, higher than that found in the present study (54.1 ± 1.2 mL kg^{-1} min^{-1}), which suggests a possible association between aerobic power and performance in the Hoff test, and consequently physical performance during a soccer match (i.e., higher $\dot{V}O_{2MAX}$ values, better performance in the Hoff test).

Also in relation to aerobic fitness, no significant associations were observed between the total distance covered in the Hoff test and values of anaerobic threshold. This study used a 400-m track field protocol with incremental velocities to determine the velocity related to the anaerobic threshold (V_{AnT}). The same protocol was used recently by Zagatto et al. [16], who did not find significant correlations between total distance covered in the Hoff test and V_{AnT}.

Again, the lack of specificity of the protocol used to determine the V_{AnT} may have limited the proposed analyzes, since continuous runs do not mimic the motor pattern and specific actions performed during a match. Corroborating with these data, recently Loures et al. [29] determined the V_{AnT} (fixed concentration of 4.0 mmol L^{-1}) and maximal lactate steady state (MLSS—gold standard for assessing aerobic endurance) on the Hoff circuit, and did not find any differences, besides high intraclass correlation (ICC = 0.80, $p < 0.05$) so confirming reliability and demonstrating that specific protocols can better assess physical fitness in soccer.

Although body composition characteristics can represent competitive advantage according to the positions on the field [24, 30], Wong et al. [24] found that despite defenders and goalkeepers having higher body weight and height, the midfielders performed better in the Hoff test, possibly due to performing a greater quantity of ball dribbling, which can contribute to reaching greater distances during the Hoff test. Corroborating with these findings, Lago-Peñas et al. [30] found differences in body composition of young soccer players, but not in performance in vertical jump tests, 30-m sprints and progressive 20-m run tests, confirming the low participation of the body composition in determining performance during physical testing of soccer players. As in the previously mentioned studies, the present study verified no correlation between body composition variables and performance in the Hoff test (Table 1), demonstrating that body composition characteristics possibly do not explain performance in this test, which appears to be strongly influenced by technical skills.

As the determinant actions in soccer require a major contribution of the anaerobic metabolism, variables of anaerobic power and capacity could explain the performance in the Hoff test. However, no correlations were observed between the RAST variables (PP, MP and FI), which can also be considered a repeated sprint ability test [31], and the total distance covered in the Hoff test (Table 3). This could be due to the RAST consisting of forward sprints, without changes of direction, which little resemble soccer efforts. Furthermore, the duration of the Hoff test (10 min) could be sustained by the contribution of the aerobic metabolism (i.e., a moderate association between the $\dot{V}O_{2MAX}$ and Hoff test), reducing the importance of the anaerobic metabolism during the test.

Therefore, we conclude that performance in the Hoff test shows moderate correlations with $\dot{V}O_{2MAX}$ and is not associated with body composition characteristics or anaerobic fitness. It is important to highlight that the circuit proposed by Hoff et al. [12] aims to simulate the actions performed during a soccer game, which gives this protocol high ecological validity when compared to other non-specific protocols, however, also affecting the possible associations between performance in the Hoff test and the V_{AnT} in the present study. Thus, the importance of using specific tests which simulate motor activities of the soccer game over laboratory tests should be used and interpreted with caution.

Conflict of interest Alessandro Zagatto, Willian Miyagi, Gabriel Brisola, Fabio Milioni, Adelino da Silva, Paulo Santiago and Marcelo Papoti declare they have no conflicts of interest.

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