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Redefining endurance testing in soccer: the reliability and impact of a ball-integrated yo-yo intermittent recovery test

Redefiniendo las pruebas de resistencia en el fútbol: fiabilidad e impacto de una prueba yo-yo intermitente con balón integrado

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Abstract

The Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo) is a widely recognized method for assessing aerobic capacity in soccer players. Despite its utility, the test does not incorporate ball manipulation, which is a critical component of soccer-specific endurance. This study aimed to evaluate the reliability of a modified soccer-specific Yo-Yo test (MYo-Yo) that includes ball dribbling, passing, and control, and to compare the physiological responses with those from the conventional Yo-Yo test. Twenty elite male soccer players (mean ± SD: age, 16.4 ± 1 years; height, 173 ± 7 cm; body mass, 65.7 ± 10.4 kg) completed both Yo-Yo tests, with and without ball manipulation. Performance metrics included the number of completed shuttles (Level), total distance covered (Distance; m), and blood lactate concentration (Lactate; mmol/L), while maximal oxygen consumption (V̇O2 max; ml/min/kg) was estimated for all trials. The modified Yo-Yo test (MYo-Yo) demonstrated high reliability, with Intraclass Correlation Coefficients (ICC) of 0.802 for Level, 0.982 for Distance, 0.997 for V̇O2 max, and 0.992 for Lactate ($P \leq 0.001$). Comparatively, the MYo-Yo test resulted in significantly lower distances than the standard Yo-Yo test (832 vs. 1520 m, respectively; $P < 0.001$) and lower lactate concentrations (5.2 vs. 10.9 mmol/L; $P < 0.001$). No significant correlations were found between the two tests for outcomes ($P > 0.05$). In summary, integrating ball manipulation in the MYo-Yo test introduces distinct physical and technical demands that influence overall performance. The MYo-Yo test offers a reliable alternative for assessing soccer-specific endurance, better replicating the physical demands encountered during a soccer match.

Keywords

Aerobic capacity, soccer-specific endurance, blood lactate, cognitive function, vo2max

Resumen

El Yo-Yo Intermittent Recovery Test Nivel 1 (Yo-Yo) es un método ampliamente reconocido para evaluar la capacidad aeróbica en jugadores de fútbol. A pesar de su utilidad, la prueba no incluye la manipulación del balón, un componente crucial de la resistencia específica del fútbol. Este estudio tuvo como objetivo evaluar la fiabilidad de una prueba Yo-Yo modificada y específica para el fútbol (MYo-Yo), que incluye el regate, pase y control del balón, y comparar las respuestas fisiológicas con las de la prueba Yo-Yo convencional. Veinte jugadores de fútbol masculinos de élite (media ± DE: edad, 16.4 ± 1 años; altura, 173 ± 7 cm; masa corporal, 65.7 ± 10.4 kg) completaron ambas pruebas Yo-Yo, con y sin manipulación del balón. Las métricas de rendimiento incluyeron el número de lanzaderas completadas (Nivel), la distancia total recorrida (Distancia; m) y la concentración de lactato en sangre (Lactato; mmol/L), mientras que se estimó el consumo máximo de oxígeno (V̇O2 máx; ml/min/kg) en todas las pruebas. La prueba Yo-Yo modificada (MYo-Yo) demostró alta fiabilidad, con Coeficientes de Correlación Intraclase (CCI) de 0.802 para el Nivel, 0.982 para la Distancia, 0.997 para V̇O2 máx, y 0.992 para el Lactato ($P \leq 0.001$). Comparativamente, la prueba MYo-Yo resultó en distancias significativamente menores que la prueba Yo-Yo estándar (832 vs. 1520 m, respectivamente; $P < 0.001$) y menores concentraciones de

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lactato (5.2 vs. 10.9 mmol/L; P < 0.001). No se encontraron correlaciones significativas entre las dos pruebas para ningún resultado (P > 0.05). En resumen, la integración de la manipulación del balón en la prueba MYo-Yo introduce demandas físicas y técnicas distintas que influyen en el rendimiento general. La prueba MYo-Yo ofrece una alternativa confiable para evaluar la resistencia específica del fútbol, replicando mejor las demandas físicas que se encuentran durante un partido de fútbol.

