https://doi.org/10.6063/motricidade.26162

Original Article

Relationship between physical tests with internal load and time spent in high intensity for male soccer players U-20 of regional level.

Short title: Physical tests and the intensity of the match

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Conflict of interest: nothing to declare. **Funding:** This work was financed by the Coordination for the Improvement of Higher Education – CAPES.

Received: 01/04/2022. Accepted: 01/22/2024.

ABSTRACT

The relationship between performance in physical tests and the match intensity from the heart rate (HR) response has not been studied in soccer. Thus, this study aimed to verify the correlation between the performance in physical tests and the intensity of the soccer match. Eleven Under-20 soccer players from the first division were evaluated in 2 official matches. The Yo-Yo intermittent aerobic test level 1 (YYIR1), 10-m and 30-m speed, repeated sprints ability (RSA, 6 x 20-20 m), the squat (SJ) and countermovement (CMJ) jump tests were performed. The heart rate (HR) was used to calculate the impulse training (M-TRIMP) by Edwards's methods, and the time spent above 90% of HR_{max} ($HR_{>90\%}$) was considered a high-intensity parameter. Pearson's correlation was applied, considering the significance level of $p < 0.05$. Significant correlations occurred between YYIR1 and M-TRIMP ($r = 0.72$) and the time in $HR_{>90\%}$ ($r = 0.51$) and between the best time in RSA (RSA_{best}) and $HR_{>90\%}$ ($r = -0.50$). YYIR1 was the best test related to the match intensity measured by the HR. RSA_{best} was also a good high-intensity indicator of the match, while jump and speed tests were not.

Keywords: Power: Speed, TRIMP, Vertical Jump, Yo-Yo test, Young players.

INTRODUCTION

Soccer is characterised by intermittent efforts and sprints with different durations, accelerations, decelerations, jumps, and constant changes of direction, which are performed with and without a ball (Modric et al., 2023). The match has a predominance of the aerobic energy system, with actions of walking, back running, and standing still (Andersson et al., 2008; Modric et al., 2023). On the other hand, many decisive actions require anaerobic metabolism, such as dribbling, acceleration, deceleration, and sprinting, characterising soccer as a high-intensity intermittent sport (Gonçalves et al., 2021; Mohr et al., 2016).

Considering the high demand of soccer matches on physical capabilities of endurance, speed, strength, and coordination skills (Chmura et al., 2015), the physical fitness evaluation should consider the intermittent aerobic characteristic, the demand for explosive actions and power, speed, and the repeated sprints ability (RSA). Tests such as Yo-Yo recovery level 1 (YYIR1), the jump tests, such as squat jump (SJ) and countermovement jump (CMJ), the speed at 10-m and 30-m, and the test of RSA have been widely used to assess physical fitness in soccer players (Doncaster et al., 2016; Rodríguez-Rosell et al., 2017; Rampinini et al., 2007; Castagna et al., 2019; Gonçalves et al., 2021) since they present specificity with the match actions. The YYIR1 test assesses intermittent aerobic fitness with similar characteristics to the actions of the match, a 20-m shuttle run with a change of direction and recovery between runs, discriminating players of different levels and presenting sensitivity to changes after training (Bangsbo et al., 2008; Castagna et al., 2020). Although the YYIR test has two distinct versions (levels 1 and 2), we chose to use the YYIR1 test because it focuses on maximal activation of the aerobic system. In contrast, the Yo-Yo recovery level 2 (YYIR2) assesses the individual's ability to recover from repeated exercise with a high contribution from the anaerobic system (Bangsbo et al., 2008), i.e., the RSA test would already bring us information about the anaerobic demand. The vertical jump tests, SJ and CMJ, are also widely used to control soccer training

(Claudino et al., 2017) considering their correlation with explosive strength (Rodríguez-Rosell et al., 2017), speed (Shalfawi et al., 2011), and maximum strength (Wisløff et al., 2004) in soccer players. Because soccer players perform most sprints in the match at distances ranging up to 30 m, tests of 10 m and 30 m are the most used distances in the evaluation of speed in soccer players, with the 10 m being more sensitive to changes in training (Stolen et al., 2005). The performance variables obtained in the RSA are sensitive in discriminating players of different competitive levels and positions (Aziz et al., 2008; Impellizzeri et al., 2008), in addition to correlating with the speed and SJ tests (Lockie et al., 2017).

While physical tests are used to identify the level of physical fitness and verify training changes, the training process has been described based on the training load, described as the input variable that is manipulated to elicit the desired training response (Coutts et al., 2018), depending on whether the measurable aspects occur internally or externally to the athlete, i.e., the external load (training prescribed by the coaches or physical work prescribed in the training plan), and the internal load (psychophysiological responses of the body to the requirements elicited by the external load) (Impellizzeri et al., 2005; Impellizzeri et al., 2019). An external load of the match has shown a positive correlation with the performance of soccer players in physical tests, i.e., the YYIR1 test (Castagna et al., 2019; Doncaster et al., 2016) and the average time of the six sprints in RSA correlates with the distance covered at high intensity and sprints (Rampinini et al., 2007). In addition, the maximal sprinting speed in 10-m from the 40-m test can impact what a player can do in actual playing (Mendez-Villanueva et al., 2011). However, actual match internal load responses have not been correlated with physical fitness tests.

