Examining laboratory tests' predictability of futsal players' on-field physical performances: a simulated game analysis

Análisis de la predictibilidad de las pruebas de laboratorio sobre el rendimiento físico de los jugadores de fútbol sala en el campo: un análisis de un juego simulado

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Abstract

Objective: This study aimed to identify the relationship between maximal oxygen uptake ($VO2_{max}$) and Wingate Anaerobic Test (WAnT) parameters with movement parameters in a simulated futsal game.
Methodology: Sixteen semi-professional futsal players participated in the study (26.8 ± 2.2 years). Statistical analyses included Pearson's correlation, with the significance level set at $p < 0.05$.
Results: $VO2_{max}$ presented a very strong significant correlation with low- (LIRD, r = 0.90, p = 0.001) and moderate-intensity running distance (MIRD, r = 0.97, p = 0.001), total distance (TD, r = 0.94, p = 0.001), and player load (PL from training impulse [TRIMP], r = 0.94 p = 0.001), moderate correlation with acceleration (ACC, r = 0.57, p = 0.022), and deceleration (DEC, r = 0.61, p = 0.012), whereas the velocity at anaerobic threshold (V_{AT}) correlated strongly with MIRD (r = 0.81, p = 0.001) and PL (r = 0.84, p = 0.001), and moderately with LIRD (r = 0.60, p = 0.015) and TD (r = 0.66, p = 0.005). Peak and mean powers correlated with sprint distance (SD) and TD—strong to very strong correlations (r = 0.76 to 0.92, p = 0.001); whereas the minimum power significantly correlated with MIRD, SD, PL, ACC, and DEC—moderate to strong correlations (r = 0.51 to 0.72, p = 0.04 to 0.002).
Conclusions: In conclusion, our findings suggest that $VO2_{max}$ effectively indicates long-duration, low-intensity activities in futsal players. Conversely, anaerobic peak power is a reliable indicator of high-intensity running distance and a significant predictor of sprinting ability.

Keywords

Aerobic capacity; anaerobic power; match demands; activity profile; futsal.

Resumen

Objetivo: El objetivo de este estudio fue identificar la relación entre el consumo máximo de oxígeno (VO2max) y los parámetros del Test Anaeróbico de Wingate (WAnT) con los parámetros de movimiento en un partido simulado de fútbol sala.
Metodología: Participaron dieciséis jugadores semiprofesionales de fútbol sala (26,8 ± 2,2 años). Los análisis estadísticos incluyeron la correlación de Pearson, con un nivel de significación de $p < 0,05$.
Resultados: El $VO2_{max}$ presentó una correlación significativa muy fuerte con la distancia de carrera de intensidad baja (LIRD, r = 0,90, p = 0,001) y moderada (MIRD, r = 0,97, p = 0,001), la distancia total (TD, r = 0,94, p = 0,001) y la carga del jugador (PL del impulso de entrenamiento [TRIMP], r = 0,94 p = 0,001), una correlación moderada con la aceleración (ACC, r = 0,57, p = 0,022) y la desaceleración (DEC, r = 0,61, p = 0,012), mientras que la velocidad en el umbral anaeróbico (V_{AT}) se correlacionó fuertemente con MIRD (r = 0,81, p = 0,001) y PL (r = 0,84, p = 0,001), y moderadamente con LIRD (r = 0,60, p = 0,015) y TD (r = 0,66, p = 0,005). Las potencias máxima y media se correlacionaron con la distancia de sprint (SD) y TD: correlaciones fuertes a muy fuertes (r = 0,76 a 0,92, p = 0,001); mientras que la potencia mínima se correlacionó significativamente con MIRD, SD, PL, ACC y DEC: correlaciones moderadas a fuertes (r = 0,51 a 0,72, p = 0,04 a 0,002).
Conclusiones: En conclusión, nuestros hallazgos sugieren que el $VO2_{max}$ indica efectivamente actividades de baja intensidad y larga duración en jugadores de futsal. Por el contrario, la potencia máxima anaeróbica es un indicador confiable de la distancia de carrera de alta intensidad y un predictor significativo de la capacidad de sprint.