Palabras clave
capacidad aeróbica, resistencia específica de fútbol, lactato en sangre, función cognitiva, vo2máx

Introduction

Soccer matches are distinguished by their intermittent, high-intensity nature, featuring brief recovery periods (Paes & Fernandez, 2024). Consequently, aerobic capacity greatly influences running performance (Fink et al., 2024). Moreover, individuals with higher aerobic endurance can execute more sprints and cover more ground throughout the game (Shahidi et al., 2023). Therefore, a high level of aerobic fitness facilitates the maintenance of a high work rate and aids in swift recovery between short, intermittent periods of intense exertion during the match (Grgic et al., 2022). High aerobic capacity levels also enable athletes to sustain prolonged effort levels and execute repeated bursts of high-intensity actions, which is particularly crucial in soccer, where players frequently engage in intense activities such as sprinting, jumping, and changing directions (Hulton et al., 2022). Thus, aerobic capacity plays a pivotal role in determining players' overall performance in soccer, where the ability to recover rapidly during brief breaks in play is vital for maintaining a consistent performance throughout the match (Pedersen et al., 2022). The Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo) is the most commonly employed field test for estimating V̇O2max, a measure of aerobic capacity, requiring players to engage in a back-and-forth running pattern closely resembling the movement patterns observed in soccer (Paes & Fernandez, 2024). The Yo-Yo test has demonstrated high accuracy and reproducibility compared to directly measured V̇O2max values obtained in laboratory settings for soccer players (Briscoe et al., 2024). Despite its popularity, it is worth noting that the Yo-Yo test, while involving variable speed running with frequent

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changes in direction, does not replicate the intricate nature of soccer-specific activities (Michailidis, 2024). Consequently, aerobic endurance assessment in soccer players has been criticized because commonly employed tests, including the Yo-Yo, do not emulate the activities performed during a soccer match (Grgic et al., 2022). In soccer, players continuously run with the ball for 90 minutes, a crucial game aspect not captured by the existing assessment protocols (Póvoas et al., 2016). While the Yo-Yo test provides valuable information, it does not encapsulate soccer-specific endurance demands (Dieter Deprez, Job Fransen, et al., 2015). One key aspect of this criticism is the lack of sport specificity in the commonly used tests. Soccer depends on aerobic and anaerobic energy production, rapid changes in intensity, frequent accelerations, decelerations, and direction changes (Briscoe et al., 2024). However, traditional endurance tests focusing primarily on continuous running or repetitive shuttle sprints do not fully capture these dynamic and unpredictable movements. Ball manipulation during the Yo-Yo could increase the assessment's specificity for soccer-specific fitness assessment and exercise prescription (Silva et al., 2011). Therefore, the current study assessed the reproducibility of a soccer-specific modified Yo-Yo test among elite soccer players while comparing the physiological responses to the conventional Yo-Yo assessment. It was hypothesized that the modified Yo-Yo test would present high levels of reliability but different physiological demands to the conventional assessment.

Material and Methods

Twenty male elite soccer players (mean ± SD: age, 16.4 ± 1 years; height, 173 ± 7 cm; body mass, 65.7 ± 10.4 kg) from the Istanbul Soccer Academy volunteered to participate in the study, with goalkeepers excluded from the investigation. The participants were not injured or taking any medication before or during testing. Before participating in the study, all players and their parents or legal representatives were informed about the experimental procedures. They provided written informed consent, with permission obtained from underage players, indicating their voluntary agreement to participate in the research. The Istanbul Gedik University Ethics Committee approved the study under the ethical approval number E-56365223-050.01.04-

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2022.137548.115 – 374. A repeated measures study design was conducted to examine the reproducibility of a Yo-Yo Intermittent Recovery Level 1 test (Yo-Yo) that included ball manipulation (modified Yo-Yo test; MYo-Yo) and how it compares to the conventional Yo-Yo assessment. Following a familiarisation session on a separate day, where anthropometric measures were obtained, the participants performed the Yo-Yo and the MYo-Yo tests 48 hours apart (Figure 1), with both testing sessions conducted at the same time of day. Both tests were repeated one week later to evaluate the test-retest reliability of the MYo-Yo compared to the Yo-Yo test. All test sessions were preceded by a 15-minute warm-up, including 5 minutes of sub-maximal running, followed by 5 minutes of dynamic stretching exercises involving hip flexion/extension, hip abduction/adduction, low-intensity forward, sideways, and backward running, progressively intensified jumping and acceleration runs. To ensure consistency and control for potential confounding factors, the training regimen in the days leading up to the testing sessions was standardized, with participants wearing the same running shoes and maintaining their usual dietary intake on the day of testing. All assessments were conducted at the same indoor venue, ensuring similar environmental conditions.