The internal load can be determined by physiological variables such as blood lactate, skeletal muscle damage marker enzymes, heart rate (HR), and psychophysiology variables as the rating of perceived exertion (RPE). Among those internal load variables, HR has been widely used to quantify the internal training load by calculating the training impulse (TRIMP).

The TRIMP is an HR-based method that considers the volume (in minutes) and intensity of training sessions determined by the HR, expressed in arbitrary units (AU) (Banister, 1991). There are different approaches to determining TRIMP, including this proposed by Edwards (1993), which is calculated by measuring the product of the accumulated exercise duration (min) of five different intensity zones relative to the percentage of maximum HR (%HR_{max}) by a coefficient (1-5) relative to five intensity zones. This approach has been used in soccer to validate the use of RPE as a parameter of internal training load (Impellizzeri et al., 2004), to compare the dose-response relationship between training load and changes in aerobic performance (Fitzpatrick et al., 2018), and to compare the intermittent performance change (Campos-Vazquez et al., 2017).

In addition to using HR to determine TRIMP, HR has also been used as an indicator of high-intensity physical activity (Castagna et al., 2009; Fox et al., 2018) and can present important information regarding the level of physical fitness. For example, in team sports, significant associations exist between the volume of high-intensity activity completed, defined as time spent above 90% of maximum HR ($HR_{>90\%}$), and changes in aerobic performance (Fox et al., 2018). In soccer, both $HR_{>90\%}$ and TRIMP from the training sessions and matches have been studied in comparison to intermittent performance change (Campos-Vazquez et al., 2017).

Considering the importance of the high level of physical fitness that soccer players must have to support the intensity of the match, the present study aimed to verify the relationship between physical fitness in tests YYIR1, RSA, SJ, CMJ, 10-m, and 30-m tests with the time spent in the high-intensity ($HR_{>90\%}$) and the internal load in the match (M-TRIMP) in Under-20 (U20) soccer players. It was expected that the players with better performance in physical tests would play at a higher intensity and present higher M-TRIMP.

MATERIALS AND METHODS

This study is quasi-experimental research since there was no control group, in addition to randomization of the sample, as the group was already formed before the experiment (Yin, 2001).

Subjects

Eleven players from a U-20 team in the first division of the State Championship participated in the study: three midfielders, three forwards, three full-backs, and two defenders (19.1 ± 0.9 years, 177.0 ± 6.0 cm, 70.7 ± 6.7 kg, 9.7 ± 0.9% fat). Only players who participated in more than 75% of the match (67.5 minutes) were considered in the analysis (Coelho et al., 2013). The players were evaluated in two matches (M-1 and M-2), with seven players participating in both M-1 and M-2, while two players participated only in M-1 and other two only in M-2, resulting in 18 observations for statistical analysis. The players trained five days a week, two hours a day (three days: 2 times/day, two days: 1 time/day). Strength training: 3 sessions; technical-tactical training: 4-6 sessions; and physical training for injury prevention, with proprioceptive, balance, and core exercises: 1 session/week. As defined by the coach, the team played in the 4-3-3 formation, marking the opponent's ball out (high pressure), and when in possession of the ball, the team organized itself with short passes from defence to attack, trying to retain possession of the ball, and avoiding long throws to the attack field.

Before data collection, the project was approved by the University's ethics committee (Process: 64920317.1.0000.5398), according to the laws of the country, which was carried out following the ethical principles of the Declaration of Helsinki. Before the study started, the team's technical committee had been contacted to request permission and explain the procedures. After the consent of the team's technical committee, as well as the awareness of the team's board, the players were invited to participate in the study. All players agreed to participate spontaneously after having understood the objectives and read the informed consent term, signed by the players (all players were over 18 years old).

Procedures

The data were collected in the final part of the first qualifying phase of the competition (August-September) after a pre-season of 3 weeks (April-May) plus -three months of a competition in which the team played 14 matches. This period of data collection was chosen because of the little variation in the physical fitness of the players during the competition. The team finished in 5th place in the first qualifying phase. The team won the match M-1 by 7 x 0 and lost the M-2 by 0 x 1. The opponents finished the classification phase in the 11th (M-1) and 1st positions (M-2), respectively.

The matches took place on Saturdays (3:00 to 5:00 p.m.), and the anthropometric and physical performance assessments were made on Mondays (at the same time as the matches), 48 hours after the matches, without the players having made any physical effort during the recovery period. The evaluations were made on a weekday to not interfere with the team's training process since it was the final classification stage. Week 1 = anthropometry and pilot match (for better familiarization of players with HR monitors and other adjustments for data collection); weeks 2 and 3 = physical evaluation (week 2 = SJ, CMJ, and RSA, week 3 = 10-m, 30-m, and YYIR1); Week 4 and 5 = data collection in matches (M-1 and M-2 in the 19th and 20th round of the competition). The matches were held at the evaluated team's home field, a 105 x 70 m natural grass field. HR was monitored throughout the matches to determine the M-TRIMP using Edwards's method. The players wore soccer shoes during the matches and the YYIR1 and RSA tests.