Palabras clave

Capacidad aeróbica; potencia anaeróbica; exigencias del partido; perfil de actividad; fútbol sala.

Introduction

Sports scientists and coaches use laboratory and field tests to diagnose and optimise athletic performance. Through physical and physiological tests, it is possible to analyse players' information to provide individual profiles and their respective strengths and weaknesses, and to evaluate the impact of interventions on the individual physical fitness profile of players, thereby evaluating the effectiveness of the training program (Svensson & Drust, 2005). Obtaining information on aerobic and anaerobic performance is essential for diagnosing, prescribing, and organising training. In futsal, obtaining information is relevant due to its complexity; it is a team sport with intermittent and acyclic actions and varying effort intensity with active recovery breaks (Barbero-Alvarez et al., 2008; Dogramaci et al., 2011); it is a game demanding both from the aerobic (90% of maximum heart rate [HR]) (Barbero-Alvarez et al., 2008) and anaerobic (blood lactate reaching 8 mmol·L-1) pathways (Dos-Santos et al., 2020). In futsal, there is an energy expenditure of 13.1 Kcal·min-1 (Silva et al., 2021), resulting from intense technical actions, such as kicks, tackles, changes of direction, constant accelerations and decelerations, and little recovery time between actions; the work-to-rest ratio is 1:1 (Barbero-Alvarez et al., 2008).

Regardless of the test characteristics, whether it is a field or laboratory test, to ensure that the data obtained are relevant to the on-pitch performance, a high construct validity is required; this can be determined by evaluating the association between the variables from the tests and the physical variables of the players during the game, determined through time-motion analysis (Aquino et al., 2020). Although information about the relationship between physical and physiological tests and physical performance during futsal games is scarce, studies have shown contradictory results in soccer, a sport with characteristics like futsal. In soccer, the results of intermittent aerobic physical tests (Castagna & Alvarez, 2010; Krustrup et al., 2003; Redkva et al., 2018) and parameters of repeated sprint ability tests (Rampinini et al., 2006) have been correlated with the high-intensity distance covered during matches. Contrastingly, in other studies, tests on aerobic fitness (Aquino et al., 2018) and repeated sprint ability (Aquino et al., 2018; Redkva et al., 2018) did not reveal a significant correlation with high-intensity running. Additionally, Krustrup et al. (2005) reported a significant association between the maximum oxygen uptake (VO2max) and high-intensity running in male players, whereas in female players, VO2max did not correlate significantly with high-intensity running. In a more recent study, none of the game performance indexes analysed correlated with VO2max (Metaxas, 2021). The methods employed in displacement analysis can partly explain the contradictory results, that is, video analysis and the use of 10 Hz GPS in comparison to 1 or 5 Hz GPS, which present limitations in the results of high-intensity running, velocity measures, and short-linear running (Scott & Kelly, 2016).

Physical test results in futsal have been validated through association with VO2max, maximal aerobic speed, and time limit to reach VO2max speed, that is, the Futsal Intermittent Endurance Test (FIET) (Barbero-Alvarez et al., 2015) and Carminatti's test (Floriano et al., 2016). The Yoyo intermittent recovery test levels 1 and 2 demonstrated sensitivity to the training response (De Freitas et al., 2015). Concerning the test with players dribbling the ball, a circuit test was employed to predict the maximum stable state of blood lactate (Barbieri et al., 2017), whereas the futsal-specific intermittent shuttle protocol, developed to simulate the physiological response and physical effort of full-duration futsal matches, is a valid simulator of physical performance, muscle damage, inflammation, and oxidative stress markers for match demands (de Freitas et al., 2017). However, to the best of our knowledge, studies have yet to be conducted to validate the aerobic and anaerobic power tests associated with displacement performance in futsal games. Thus, this study aimed to verify the relationships among aerobic (VO2max) and anaerobic (Wingate Anaerobic Test [WAnT]) power test variables, displacement variables, and the player load (PL) determined by the impulse of training (TRIMP) in a futsal simulated game.