Yo-Yo and MYo-Yo assessment

The participants performed the Yo-Yo test, as outlined by Krustrup et al. (P. Krustrup et al., 2003), valid and reliable for evaluating aerobic capacity, endurance performance, and estimating V̇O2 max (Bangsbo et al., 2008; Peter Krustrup et al., 2003). In brief, the athletes performed repeated shuttle runs between two lines set 20 meters apart, with another five meters used to allow deceleration (Figure 1). Starting the test from the middle line, the participants ran toward the top cone in synchrony with an audible signal before turning and returning to the starting point. Subsequently, they were allowed 10 seconds to complete the 5-meter deceleration zone before returning to the starting point in a stationary stance. The test was terminated when unable to reach the marker before the subsequent audio signal for two consecutive shuttle runs. The same setup was used for the MYo-Yo test. However, during each shuttle run, the MYo-Yo test required ball interaction, including dribbling, passing, and control, based on individual preferences and skills. Test administrators monitored adherence to the rules,

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including false starts or incomplete shuttles, with participants receiving warnings for non-compliance. The distance covered during the test was recorded in meters. To estimate VO2 max, a regression equation was used based on the distance covered (Krustrup et al., 2003): VO2max (ml/kg/min) = 31.025 + (3.238 × distance covered in meters) - (3.248 × participant's body weight in kilograms).

Blood Sampling

Blood lactate sampling was collected to analyze the level of fatigue during both assessments. After each trial, blood lactate samples (La-) were collected from the participants' fingertips. The fingertips were cleaned with an alcohol swab to ensure proper hygiene and to remove any contaminants that could affect the accuracy of the measurements. The blood samples were obtained from the participants' fingertips and promptly analyzed using a Lactate Plus analyzer (Nova Biomedical; Waltham, MA, USA). The Lactate Plus analyzer is a portable device designed to measure blood lactate levels rapidly and accurately by enzymatic amperometric detection. It uses an enzymatic electrochemical reaction to measure lactate concentrations in whole blood samples. Blood lactate reacts with the reagent on the test strip, which produces a small electrical current proportional to the blood lactate concentration. The Lactate Plus analyzer requires 0.3 µl of a whole-blood sample and 15 s to measure the lactate value, with a measurement range between 0.5–25.0 mmol/L. When "Hi" or "Lo" appear on the display, the blood lactate level is above 25.0 mmol/L or below 0.5 mmol/L, respectively.

Statistical analyses

All statistical analyses were conducted using SPSS, version 25 (SPSS Inc., Chicago, IL). Descriptive statistics are presented as mean values and standard deviations (SD). The normality assumption was assessed and confirmed using the Shapiro-Wilk test. The significance level was set at $p \leq 0.05$.

Reliability assessment

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A paired Student's t-test was used to examine differences between the initial assessment and the retest to evaluate the reliability of both assessments. The validity was established by assessing the relationship between Yo-Yo and MYo-Yo via the Intraclass correlation coefficient (ICC). ICC data were calculated using the following parameters: (1) model: two-way mix effects; (2) type: average rates; and (3) definition: consistency. An ICC with a value greater than 0.90 was considered excellent, and an ICC with a value between 0.75 and 0.90 was considered good with a 95% confidence interval (CI). The Absolute reliability of the standard error of measurement (SEM) and minimum detectable change (MDC) with a 95% confidence interval was calculated by dividing the SD of the mean differences between the two measurements by the square root of 2 (SEM = SD × √ 1 - ICC). SEM % was defined as (SEM /X) x 100, where X is the mean for all observations from test sessions 1 and 2. MDC was calculated using the following formula: MDC = Z × SEM × √ 2, where z = 1.96 (based on 95% confidence), indicating the smallest observable change that is real and not due to measurement error in the measurement. To calculate MDC independent of the units of measurement, MDC% was defined as (MDC/X) x 100, with a smaller MDC indicating a more sensitive measure.