Body composition

Body composition was determined using the bi-compartmental model by measuring skinfolds. First, body density was calculated by measuring seven skinfolds: triceps, subscapular, middle axillary, pectoral, abdominal, supra-iliac, and thigh (Jackson & Pollock, 1978). The collection was made with a scientific adipometer of the brand Cescorf® (Porto Alegre, Rio Grande do Sul, Brazil), and the percentage of body fat was determined with the Siri equation (Siri, 1961). Body mass and height were measured using a digital scale with an adult ruler Welmy® brand (Santa Bárbara do Oeste, São Paulo, Brazil).

Intermittent aerobic assessment (YYIR1)

The YYIR1 protocol, proposed by Bangsbo (1994), consists of travelling the distance of 20 m of the shuttle run (40 m) with an active recovery of 10s in the space of 5 m (recovery area) between each shuttle run. The test was conducted on a natural grass field with a CD player and a sound box for speed control. The test started with a speed of 10 $km \cdot h^{-1}$, and the speed was increased progressively, according to the protocol previously recorded on the CD player, until the player's voluntary exhaustion. At the end of the test, the total distance covered (m) was registered. Players who were unable to follow the sound signals for more than two consecutive times were eliminated from the test, and their last completed stage was considered the test result, and the total distance travelled was recorded in meters.

Speed test (10-m and 30-m)

The speed protocol adopted was described by Chamari et al. (2004). The athlete started from the standing position and ran 30 meters in the shortest time possible. The times of 10-m and 30-m were recorded using three photocells (CEFISE®, Campinas, Brazil) placed in the zero, 10-m, and 30-m marks. The times were recorded in hundredths of a second, considering the best time of three attempts, with a two-minute recovery interval between runs.

Repeated run test (RSA)

The RSA test was performed in six 40-m shuttle runs (20-20m) with 20 s of recovery between the bouts (Impellizzeri et al., 2008). The time was recorded using the photocell system (CEFISE®, Campinas, Brazil). For data analysis, we considered the average time of the six sprints (RSA_{mean}), the best time achieved in the six sprints (RSA_{best}), and the index of the decrement ($RSA_{decrement}$), using the formula: ([RSA_{mean}] / [RSA_{best}] × 100) - 100, proposed by Rampinini et al. (2007).

Jumping test (SJ and CMJ)

The vertical jumps were evaluated using two jumps, SJ and CMJ, as proposed by Bosco et al. (1995). In both jumps, the players started on a contact platform (CEFISE®, Campinas, Brazil) with their hands on their hips and feet hip-width apart. The players were instructed to jump as high as possible in three attempts. The average value of the three attempts of each jump, SJ and CMJ, was considered for the analysis, with an interval of 2-3 min between jumps (Claudino et al., 2017). In SJ, the player starts the jump from the standing position and then flexes his knees up to 90º, holding this position for two seconds before jumping. In CMJ, the player starts the jump standing up, with the knees extended, and after the signal, he must flex the knee to 90º as quickly as possible and jump. Before the evaluation, the players had gone through a jumping learning session with the main researcher of the study.

Heart rate

HR was recorded by second, using the Team System2 monitor and the software from the same manufacturer (Polar, Kempele, Finland). Subsequently, the data were transferred to a computer for analysis using the spreadsheet editor Excel version 2013 (Microsoft Office, Washington, USA). Before the collections, the players had performed two training sessions and a pilot match with the HR monitors to familiarise themselves with the equipment. HR_{max} was considered the highest value reached by the player in the match or the YYIR1 test.

The HR from the match was used to calculate the M-TRIMP, according to the method proposed by Edwards (1993), as described below: HR was divided into five intensity zones according to the HR_{max}: zone 1: 50 to 60%; zone 2: 60 to 70%; zone 3: 70 to 80%; zone 4: 80 to 90%; zone 5: 90 to 100%. The accumulated time in each of the five intensity zones was multiplied by the value of each zone (1-5). The sum in the five intensity zones was the total M-TRIMP, expressed in arbitrary units (UA). In addition to TRIMP, the most intense zone ($HR_{>90\%}$), considered the zone of high-intensity activity (Fox et al., 2018), was also used in the statistical analysis.

Statistical analysis

The normality of the data was tested using the Shapiro-Wilk test, and the data showed normal distribution. The relationship between the physical tests and the M-TRIMP was tested using Pearson's correlation. The correlation classification was adopted according to the correlation coefficient (*r*): 0-0.1 very weak; 0.1-0.3 weak; 0.3-0.5 moderate; 0.5-0.7 strong; 0.7-0.9 very strong; 0.9-1.0 almost perfect (Hopkins, 2000). The significance level adopted was $p < 0.05$, and the data were expressed as mean and standard deviation. The data were analysed using the Statistical Package for Social Sciences (SPSS) (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.).

