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Relationship between Repeated Sprint Ability and Maximal Oxygen Uptake in Youth Football Players

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Abstract

The aims of this study were to explore the repeated sprint ability (RSA) test (8 x 30 m) with 25 seconds of jogging recovery and to determine the relationship to the maximal oxygen uptake (VO2max) in a Colombian elite football team. 24 male youth football players aged 20.21±0.39 years, height 72.96±6.99 cm, and body mass 69.0±6.78 kg who competed in the first A category participated in this study (Tier 3). Descriptive statistics included the mean and SD of the anthropometry, each sprint, RSA outputs and Vo_{2max}. Spearman correlations were used between each sprint, the best sprint, the worst sprint, estimated fatigue, and Vo_{2max}. Finally, a correlation between VO_{2max} and RSA was plotted. The results identified that VO_{2max} mL/kg·min was related to the 4th sprint $p < 0.01$ and the 5th, 6th and 8th sprints $p < 0.05$ of RSA and the relationship between RSA, total time and VO_{2max} was moderate $r = -0.422$, 95% CI -0.711 to -0.010, $p = 0.039$. In conclusion, estimated Vo_{2max} mL/kg·min seems to influence better performance in the last sprints of RSA and does not have a strong relationship to RSA total time in this sample of Colombian players. Coaches and physical trainers should take advantage of the ecological validity of field tests in developing countries.

Keywords: *physical conditioning, sports performance, physical assessments*

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Introduction

Football requires different performance actions during a match, and players cover 11 km, and 3% of the distance is running at high intensity (Gualtieri et al., 2023; Martínez-Hernández et al., 2023). A match needs repeated high-intensity sprints combined with aerobic-type recovery activities (Beato et al., 2021). For example, sprinting has been found to be the most common locomotive action done before a goal by either the player scoring or helping to score (Martínez-Hernández et al., 2023). Hence, the repeated performance in sprinting is known as repeated-sprint ability (RSA) (Girard et al., 2011). Several authors agree that RSA is an important part of footballers' performance because being able to do it can be necessary to get to the professional level (Gualtieri et al., 2023).

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Nowadays, intensification typically shows up as a rise in the overall running distance at high to maximum intensity during the game, which has been empirically demonstrated in considerable research studies (Pons et al., 2021). Actually, between 335 to 596 m per match are in high-intensity runs (19.8–25.1 km/h) (Gualtieri et al., 2023), and 96 to 295 m at (> 25.1 km/h) per match (Pons et al., 2019). Therefore, developing players' ability to perform RSA is critical for sport science departments and coaching in professional football teams (Beato et al., 2021; Gualtieri et al., 2023). The use of field RSA tests consisting of several sprints interspersed with brief recovery periods, the distances more used are RSA 6x40 m (20 seconds of 20+20 m with a 180 turn) and linear RSA 6x30 m (15 seconds of recovery). Field tests must guarantee physiological reactions akin to those experienced during intense segments of actual match play; for these reasons, the RSA is crucial in the training and testing of football players (Spencer et al., 2005).

On the other hand, maximal oxygen consumption (VO_{2max}) has received significant research attention in youth players (Bahtra et al., 2020). VO_{2max} is defined as the maximum amount of oxygen (O2) that an organism can absorb, transport, and consume per unit of time (Hoffmann et al., 2014), and athletes with higher VO_{2max} have a better ability to resist fatigue (Bishop et al., 2011). The literature commonly reports VO_{2max} values in football players, with international teams averaging between 55 and 68 mL/kg·min (Slimani et al., 2019), professionals 56.5 mL/kg·min, and amateurs 55.7 mL/kg·min. It ranges from semi-professional (53±7 mL/kg·min) to professional team level (55.2±4 mL/kg·min).

Recent sports science has focused on practical field tests for coaches, improving ecological validity and reliability in young football players (Castagna et al., 2019; Impellizzeri et al., 2008). RSA tests, primarily based on match characteristics, aim to assess sport-specific physical performance (Impellizzeri et al., 2008). Similarly, in team sports like football, rugby, and basketball, which involve acyclic movements, direction changes, accelerations, and decelerations, the Course Navette test (Leger et al., 1988) is relevant. Results indicated no significant differences between VO_{2max} values obtained in field and laboratory settings (Aziz et al., 2007).