Comparative analysis between the Yo-Yo and MYo-Yo tests

A paired Student's t-test was used to compare the Yo-Yo to the MYo-Yo. Since there were no significant differences between the test and retest for either condition, the average between the test and retest was used for all variables examined. Finally, correlations between the Yo-Yo and MYo-Yo test results were calculated using the Pearson correlation coefficient (r). A significance level of 0.05 was chosen to determine statistical significance. The following criteria were adopted to interpret the magnitude of the correlation: "trivial" ($r < 0.1$), "small" ($0.1 \leq r < 0.3$), "moderate" ($0.3 \leq r < 0.5$), "large" ($0.5 \leq r < 0.7$), "very large" ($0.7 \leq r < 0.9$), "nearly perfect" ($0.9 \leq r < 1$), and "perfect" ($r = 1$).

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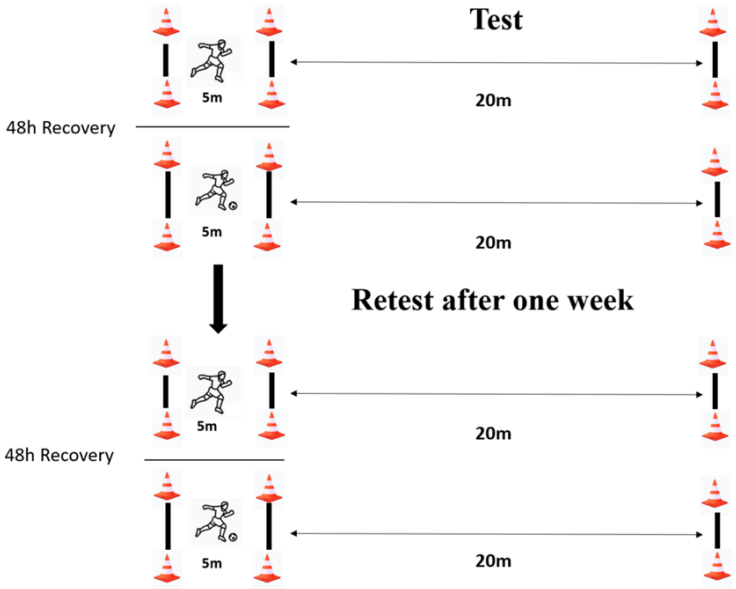

Figure 1. Schematic of the Yo-Yo Intermittent Recovery Test Level 1 without (Yo-Yo) and with ball manipulation (modified Yo-Yo test; MYo-Yo).

Results

Reliability assessment

The paired sample t-test revealed no significant differences between the test and retest results for the Yo-Yo and MYo-Yo for any variables examined ($P > 0.05$; Table 1, Figure 2). The ICC showed excellent agreement between the test and retest measurements, with ICC values ranging between 0.80 and 0.99 (Table 2). Finally, the SEM values for all tests' measurements were relatively "low" (< 5%), with the MDC95% limits of agreement "small" for all the variables.

Table 1. Mean ± SD for the Yo-Yo and MYo-Yo assessments for the test and retest conditions.

Variables	Yo-Yo (test)	Yo-Yo (retest)	MYo-Yo (test)	MYo-Yo (retest)
Completed levels	17.5 ± 0.5	17.1 ± 0.5	14.8 ± 0.6	14.8 ± 0.6
Shuttle (m)	1600.1 ± 175.1	1612.5 ± 150.3	734.5 ± 196.1	736.5 ± 196.6
VO2 max (ml/min/kg)	49.8 ± 1.4	47.7 ± 10	42.5 ± 1.6	42.5 ± 1.5
Lactate (mmol/L)	9.5 ± 2.1	9.6 ± 1.9	4.5 ± 1.4	4.5 ± 1.4