RESULTS

The results of the physical tests are shown in Table 1. The average participation of players per match was 80.2 ± 5.2 min since not all players played the 90 min (see subjects description). Table 2 shows the HR results, time in the five intensity zones, and the calculated M-TRIMP (348.46 UA). Players spent over 50% of their time playing on high intensity, ≥90%FC_{max}. The three zones of lesser intensity (Z-1 to Z-3) represented less than 15% of the spent in the game.

Table 1 – Results of the physical tests.

	YYIR1 (m)	**10-m (s)**	**30-m (s)**	**SJ (cm)**	**CMJ (cm)**	**RSA_{mean} (s)**	**RSA_{best} (s)**	**$RSA_{decrement}$ (%)**
Mean	1596	1.83	4.28	39.0	40.0	7.24	6.91	4.85
SD	304	8.25	1.34	4.04	3.79	1.49	1.22	2.35

YYIR1 = Yo-yo intermittent recuperative level 1; 10-m = Speed of 10 meters; 30-m = Speed of 30 meters; SJ = Squat jump; CMJ = Countermovement jumps; RSA_{mean} = mean time; RSA_{best} = best time; $RSA_{decrement}$ = Decrement time. Values expressed in mean and standard deviation (SD).

Table 2 - Distribution of internal match load and time at the zone of intensity relative to HR_{max}.

Zone of Intensity	**HR_{max} (%)**	**Time (min)**	**Time (%)**	**TRIMP (UA)**
Z-1	50 – 60	0.06 ± 0.12	0.07 ± 0.16	0.06 ± 0.25
Z-2	60 – 70	2.21 ± 1.66	2.75 ± 2.18	4.42 ± 4.10
Z-3	70 – 80	9.29 ± 5.64	11.57 ± 7.02	27.85 ± 20.75
Z-4	80 – 90	27.06 ± 7.55	33.72 ± 7.58	108.22 ± 45.43
Z-5	90 – 100	41.58 ± 13.41	51.84 ± 14.47	207.90 ± 94.69
Total		80.20 ± 5.25	100	348.46

UA = arbitrary units; TRIMP = Training impulse calculated; HR_{max} = Maximum heart rate. *High intensity zone, $HR_{>90\%}$ = minutes above 90% of HR_{max}.

Only YYIR1 and RSA_{best} showed significant correlations with match intensity parameters (Table 3). YYIR1 presented a very strong correlation with M-TRIMP (r = 0.72) and correlated strongly with the time ≥90%FC_{max} (r = 0.51). RSA_{best} presented significant correlation only with ≥90%FC_{max} (r = -0.50). The other physical tests showed correlations between weak-moderate (r = -0.129 – 0.448).

Table 3 - Correlation between the indicators of the intensity of the match with the physical tests.

***r*-value**	**YYIR1 (m)**	**RSA_{mean} (s)**	**RSA_{best} (s)**	**$RSA_{decrement}$ (%)**	**10-m (s)**	**30-m (s)**	**SJ (cm)**	**CMJ (cm)**
M-TRIMP	0.722[#]	0.192	-0.245	0.448	-0.197	-0.363	0.011	0.142
$HR_{>90\%}$	0.512*	-0.129	-0.507*	0.323	-0.146	-0.282	0.139	0.229

Significant correlation: *$p < 0.05$; # $p < 0.01$. M-TRIMP = Training impulse of the match; $HR_{>90\%}$ = minutes above 90% HR_{max}; YYIR1 = Yo-yo intermittent with recovery level 1; 10-m = Speed of 10 meters; 30-m = Speed of 30 meters; SJ = Squat jump; CMJ= Countermovement jump.

DISCUSSION

The present study aimed to evaluate whether the performance in physical tests correlates with the M-TRIMP and the time in the $HR_{>90\%}$. M-TRIMP presented a very strong correlation only with YYIR1 ($r = 0.72$) and a strong correlation with the time in the zone of highest HR intensity, $HR_{>90\%}$ ($r = 0.51$). RSA_{best} presented a significant correlation ($r = -0.50$) with the $HR_{>90\%}$. On the other hand, the other parameters of the RSA test, just as the SJ with CMJ, did not present a significant correlation with the M-TRIMP and $HR_{>90\%}$. Our results indicate that not all physical tests correlate with the intensity that the player performed in the match. This is likely because TRIMP is a general response to the exercise period, while some physical tests are more specific, explaining specific responses and not global ones, such as some RSA test parameters, jumps, and speed tests, as opposed to YYIR1, respectively.

YYIR1 assesses intermittent aerobic physical fitness (Bangsbo et al., 2008; Castagna et al., 2020) and has an important anaerobic demand (Rampinini et al., 2010). YYIR1 also has a positive correlation with the distance travelled at high speed and speed (Castagna et al., 2019; Doncaster et al., 2016), the number of sprints (Castagna et al., 2019), and the total distance covered in the match (Doncaster et al., 2016; Castagna et al., 2019). Our results with M-TRIMP ($r = 0.72$) and $HR_{>90\%}$ ($r = 0.51$) confirm that the YYIR1 test is a good indicator of the intensity of the soccer match, indicating the intermittent aerobic fitness and that M-TRIMP can also be used to calculate the internal load of the match, as done in training sessions. Training intensity at $HR_{>90\%}$ is also strongly related to aerobic performance in team sports (Fox et al., 2018), demonstrating that $HR_{>90\%}$ is a good indicator for analysing aerobic performance in team sports.