Previous research has consistently correlated VO_{2max} with RSA, showing positive outcomes (Girard et al., 2011). This may be because higher VO_{2max} allows faster resynthesis of phosphocreatine (Tomlin & Wenger, 2001). The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT-1) and an RSA test (6x40 m, 20+20 m, with a 180° turn) were compared by Pareja-Blanco et al. (2016). They found that an aerobic intermittent field test is better than a continuous one ($r = -0.62$, $p < 0.05$). Consequently, Campa et al. (2019) reported that YYIRT-1 correlates more strongly with RSA than other factors, such as body composition or jump performance, in a study of 36 Italian football players (16.6 ± 0.5 years), including 19 professionals and 17 non-professionals. Nevertheless, VO_{2max} seems to be a poor indicator of RSA and is more commonly associated with anaerobic patterns (Thurlow et al., 2024).

In South America, a study presented the physical characteristics of Brazilian football players (Loturco et al., 2018), where apparently, neuromuscular training is ineffective in the different categories of a professional team. Also, Da Silva et al. (2008) reported maximal oxygen uptake differences between Brazilian and European football regarding anthropometric values and VO_{2max} profiles. However, physical information about South American and particularly Colombian professional and amateur football is very limited in the scientific literature. Therefore, this study seeks to contribute to impact and promote scientific production and support coaches, strength and conditioning professionals, physical therapists, and medical staff. According to the precedents, this study aimed 1. to explore the RSA test (8 x 30 m) with 25 seconds of jogging recovery and 2. to determine the relationship between RSA VO_{2max} in a team of elite football players from Colombia.

Methods

Participants

Twenty-four male youth football players between the ages of 18 and 25 comprised the sample. All participants have more than five complete seasons of competitive soccer experience registered, and they were part of the same team, competing in the A category of the Antioquia Football League (Colombia), which aligns with Tier 3, well-trained/national level, according to the participant classification system (McKay et al., 2022). In terms of training, the players adhered to a regimen of five sessions per week, each lasting 80 minutes, in addition to participating in a competitive match. The inclusion criteria were outfield players who had no injury or illness during the assessment intervention and had at least 8 years of experience. On the other hand, the exclusion criteria were players older than 25 years or players who experienced important muscle/skeletal injuries in the last six months after passing the pre-medical evaluation conducted by the medical department of Indeportes Antioquia (a provincial entity). This research excluded players not registered in the national health system. Table 1 summarises the anthropometrical and age variables.

Procedures

All measurements were taken in the same sequence and conditions on Day 1 on Wednesday: basic information, anthropometry, and assessment of maximal oxygen consumption. Day 2 on Friday: The RSA Test. The first assessment day was preceded by 24 hours of rest following the last session, and the second assessment day also had a 24-hour rest.

The club of habitual training (VO_{2max} and RSA) conducted the assessments at 8:00 a.m. with 24°C of temperature and 60% humidity. The main coach divided the players into groups of eight and guided them through a standardised warm-up, explaining the protocol to participants who had prior experience. Four trainers participated in these evaluations: the primary trainer (seven years of experience), the fitness trainer (15 years of experience), a guest coach (eight years of experience), and a professional sports expert. Each trainer was assigned specific responsibilities: one managed the audio cues for the testing protocol, another provided verbal encouragement to motivate athletes to perform at their best, while the remaining two recorded performance data for four athletes each. Familiarisation tests were performed one week before the test.

Anthropometry

Anthropometric measurements included height and body mass, which were realised by the same observer who wore lightweight clothing and no shoes. The measurements were taken using a stadiometer (Seca 222, Hamburg, Germany) with a precision 0.1 cm and a scale (Seca 634, Hamburg, Germany) with a precision 0.01 kg). The laboratory conducted these measurements according to standardized procedures, which included refraining from eating or drinking any liquids for three hours before the measurements, refraining from diuretics for seven days before the measurements, and ensuring the absence of any metallic elements in the body.

Test

VO_{2max} was assessed using the Course Navette test (Léger et al., 1988), which involves running back and forth along a 20-metre track (Figure 1). The protocol begins at a speed of 8.5 km/h and increases by 0.5 km/h every minute, following auditory beeps. The test concludes when the participant voluntarily stops or is unable to maintain the required minimum speed. The maximum number of failures for participants is two, which is defined as failing to reach the 20-metre mark with both feet before the auditory signal. The club and the research don't have the tools to do the measurement treadmill testing with gas exchange, and the ecological validity and reliability of the beep test support it (Aziz et al., 2007; Castagna et al., 2019; Impellizzeri et al., 2008)