Figure 2. Comparison of Yo-Yo and MYo-Yo test and Retest Results

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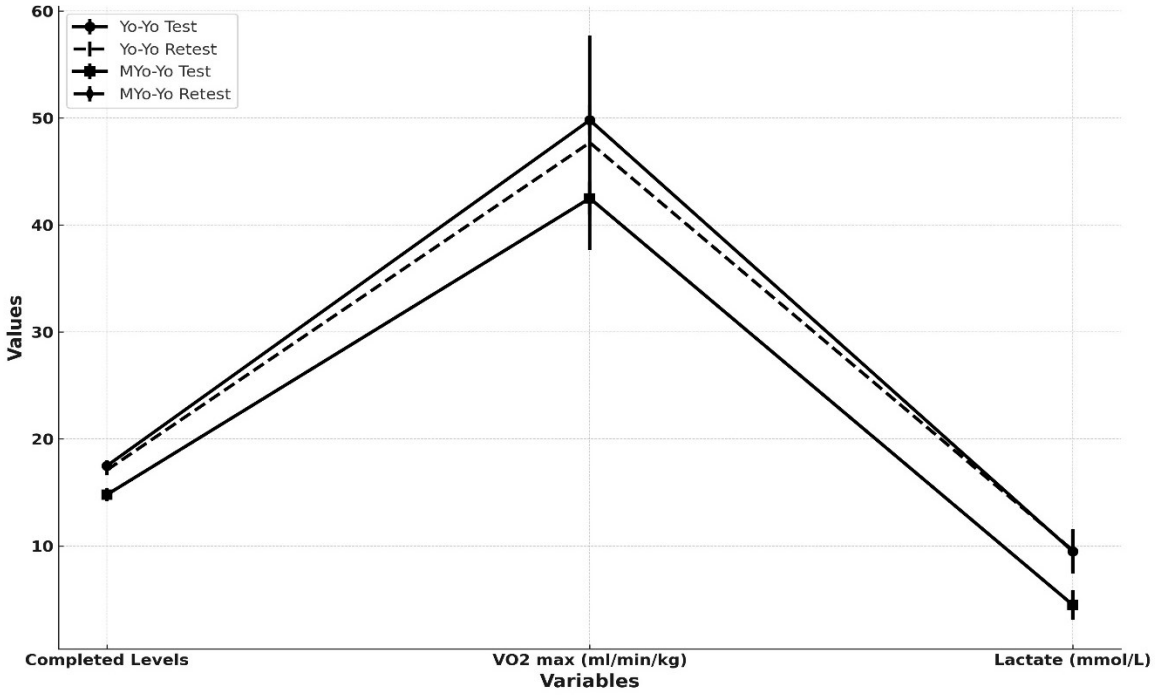

Note: This graph presents a comparison between the Yo-Yo and MYo-Yo test and retest results across three key variables: Completed Levels, VO2 max (ml/min/kg), and Lactate (mmol/L).

Table 2. Test-retest Reliability measures for Yo-Yo and MYo-Yo tests.

Variables	**ICC**	**%95 Cl (Lower - Upper)**	**Value**	**df1**	**P**
Level	0.802	0.2 - 0.9	4.946	19	0.001
Distance (m)	0.982	0.8 - 0.9	58.645	19	0.001
Vo2max (ml/min/kg)	0.997	0.9 - 0.9	48.696	19	0.001
Lactate (mmol/L)	0.992	0.9 - 0.9	129.02	19	0.001
Yo-Yo Test-Retest Reliability					
Variables	**ICC**	**%95 Cl (Lower - Upper)**	**Value**	**df2**	**P**
Level	0.98	0.23 - 0.10	3.895	19	0.001
Distance (m)	0.99	0.9 - 0.98	49.598	19	0.001
Vo2max (ml/min/kg)	0.98	0.9 - 0.9	223.3496	19	0.001
Lactate (mmol/L)	0.95	0.98 - 0.99	277.046	19	0.001

3.2. Comparative analysis between the Yo-Yo and MYo-Yo tests

A statistically significant difference was identified between the Yo-Yo and MYo-Yo tests ($P \leq 0.001$; Table 3).