Another physical test used in the present study was the RSA. Among the test variables, only the RSA_{best} showed a significant negative correlation with the $HR_{>90\%}$, indicating that the players with the best performance, i.e., lower time in the RSA test, remained longer at high intensity in the match. On the other hand, the RSA_{best} did not present a significant relationship with physical performance in the match (Rampinini et al., 2007). Even so, the authors did not exclude the possibility that the RSA_{best} may be related to the other variables of the match. Our results confirm that idea. RSA_{best} represents the best sprint among the six maximal sprints. However, the recovery between each sprint is 20 s, which is insufficient to complete recovery. Thus, RSA_{best} does not represent the player's maximum speed; there is an aerobic demand during the recovery in the RSA test that can influence RSA_{best} and explain a relationship with the time in $HR_{>90\%}$. RSA_{best} can also be useful for evaluating the time the player remains at high intensity during the match, time in the $HR_{>90\%}$ zone. On the other hand, no RSA's variable did not correlate significantly with M-TRIMP. A possible explanation for the lack of significant relationships between the RSA and M-TRIMP is the fact that M-TRIMP is a more general indicator. M-TRIMP considers all the time of the match, including the lower-intensity zones, which represent the moments of the match in which the players are in aerobic activities, such as walking, jogging, or even resting without displacement.

Regarding jump tests, SJ and CMJ did not show a significant correlation with M-TRIMP or $HR_{>90\%}$. Vertical jumps are used to assess the power of lower limbs (Claudino et al., 2017) and have a significant correlation with explosive strength (Rodríguez-Rosell et al., 2017), speed in soccer (Loturco et al., 2020), speed in basketball (Shalfawi et al., 2011), and the number of balls stolen by basketball players (Gomes et al., 2017). The SJ and CMJ test performance depends on the simultaneous rapid and vigorous contractile strength of the knee and hip extensor muscle groups (Requena et al., 2011; Tsiokanos et al., 2012). Therefore, the evaluation of very short-duration muscle power, such as jumps, does not affect HR elevation, i.e., jumps do not depend on the cardiorespiratory response, which certainly explains why the performance in jumps did not correlate with the internal load and time at high-intensity in the present study, M-TRIMP and $HR_{>90\%}$, respectively.

The 10-m and 30-m speed tests did not correlate with M-TRIMP and $HR_{>90\%}$ either. In the speed tests, the movements are also made with vigorous and rapid contractions of the hip and knee muscles (Bloomquist et al., 2013). Although they have a longer duration than the jumping tests, the cardiorespiratory dependence for the test is not large enough for cause-and-effect relationships to be detected between the test performance and the HR response of the entire match. Jumping tests correlate with speed performance and have been proposed to control the training of speed athletes (Loturco et al., 2018), which may help to explain, in part, why the jumps and sprint runs did not correlate with TRIMP or $HR_{>90\%}$. The M-TRIMP, as a method of assessing the intensity of the match, as well as time in $HR_{>90\%}$, did not show enough sensitivity to distinguish players with better performance in neuromuscular tests, such as jumping and speed tests since the TRIMP considers the HR of the entire match. Complementing our results, Fox et al. (2018) concluded in a systematic review that the associations between training load and neuromuscular tests are not clear. In addition, the maximal sprinting speed in 10 m from the 40-m test can impact what a player can do in actual playing (Mendez-Villanueva et al., 2011), the maximum speed achieved in the match is higher than that verified in the 40-m field test (Massard et al., 2018).

The present study confirmed that the YYIR1 test is a good test for assessing the intermittent aerobic performance of soccer players, capable of estimating the internal load of the match. At the same time, the RSA_{best} correlated only with time in $HR_{>90\%}$, reinforcing the idea that activity time above $HR_{>90\%}$ is also a good indicator of physical performance. On the other hand, the performance in the power and speed tests with short durations were not good indicators of the overall intensity of the match, the M-TRIMP. As for practical applications, our results indicate that the YYIR1 is of great value for coaches and physical trainers to obtain information about the intermittent aerobic capacity of the players and if the players played the match at high intensity, while the tests with anaerobic characteristics, RSA and jumps SJ and CMJ are not indicative of the overall intensity at which players will develop in the match.

On the other hand, it would be interesting that in future studies, in addition to physical tests, the M-TRIMP also be correlated to the external load of the match through the analysis of displacement during the match to add more information since Aquino et al. (2018) analysing the displacement of players of the same age in the present study, with 30 Hz cameras as opposed to 1-5 Hz GPS from other studies, did not find correlations between high-intensity activity with field tests, YYIR1 correlated positively only with medium-intensity running. A Zig-Zag test only correlated significantly with the maximum speed of the match. In contrast, the 10-m and 30-m speed tests and the RSA test (RAST) did not present significant correlations with any match displacement variables.