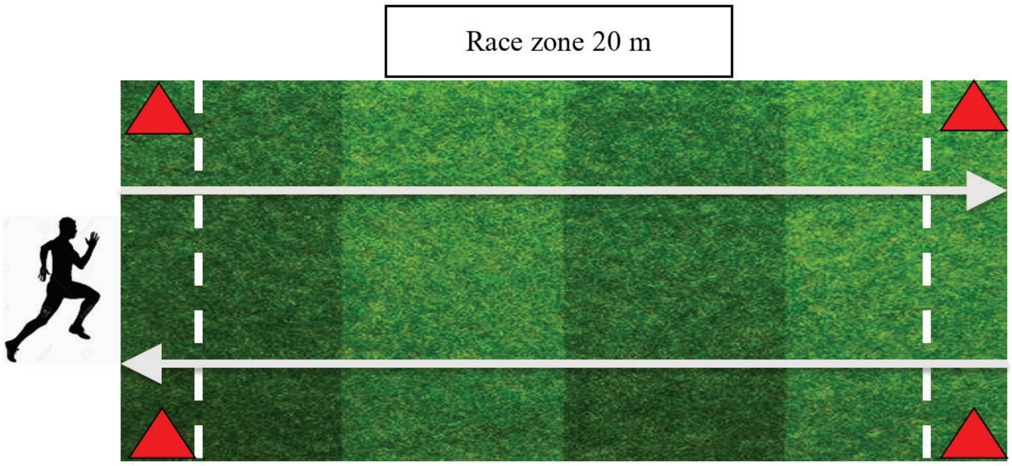

Figure 1. Course Navette test.

The RSA test comprised eight 30-metre maximal sprints with 25 seconds of active recovery (Rodriguez-Fernandez et al., 2017). The individuals moved past the photocells at the finish line before jogging back to the starting line to repeat the sprints (Figure 2). The athletes had to position themselves 0.5 m behind the starting line (DSDLaser System®, DSDInc., León, Spain) to avoid activating the first photocell before the test began (Chaouachi et al., 2010). The intraclass correlation confidence (ICC) was 0.71 (95% confidence interval (CI), 0.45-0.90), and the coefficient of variation (CV) was 6.8% of the data.

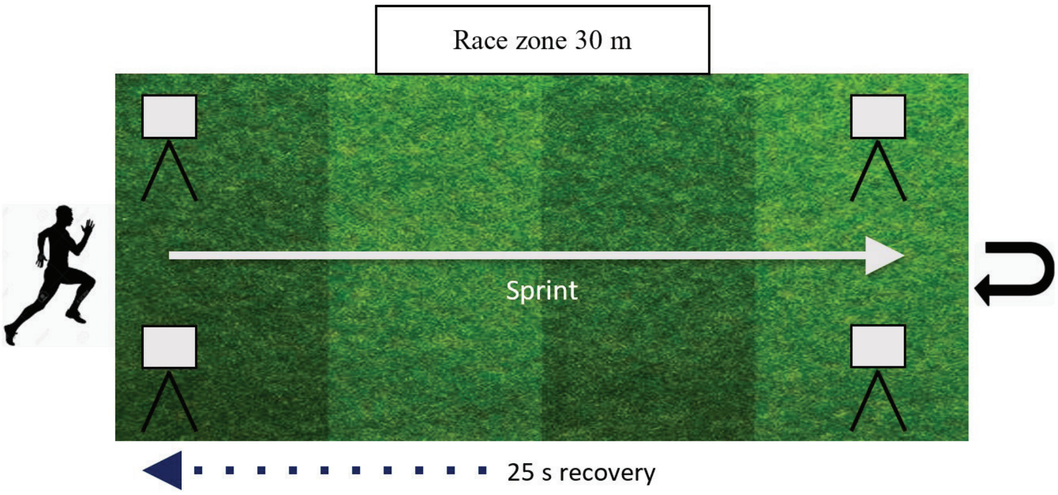

Figure 2. Repeated sprint ability test

Analysis

Descriptive statistics were performed, including the mean and standard deviation for age, height, body mass, oxygen consumption, and RSA (Table 1). The equations of the RSA percentage decrement score (Sdec) and the fatigue index (FI) were calculated (Girard et al., 2011).

$$\text{(Equation 1) } S_{dec}(\%) = \left[\left(\frac{S_1 + S_2 + S_3 + S_{final}}{S_{best} \text{ x N}}\right) - 1\right] x\ 100$$

$$\text{(Equation 2) FI } = \left(\frac{S_{best} - S_{worst}}{S_{best}}\right) x\ 100$$

A description of the performance by each sprint and Spearman correlations to RSA outputs of Sdec, FI, and VO_{2max} was performed. Subsequently, a correlation between the VO_{2max} (mL/kg·min) and RSA time total (T.T.) was plotted. A power sample was obtained using the G*power tool (V.3.1.9.7, University of Düsseldorf, Germany). It was based on a post hoc analysis of the bivariate normal model with a result of actual power of (1-β) 0.73.