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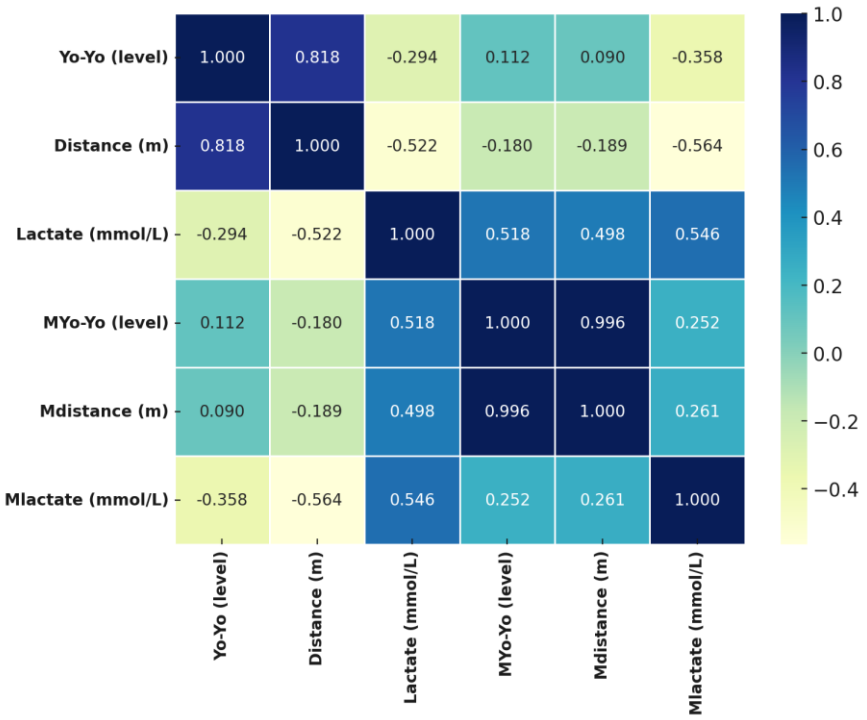
Table 3. Displays the descriptive statistics and results of the Paired t-test for the Yo-Yo and MYo-Yo tests.

Variables	*95% CI (L - U)*	*t*	*df*	*P*
(Yo-Yo) – (MYo-Yo)	**2.2 - 2.8**	**15.746**	**19**	**0.001**
(Distance) - Mdistance (m)	**741.2 - 10**	**14.068**	**19**	**0.001**
(VO2max) – (MVO2max) (ml/min/kg)	**3.4 - 9**	**4.65**	**19**	**0.001**
(Lactate) – (MLactate) (mmol/L)	**4.2 - 5.8**	**13.015**	**19**	**0.001**

Not: M: modified (with ball)

The results of the Pearson correlation coefficient are shown in Figure 2. The correlations between the Yo-Yo and MYo-Yo tests vary across different performance metrics. The strongest relationship is observed in lactate levels, where a moderate positive correlation indicates some consistency between the two tests. However, the correlations for performance levels and distances are weak. The Yo-Yo and MYo-Yo tests might measure slightly different aspects of an individual's physical capabilities or the performance in one test does not strongly predict performance in the other.

Figure 2. Correlation matrix heatmap



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Note: Blue/Teal Shades: Indicate positive correlations. The stronger the correlation, the more intense the blue/teal color. Yellow/Green Shades: Indicate negative correlations. The stronger the negative correlation, the more intense the yellow/green col

Discussion

This study examined the reliability of a modified Yo-Yo test to assess intermittent high-intensity endurance capacity in a sport-specific context and compared the Yo-Yo performed with and without a ball. The findings of this study revealed that the MYo-Yo test resulted in slightly lower distances covered than the Yo-Yo, which suggests that a ball during the test introduces additional physical and technical demands on the players, impacting their overall performance. The requirement to control and manipulate the ball while running at high intensities may lead to increased energy expenditure and potentially affect the player's ability to sustain running speed and endurance. The reduced distances covered during the test with a ball should not be solely attributed to a decline in physical fitness but rather to the added technical and cognitive aspects required, emphasizing the need for a balanced approach when evaluating performance in soccer-specific fitness tests that include technical components (Dieter Deprez, Martin Buchheit, et al., 2015; Dieter Deprez, Job Fransen, et al., 2015; D. Deprez et al., 2015). Moreover, analyzing the physiological responses during both versions of the Yo-Yo test provided further insights. The study's findings reveal a noteworthy disparity in blood lactate levels among participants engaged in the Yo-Yo test with and without incorporating a ball. Specifically, it was observed that individuals undertaking the Yo-Yo test with the inclusion of a ball exhibited diminished blood lactate concentrations. This outcome underscores the proposition that the mere presence of a ball introduces augmented technical requisites and heightened cognitive processing demands (Matthys et al., 2013; Silva et al., 2011; Vernillo et al., 2012).