The use of only one method of determining the TRIMP, proposed by Edwards (1993), can be pointed out as a limitation of the present study. For example, the individual TRIMP proposed by Manzi et al. (2009) presented a better understanding of the dose-response relationship, considering the comparison between a load of training sessions with physical performance and aerobic and anaerobic variables (Malone et al., 2020). Thus, in future studies with objectives like those of the present study, we propose comparing different TRIMP methods and displacement analysis to add more information about M-TRIMP.

CONCLUSIONS

Among the physical tests studied, YYIR1 correlated positively with M-TRIMP and with playing time in the most high-intense zone ($HR_{>90\%}$), reaffirming that the YYIR1 test is a good performance indicator for soccer players. In the RSA test, only the RSA_{best} correlated with the spent time $HR_{>90\%}$ during the U-20 soccer match, indicating that the RSA test adds information about the players' physical fitness about the possibilities of what they can perform in the real match. The present study leaves a practical application for the coaches and physical trainers of soccer teams using the YYIR1 and RSA tests as a parameter for analysing the physical capacity of the players. They can predict that players with higher performance on those tests will be able to play the game at a greater intensity than players who perform less on those tests. However, although all physical tests used in this study are supported by the literature, presenting specificity with the actions of the match and correlations with external load variables of the match, the results in physical tests should be viewed with caution. When one intends to correlate the results of the physical tests with the internal load and high-intensity time of the real match, coaches should carefully consider the purposes of doing an extensive battery of physical tests, mainly the jump speed tests. Based on our results and considering the studied population, YYIR1 and RSA tests can help to understand the internal load response and the time spent in high intensity in the game. Further studies are needed to understand better the relationship between physical tests and M-TRIMP in soccer players.

ACKNOWLEDGEMENTS

We would like to thank Sport Club Noroeste, managers, coaching staff and players for participating in the research during the competitive period.

REFERENCES

Andersson, H., Ekblom, B., Krustrup, P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *Journal of Sports Sciences, 26*(2), 113–122. doi: 10.1080/02640410701422076

Aquino R, Vieira, L. H. P., Oliveira, L. P., Gonçalves, L. G. C., Santiago. P. R. P. (2018). Relationship between field tests and match running performance in high-level young Brazilian soccer players. *The Journal of Sports Medicine and Physical Fitness, 58*(3), 256-262. doi: 10.23736/S0022-4707.17.06651-8

Aziz, A. R. M., Chia, M., Teh, K. C. (2000). The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *The Journal of Sports Medicine and Physical Fitness, 40*(3), 195 –200.

Bangsbo, J., Iaia, F. M., Krustrup, P. (2008). The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine, 38*(1), 37-51. doi: 10.2165/00007256-200838010-00004

Bangsbo, J. (1994). The physiology of soccer – with special reference to intense intermittent exercise. *Acta physiologica Scandinavica, 619*, 1-155.

Banister E. W. (1991). Modeling elite athletic performance, in *Physiological Testing of Elite Athletes*, eds Green H., McDougal J., Wenger H. (Champaign: Human Kinetics), 403–24.

Bloomquist, K., Langberg, H., Karlsen, S., Madsgaard, S., Boesen, M., Raastad, T. (2013). Effect of range of motion in heavy load squatting on muscle and tendon adaptations. *European Journal of Applied Physiology, 113,* 2133–2142. doi: 10.1007/s00421-013-2642-7

Bosco, C.; Belli, A.; Astrua, M.; Tihanyi, J.; Pozzo, R.; Kellis, S.; Tsarpela, O.; Foti, C.; Manno, R.; Tranquilli, C. (1995). A dynamometer for evaluation of dynamic muscle work. *European journal of applied physiology and occupational physiology, 70*, 379–386. doi: 10.1007/BF00618487

Campos-Vazquez, M. A., Toscano-Bendala, F. J., Mora-Frrrera, J. C., Suarez-Arrones, L. J. (2017). Relationship between internal load indicators and changes on intermittent performance after the preseason in professional soccer players. *Journal of Strength & Conditioning Research, 31,* 1477–1485. doi: 10.1519/JSC.0000000000001613

Castagna, C., Krustrup, P., D'Ottavio, S., Pollastro, C., Bernardini, A., Póvoas, S. (2019). Ecological Validity and Reliability of an Age-Adapted Endurance Field Test in Young Male Soccer Players. *Journal of Strength & Conditioning Research, 33*(12): 3400-3405. doi: 10.1519/JSC.0000000000002255.