Method

Participants

This is an observational cross-sectional study. Sixteen semi-professional futsal players in the 1st Division of the Turkish Futsal League were evaluated in a simulated game during the pre-season period (26.8 ± 2.2 years, 72.4 ± 3.9 kg, 176.0 ± 4.3 cm). The players trained 4–5 days a week, approximately 2 hours per session, during a 3-month pre-season period and participated in the preliminary round of the UEFA Futsal Champions League. Inclusion criteria were as follows: voluntarily accepting participation in the study, not being injured or recovering from an injury, and not continuously using any medication. Sixteen outfield players voluntarily participated in this study. The futsal players were categorised as defenders (n = 4), wingers (n = 8), and pivots (n = 4), as previously suggested according to futsal-specific playing positions (Caetano et al., 2015; Illa et al., 2021; Serrano et al., 2020). All participants signed an informed consent form after being fully informed of the purpose and details of the study, which conformed to the recommendations of the Declaration of Helsinki and was approved by the ethics commission board of the local university (2022-344).

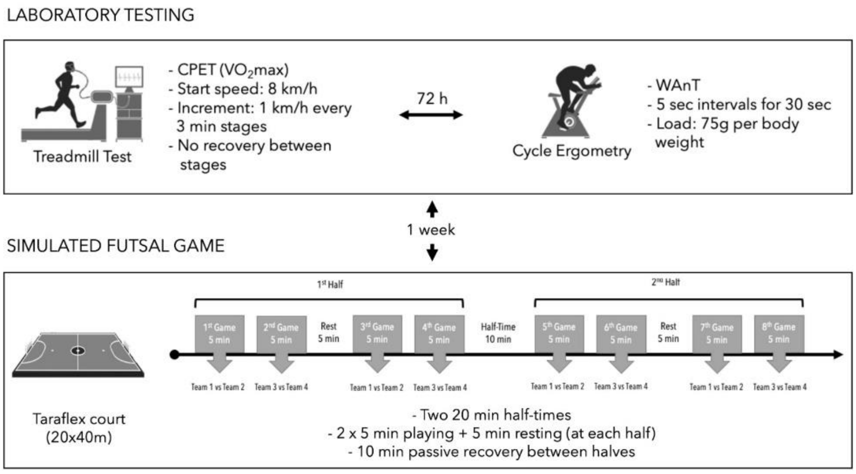
Procedure

During the first laboratory evaluation, athletes underwent anthropometric measurements (weight and height). In the two subsequent sessions, aerobic capacity and anaerobic power were randomly conducted under laboratory conditions: (1) treadmill test and (2) cycle ergometry, separated by 72 hours. In the third session, the activity profile of the athletes was examined during the one-off simulated game in an official futsal court 1 week after the laboratory tests (Figure 1). On the day of the evaluation session, they were not allowed to consume any caffeine-containing beverages and were advised to avoid exercising the previous day.

Simulated futsal game

One week after laboratory testing, an intrasquad simulated game (Vieira et al., 2021) was scheduled on a Taraflex indoor court (20 × 40 m) with the official FIFA Futsal rules. The team (N = 16) was divided into four sub-teams (T1, T2, T3, and T4) based on the decisions of the head and physical performance coaches to maintain similar technical and physical performances among the subgroups. Each player (from each sub-team) performed four sets of 5 minutes—two in the first and two in the second half. There were 10 minutes of recovery between each bout and 15 minutes between the first and second half (Figure 1). The players performed 25 minutes of their habitual official game warm-up, consisting of 5-minute activation (e.g., mobility and resistance band exercises), 10-minute dynamic exercises, short sprints, change of direction activities, and 10-minute technical drills with the ball (e.g., passing, dribbling, and shooting). The head coach encouraged all the players to demonstrate their maximum potential.

Figure 1. Schematic representation of the evaluation procedures of futsal players. CPET: Cardiopulmonary exercise test, WAnT: Wingate anaerobic test.