For inferential statistics, a significance level of 5%

was used, and the correlation coefficients were interpreted according to Hopkins et al. 2009: trivial (r<0.1), small (0.1<r<0.3), moderate (0.3<r<0.5), large (0.5<r<0.7), very large (0.7<r<0.9), and nearly perfect (r>0.9). The statistical packages IBM SPSS version 27 software (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 8 (GraphPad Software, San Diego, California, USA, www.graphpad.com) were used.

Table 1. Descriptive information of the sample (n = 24)

Variable	Unit	Mean	SD
Age	years	20.21	0.39
Height	cm	172.96	6.99
Body mass	kg	69.00	6.78
VO_{2max}	L/min	3.32	0.07
VO_{2max}	mL/kg·min	48.31	4.27
RSA T.T.	s	36.24	2.08
RSA speed mean	km/h	23.90	1.25
RSA speed max	km/h	25.24	1.04

Note. RSA T.T.= Repeated sprint ability expressed in total time (s)

Results

The descriptive statistics are summarised in Table 2. The mean time in each sprint increases between each repetition until it reaches 30 tenths of the difference between the first and the eighth sprints (7% slower). The minimum value represents the best sprint the athletes had, and these scores increased progressively across repetitions, with the 6th sprint being 19 tenths slower than the fastest initial sprint (5% slower) and the maximum values, which in turn represent the worst sprint that the athletes had, there is a difference of 1 second and 26 tenths (26% slower), although it is not a constant incremental value. The worst records of the maximum values are in the last four sprints.

Table 3 shows the Spearman correlations. The best RSA

Table 2. Descriptive statistics in the RSA by each sprint, percentage decrement and fatigue index for the total sample (n = 24)

Variable	Unit	Mean ± SD	Minimum	Maximum
First sprint	s	4.36 ± 0.26	3.97	5.25
Second sprint	s	4.40 ± 0.17	4.06	4.74
Third sprint	s	4.51 ± 0.24	4.07	5.03
Fourth sprint	s	4.51 ± 0.25	4.11	5.50
Fifth sprint	s	4.55 ± 0.36	4.13	6.00
Sixth sprint	s	4.61 ± 0.40	4.16	5.91
Seventh sprint	s	4.61 ± 0.35	4.07	5.66
Eighth sprint	s	4.66 ± 0.42	4.15	5.94
RSA mean	s	4.53 ± 0.26	4.15	5.42
RSA best sprints	s	4.28 ± 0.18	†	4.70
RSA worst sprints	s	4.74 ± 0.43	4.28	††
RSA S_{dec}	%	-5.80 ± 5.40	-21.66	-2.32
RSA FI	#	-10.96 ± 10.58	-44.17	-2.32

Note. RSA S_{dec}: percentage decrement score of the repeated sprint ability; RSA FI: fatigue index of the repeated sprint ability; †: same score of the best minimum values; ††: same score of the worst maximum values

Table 3. Spearman correlations between each sprint time, indicators of fatigue and $VO_{2\,max}$

Variable	Best sprint	Worst sprint	RSA FI	RSA S dec (%)	VO_{2max} L/min	VO_{2max} mL/kg·min
First sprint	0.702†	0.337	0.241	0.211	-0.241	-0.281
Second sprint	0.611†	0.438*	0.067	-0.002	-0.107	-0.221
Third sprint	0.259	0.732†	-0.446*	-0.463*	-0.140	-0.320
Fourth sprint	0.420*	0.723†	-0.311	-0.337	-0.463*	-0.617†
Fifth sprint	0.429*	0.612†	-0.268	-0.362	-0.225	-0.408*
Sixth sprint	0.266	0.760†	-0.447*	-0.457*	-0.320	-0.426*
Seventh sprint	0.225	0.755†	-0.447*	-0.457*	-0.408*	-0.250
Eighth sprint	0.196	0.890†	-0.520†	-0.532†	-0.262	-0.437*

Note. RSA FI: fatigue Index of RSA; RSA Dec%: Percent of decrease RSA; *p < 0.05, †p < 0.01

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sprints this sample got (minimum sprint) are linked to the first and second sprints first and second sprints (1st, 2nd) $p < 0.01$, and the fourth and fifth sprints (4th, 5th) $p < 0.05$. On the other hand, the RSA worst sprints achieved are associated with all sprints except the first one (1st).