Castagna, C. Krustrup, P. Póvoas, S. (2020). Yo-Yo intermittent tests are a valid tool for aerobic fitness assessment in recreational football. *European Journal of Applied Physiology, 120*(1):137-147. doi: 10.1007/s00421-019-04258-8

Castagna, C., D'Ottavio, S., Vera, J. G., Alvarez, J. C. B. (2009). Match demands of professional Futsal: a case study. *Journal of Science and Medicine in Sport, 12*(4), 490-494. doi: 10.1016/j.jsams.2008.02.001

Chamari, K., Hachana, Y., Ahmed, Y. B., Galy, O., Sghaier, F., Chatard, J. C., Hue, O., Wisloff, U. (2004). Field and laboratory testing in young elite soccer players. *British Journal of Sports Medicine, 38,* 191-196. doi: 10.1136/bjsm.2002.004374

Chmura, P., Konefał, M., Kowalczuk, E., Andrzejewski, M., Rokita, A., Chmura, J. (2015). Distances covered above and below the anaerobic threshold by professional football players in different competitive conditions. *Central European Journal of Sport Sciences and Medicine, 10*(2), 25–31.

Claudino, J.G., Cronin, J., Mezêncio, B., McMaster, D.T., McGuigan, M., Tricoli, V., Amadio, A.C., Serrão, J.C. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. *Journal of Science and Medicine in Sport, 20*(4), 397-402. doi: 10.1016/j.jsams.2016.08.011

Coelho, D. B., Pimenta, E. M., Veneroso, C. E., Morandi, R. F., Pacheco, D. A. S., Pereira, E. R., Coelho, L. G. M., Silami-Garcia, E. (2013). Assessment of acute physiological demand for soccer. *Brazilian Journal of Kinanthropometry and Human Performance,* 15(6), 667-676. doi: 10.1590/1980-0037.2013v15n6p667

Coutts A. J., Crowcroft S., Kempton T. (2018). Developing athlete monitoring systems: theoretical basis and practical applications, in *Sport, Recovery and Performance: Interdisciplinary Insights*, ed Kellmann M. (Abingdon: Routledge;), 19–32.

Doncaster, G., Marwood, S., Iga, J., Unnithan, V. (2016). Influence of oxygen uptake kinetics on physical performance in youth soccer. *European Journal of Applied Physiology, 116*(9), 1781-1794. doi: 10.1007/s00421-016-3431-x

Edwards, S. (1993). *The Heart Hate Monitor Book.* Sacramento, C. A: Fleet Feet Press.

Fitzpatrick, J. F., Hicks, K.M., Hayes, P.R. (2018). Dose-response relationship between training load and changes in aerobic fitness in professional youth soccer players. *Jornal Internacional de Fisiologia e Desempenho Esportivo, 19,* 1-6. doi: 10.1123/ijspp.2017-0843

Fox, J. L., Stanton, R, Sargent, C., Wintour, A. S., Scanlan, A. T. (2018). The Association Between Training Load and Performance in Team Sports: A Systematic Review. *Sports Medicine, 48*(12), 2743-2774. doi: 10.1007/s40279-018-0982-5

Gomes, J. H., Mendes, R. R., Almeida, M. B., Zanetti, M. C., Leite, G. S., Ferreira Júnior, A. J. (2017). Relationship between physical fitness and game related statistics in elite professional basketball players: Regular season vs. Playoffs. *Motriz, 23*(2), e101626. doi: http://dx.doi.org/10.1590/S1980-6574201700020004

Gonçalves, L., Clemente, F.M., Barrera, J.I., Sarmento, H., González-Fernández, F.T., Vieira, L.H.P., Figueiredo, A.J., Clark, C.C.T., Carral, J.M.C. (2021). Relationships between Fitness Status and Match Running Performance in Adult Women Soccer Players: A Cohort Study. *Medicina (Kaunas), 57*(6):617. doi: 0.3390/medicina57060617

Hopkins, W. G. (2000). Correlation coefficient: a new view of statistics. Disponível em:<http://www.sportsci.org/resource/stats/correl.html.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., Ferrari Bravo, D., Tibaudi, A., Wisloff, U. (2008). Validity of a repeated-sprint test for football. *International Journal of Sports Medicine, 29*(11), 899-905. doi: 10.1055/s-2008-1038491

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Medicine & Science in Sports & Exercise, 36*(6), 1042-1047. doi: 10.1249/01.mss.0000128199.23901.2f

Impellizzeri, F. M., Marcora, S. M., Coutts, A. J. (2019). Internal and External Training Load: 15 Years On. *International Journal of Sports Physiology and Performance,* 14(2):270-273. doi: 10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of Sports Sciences*, 23(6): 583-592. dói: 10.1080/02640410400021278

Jackson, A. S., Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal Nutrition, 40*, 497-504. doi: 10.1079/bjn19780152

Lockie, R. G., Jalilvand, F., Moreno, M. R., Orjalo, A. J., Risso, F. G., Nimphius, S. (2017). Yo-Yo Intermittent Recovery Test Level 2 and Its Relationship With Other Typical Soccer Field Tests in Female Collegiate Soccer Players. *Journal of Strength & Conditioning Research*, v. 31, n. 10, p. 2667-2677. doi: 10.1519/JSC.0000000000001734

Loturco, I., Contreras, B., Kobal, R., Fernandes, V., Moura, N., Siqueira, F., Winckler, C., Suchomel, T., Pereira, A. P. (2018). Vertically and horizontally directed muscle power exercises: Relationships with top-level sprint performance. *PLoS One, 13*(7), e0201475. doi: 10.1371/journal.pone.0201475