Hence, the ball's involvement appears to restrict athletes from attaining their maximum exertional capacities. Considering the sport-specific nature of soccer and the integration of technical skills with physical fitness, the MYo-Yo test can be a valuable tool for assessing a player's ability to sustain high-intensity efforts while simultaneously handling a ball. It, therefore, provides a more ecologically valid representation of the

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demands faced during a soccer match compared to the test performed without a ball (Bangsbo & Fiorenza, 2016; Schmitz et al., 2018, 2019). However, it is essential to consider the trade-off between technical demands and physical performance when interpreting the MYo-Yo test results. Therefore, both Yo-Yo versions offer distinct insights into a player's intermittent high-intensity endurance capacity. The Yo-Yo provides a standardised assessment of physical fitness, while the MYo-Yo incorporates the specific technical demands of soccer (Bangsbo et al., 2008; Peter Krustrup et al., 2003). Aligned with the principal emphasis of our study, the investigation pertained to the discernment of the impact emanating from the incorporation of a ball on the outcomes derived from sprint and agility assessments within the realm of basketball players. This encompassed evaluations conducted both in conditions involving ball engagement and those where the ball was absent. The findings unveiled conspicuous differentiations between these two discrete conditions. Significantly, the introduction of the ball engendered a palpable influence, evidenced by participants manifesting moderately subdued sprint times. This attenuation was attributed to the additional mass introduced by the ball, coupled with the attendant modifications in biomechanical dynamics consequent to its manipulation. In tandem with this observation, the outcomes yielded by agility assessments disclosed a thought-provoking pattern. When executing agility tasks in concert with ball manipulation, participants exhibited marginal reductions in performance times. This decrement was ascribed to the requisite demand of managing the ball during the agility tasks, thereby imparting a discernible impact upon the fundamental mechanics governing directional modifications (DiCesare et al., 2019; Vernillo et al., 2012; Yanci et al., 2015).

The selection between the two variants of the Yo-Yo test, namely with and without the inclusion of a ball, should be contingent upon the distinct aims underpinning the assessment and the contextual framework within which it is administered in the context of youth soccer players. Further study is warranted to examine the relationship between the Yo-Yo and MYo-Yo by measuring heart rate during soccer matches, offering valuable insights into the applicability and effectiveness of the test in assessing players' abilities in real-game situations. Finally, there is a need for further investigation into the relationship between anthropometric measurements and

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Yo-Yo test results and to understand the multifactorial influence of variables such as training status, genetics, and physiological adaptations. From a youth soccer player assessment context, the Yo-Yo test with ball emerges as a compelling tool for holistic evaluation. Its integration of technical, cognitive, and physiological dimensions reflects the multifaceted demands of the sport. By offering insights into players' ability to navigate intricate scenarios while maintaining physical intensity, this test variant can refine training approaches, optimize player development, and elevate the precision of performance evaluation.

Conclusion

The study's findings would yield pertinent insights with practical ramifications for coaches, trainers, and professionals engaged in soccer development. In the event that the training protocol incorporating ball-handling activities exhibits a discernibly superior efficacy in augmenting dribble skills, it could potentially infer the constructive influence of embedding ball-centric exercises within training regimens and assessment frameworks. Such a conclusion may prompt a reevaluation of coaching strategies and the implementation of pedagogical methodologies that encompass ball engagement. In conclusion, the findings of this study suggest that the MYo-Yo introduces additional physical and technical demands on soccer players, resulting in slightly lower distances covered than the Yo-Yo. However, both versions offer distinct insights into a player's intermittent high-intensity endurance capacity, with the Yo-Yo providing a standardized physical fitness assessment and the MYo-Yo incorporating soccer-specific technical demands. Each version can be used based on assessment objectives and the context in which it is employed.

Limitations

One limitation of this study is the relatively small sample size, consisting of only 20 elite male soccer players from a single soccer academy. This limits the generalizability of the findings to a broader population of athletes, especially those from different levels of play, genders, or training backgrounds. Additionally, the study's focus on young male soccer players may not fully capture the effects of the

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MYo-Yo test across other sports or in different age groups. Future studies should include larger and more diverse participant groups to validate the findings in broader athletic contexts.

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