RSA FI and RSA S dec (%) had a relation of $p < 0.05$ with the third, sixth, and seventh sprints and $p < 0.01$ with the last sprint (8th). Finally, VO_{2max} L/min was related to the fourth and seventh sprints (4th, 7th) $p < 0.05$, and VO_{2max} mL/kg·min was related to better scores in the final part of the RSA test, the fourth sprint (4th) $p < 0.01$; and the fifth, sixth, and eighth sprints (5th, 6th, 8th) $p < 0.05$.

Figure 3 shows the connection between the maximum oxygen consumption VO_{2max} (mL/kg·min) and the RSA, which is shown in T.T. (s). It indicates that there is a moderate relationship r = -0.422, 95% CI -0.711 to -0.010, p = 0.039.

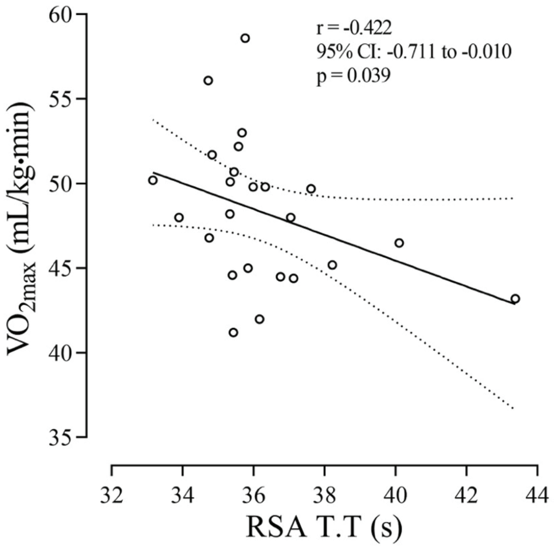

Figure 3. Relationship plot between estimated VO_{2max} and RSA. RSA T.T: repeated sprint ability expressed in total time (s)

Discussion

The aim of this study was to explore the RSA test and determine the relationship between RSA and VO_{2max} in a team of elite football players from Colombia. At first, the mean time values and best records trended to increase throughout the RSA test; the worst records of the maximum values were the last four sprints. Secondly, the faster sprints were primarily associated with the first and the second sprints (1st, 2nd), reaching a mean of 25.24±1.04 km/h of maximal speed; the slower sprints were associated with all repetitions of sprints, with the exception of the 1st. Thirdly, VO_{2max} mL/kg·min was related to better scores in the last part of the RSA test (4th, 5th, 6th, 8th); finally, there is a relationship inversely proportional between RSA and VO_{2max}.

The results were due to the nature of the RSA, i.e., performance decreases when the repetitions are executed (Girard et al., 2011); from a simple point of view, it appears to be logical that the best records are always in the first and second repetitions, but they can vary depending on how familiar athletes are with the test (Rampini et al., 2007; Girard et al., 2011); in this case, the familiarisation with the test was performed one week before the test. Studies that looked at RSA by each repetition time inform that faster sprints are not always done in the first two repetitions (1st and 2nd). Sometimes the RSA has to be stopped, and the protocol has to be repeated to make sure that all the tests are done with the most effort (Rampini et al., 2007); however, the first repetition can show the fastest speed possible (Pareja-Blanco et al., 2016). The best sprint and the mean time are usually analysed in RSA (Campa et al., 2019; Chaouachi et al., 2010), and it is also recommended to compare the best sprint time as well as their entire sprint time from an RSA test (Pareja-Blanco et al., 2016). It allows an understanding of the parts and logical workings of the RSA; it is the primary variable in the formula to determine FI and the percentage of performance decline scores (Girard et al., 2011).

This study found relationships between VO_{2max} mL/kg·min and scores of the last part of the RSA test (4th, 5th, 6th, 8th sprints); it can explain that maybe the main contribution of the VO_{2max} is related to maintaining the performance in the last repetitions of RSA (Taylor et al., 2015). The mean speed of the sample was 23.90±1.25 during the RSA, values that exceeded the maximal aerobic speed (MAS) and trended to decrease performance. Different studies associated velocity with the maximal oxygen uptake in football players; for instance, 16 semi-professional Italian players aged 22.1±1.8 participated in a study that described that the maximal aerobic speed (MAS) can vary within 16.1-19.4 in continuous and discontinuous tests in different protocols of VO_{2max} on treadmills (Riboli et al., 2022).