Loturco, I., Pereira, L.A., Fílter, A., Olivares-Jabalera, J., Reis, V.P., Fernandes, V., Freitas, T.T., Requena, B. (2020). Curve sprinting in soccer: relationship with linear sprints and vertical jump performance. *Biology of Sport, 37*(3), 277-283. doi: 10.5114/biolsport.2020.96271

Malone, S., Hughes, B., Collins, K., Akubat, I. (2020). Methods of monitoring training load and their association with changes across fitness measures in hurling players. *Journal of Strength & Conditioning Research, 34*(1), 225-234. doi: 10.1519/JSC.0000000000002655

Manzi, V., Iellamo, F., Impellizzeri, F., D'Ottavio, S., Castagna, C. (2009). Relation between individualized training impulses and performance in distance runners. *Medicine & Science in Sports & Exercise, 41*(11), 2090-2096. doi: 10.1249/MSS.0b013e3181a6a959

Massard, T., Eggers, T., Lovell, R. (2018). Peak speed determination in football: is Sprint testing necessary? *Science and Medicine in Football,* 2(2), 123-126. dói: 10.1080/24733938.2017.1398409

Mendez-Villanueva, A., Buchheit, M., Simpson, B., Peltola, E., Bourdon, P. (2011). Does on-field sprinting performance in young soccer players depend on how fast they can run or how fast they do run? *Journal of Strength & Conditioning Research, 25*(9):2634-8. doi: 10.1519/JSC.0b013e318201c281

Modric, T., Versic, S., Stojanovic, M., Chmura, P. Andrzejewski, M. Konefał, M., Sekulic, D. (2023). Factors affecting match running performance in elite soccer: Analysis of UEFA Champions League matches. *Biology of Sport, 40*(2): 409-416. doi: 10.5114/biolsport.2023.116453

Mohr, M., Draganidis, D., Chatzinikolaou, A., Barbero-Álvarez, J. C., Castagna, C., Douroudos, I., Avloniti, A., Margeli, A., Papassotiriou, I., Flouris, A. D., Jamurtas, A. Z., Krustrup, P., Fatouros, I. G. (2016). Muscle Damage, Inflammatory, Immune and Performance Responses to three Soccer Games in 1 Week in Competitive Male Players. *European Journal of Applied Physiology, 16*(1), 179-193. doi: 10.1007/s00421-015-3245-2

Rampinini, E., Bishop, D., Marcora, S. M., Bravo, D. F., Sassi, R., Impellizzeri, F. M. (2007). Validity of Simple Field Tests as Indicators as Match related Physical Performance in Top-Level Professional Soccer Players. *International Journal of Sports Medicine , 28*(3), 228-235. doi: 10.1055/s-2006-924340

Rampinini, E., Sassi, A., Azzalin, A., Castagna, C., Menaspà, P., Carlomagno, D., Impellizzeri, F. M. (2010). Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. *European Journal of Applied Physiology, 108,* 401-409. doi: 10.1007/s00421-009-1221-4

Requena, B., Garcia, I., Requena, F., de Villarreal, E. S., Cronin, J. B. (2011). Relationship between traditional and ballistic squat exercise with vertical jumping and maximal sprinting. *Journal of Strength & Conditioning Research, 25,* 2193-2204. doi: 10.1519/JSC.0b013e3181e86132

Rodríguez-Rosell, D., Mora-Custodio, R., Franco-Márquez, F., Yáñez-García, J. M., González-Badillo, J. J. (2017). Traditional vs. Sport-Specific Vertical Jump Tests: Reliability, Validity, and Relationship With the Legs Strength and Sprint Performance in Adult and Teen Soccer and Basketball Players. *Journal of Strength & Conditioning Research, 31*(1), 196-206. doi: 10.1519/JSC.0000000000001476

Shalfawi, S. A., Sabbah, A., Kailani, G., Tønnessen, E., Enoksen, E. (2011). The relationship between running speed and measures of vertical jump in professional basketball players: a field-test approach. *Journal of Strength & Conditioning Research, 25*(11), 3088-3092. doi: 10.1519/JSC.0b013e318212db0e

Siri, W. E. (1961). *Body composition from fluid space and density.* In. J. Brozek & A. Hanschel. (Eds). Techniques for measuring body composition. Washington D.C., National Academy of Science.

Stolen, T., Chamari, K., Castagna, C., Wisloff, U. (2005). Physiology of soccer: An update. *Sports Medicine, 35*(6), 501-536. doi: 10.2165/00007256-200535060-00004

Tsiokanos, A., Kellis, E., Jamurtas, A., Kellis, S. (2002). The relationship between jumping performance and isokinetic strength of hip and knee extensors and ankle plantar flexors. *Isokinetics and Exercise Science, 10,* 107-116. doi: 10.3233/IES-2002-0092

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine, 38,* 285-288. doi: 10.1136/bjsm.2002.002071

Yin, R. (2001). *Estudo de caso: planejamento e métodos*. 5. ed. Porto Alegre: Bookman.