It is possible that players who have a better MAS do not depend on a magnificent relative VO_{2max} mL/kg·min to get a constant RSA, avoiding an increase in the percent performance decline score % / FI in the last part of the test (5th, 6th, 7th, 8th). Still, Olsen et al. (2023) looked at a MAS (15.1 km/h) and a mean sprint time of 20 m (20.0 km/h) in 17 semi-professional players aged 19±4 and found a strong correlation (r = 0.76, SEE = 3.6%). This means that MAS seems to affect RSA.

This study demonstrated a moderate relationship between RSA and VO_{2max}. Similar findings were reported by Chaouachi et al. (2010), who observed a correlation between Yo-Yo IR1 performance and best RSA time (r = -0.44, p = 0.04). Likewise, Yo-Yo IR1 performance and TT showed a comparable association (r = 0.40, $p < 0.05$) in a sample of twenty-three soccer players (age: 19 ± 1 years; height: 181 ± 5.7 cm; body mass: 73.2 ± 4.1 kg) undergoing an RSA test (7 × 30 m with 25-second recovery). Moreover, previous research has linked VO_{2max} with RSA, generally demonstrating positive associations (Girard et al., 2011). For instance, Pareja-Blanco et al. (2016) found a significant correlation ($r = -0.62$, $p < 0.05$), as did Campa et al. (2019) ($r = -0.79$, $p < 0.01$) and López-Segovia et al. (2015), who reported a correlation between YYIRT-1 and RSA mean time ($r = -0.78$, $p < 0.01$) in a sample of twenty-one Spanish under-19 national-level players.

The strength of the correlation between the aerobic beep field test and RSA varies, indicating that there is no clear and consistent unique result. In fact, VO_2max sometimes appears to be a poor predictor of RSA, showing stronger correlations with anaerobic activity instead (Thurlow et al., 2024). To the author's knowledge, this study is the first to examine the relationship between VO_2max and RSA in Colombian football players competing in the First A category of the Antioquia Soccer League (Colombia), which corresponds to a Tier 3, highly trained/national level. Consequently, the findings of this study contribute to the field of sports science.

It is important to note that RSA results on a cycle ergometer may yield lower correlation values, potentially due to VO_2max being primarily influenced by central factors such as fatigue, whereas RSA performance is largely determined by locomotor factors (Mendez-Villanueva et al., 2007). On treadmills, different VO_2max testing protocols exist, including continuous and discontinuous methods. Although treadmill tests are considered the gold standard for assessing VO_2max, final results can vary depending on modifications, potentially altering associations with maximal speed and maximal effort in players (Riboli et al., 2022). Undoubtedly, speed capacity is fundamental for top-level football players (Impellizzeri et al., 2008). For instance, in UEFA Champions League matches, high RSA is evident in total running volumes exceeding 25 km/h (Bradley et al., 2014).

This study has certain limitations, primarily related to sample size, fat mass estimation, and potential bias due to the indirect measurement of VO_2max using the beep test (Course Navette). The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT-1) is more commonly used in football and has gained ecological validation in recent years within sports science research. Furthermore, previous research has practical applications; however, it may not fully capture training characteristics. Nevertheless, it provides valuable insights, encouraging coaches and physical trainers to assess football-related abilities through intermittent tests of VO_2max and sprint repetition. Additionally, ecologically valid field tests can serve as useful tools for performance quantification, particularly in developing countries.

Conclusion

In conclusion, RSA expressed in mean time and best sprints trended to increase progressively across repetitions (being 7% slower); first and second sprints (1st and 2nd) were associated with faster sprints, and VO_{2max} mL/kg·min was related to the final part of the RSA test (4th, 5th, 6th, and 8th sprints). There is a moderated relationship between RSA and VO_{2max}, mL/kg·min in this sample of Colombian youth football players, it means there are no confirmed direct training implications. Finally, this study promotes that RSA and VO2 max should be assessed in football players and developed countries use the ecological validity of field tests as a tool for the quantification of abilities.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical approval

This study was approved in advance by Institute of Physical Education and Sports at the University of Antioquia (Act # 074 on March 23, 2021). Each participant voluntarily provided written informed consent before participating.

Data availability statement

Data available on request.

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