Laboratory testing

After initial familiarization with the testing protocols, all tests were conducted for 2 days, separated by a 72-hour gap. All participants were tested between 1 and 3 p.m. in the laboratory for ± 1 hour, with similar climate conditions (temperature: 21.5°C, humidity: 63%). Verbal encouragement was provided during all laboratory tests throughout the administration.

Aerobic power

To determine participants' aerobic power (VO2max), a cardiopulmonary exercise test (CPET) was performed using an incremental running test protocol on a motorised treadmill (T-200; COSMED, Rome, Italy), which was previously used in futsal players (Castagna & Alvarez, 2010; Milioni et al., 2016; Silva et al., 2021). Following a personalised 5-minute warm-up, the test was initiated at a work rate of 10 km·h-1; then, the speed was increased by 1 km·h-1 every 3 minutes (with a 1% constant inclination) until VO2max was achieved. During the test, the VO2 of players was measured by the breath-by-breath method using a Quark-CPET (COSMED, Rome, Italy), which was calibrated prior to each test using gas mixtures with the following concentrations: 16% O2, 5% CO2, and balanced N2. HR was continuously monitored using a chest strap (Polar H-10, Electro Oy, Kempele, Finland). At least three of the following requirements had to be satisfied for VO2max to be accepted: (i) the HR during the last minute was greater than 90% of the predicted maximum HR (HRmax) (220-age); (ii) VO2 plateaued during the last two stages of CPET (range < 2.1 mL·kg·min-1); (iii) a respiratory gas exchange ratio of at least 1.1 was reached; and (iv) the participants were no longer able to continue running (Howley et al., 1995).

Anaerobic power

The participants' anaerobic power was measured using the WAnT, as described by Inbar et al. (1996), and the test was performed using a Monark 814E bicycle ergometer (Monark-Crescent AB, Varberg, Sweden). The participants warmed up by pedalling slowly for 5 minutes on a bicycle ergometer. A 3-minute rest period was provided after the warm-up. The participants were asked to accelerate to the highest possible speed on the ergometer for 30 seconds while remaining seated. The seat height was adjusted depending on the leg-length of each participant when the pedal was adjusted at the bottom of the lower end at a knee angle of 165–175°. The workload was set to 75 g·kg-1 per body weight for each participant. During the WAnT, power output was continuously measured using a specialised cycle ergometer equipped with a power meter. The ergometer recorded the force applied to the pedals and the rotation speed, allowing power calculation using computer software specific to the WAnT. Peak power output was calculated from the highest value obtained at 5 seconds. The mean power output was determined from the average power of the 30-second test, whereas the minimum power was calculated from the lowest power output during the test. The fatigue index (FI) was calculated as the percentage of the peak power minus the minimum power divided by the peak power, and multiplied by 100 (Inbar et al., 1996; Kin-Isler, 2006).

Displacement and player load (TRIMP)

The Polar Team Pro2 (Polar Electro Oy, Kempele, Finland) analysed the activity profiles of futsal players during a simulated game, which consisted of a 10-Hz GPS integrated with MEMS motion sensors with a frequency of 200 Hz. According to the manufacturer, because GPS data were unavailable indoors, all movement data were calculated from the information provided by the Inertial Measurement Unit (IMU). The implementation of the algorithms relies heavily on the sensor fusion technologies developed by 9D Polar Electro; all activity data are calculated using information from the IMU, comprising acceleration, gyroscope, and magnetometer sensors. This technology has been previously employed in many studies to analyse locomotor profiles indoors (Hůlka et al., 2022; Silva et al., 2022; Stojiljković et al., 2020). The total distance covered at various intensities of running was calculated as < 6 km·h-1 for standing/walking, 6.01–12 km·h-1 for low-intensity running distance (LIRD), 12.01–18 km·h-1 for moderate intensity running distance (MIRD), 18.01–24 km·h-1 for high-intensity running distance (HIRD), and > 24 km·h-1 for sprint distance (SD) (Castagna et al., 2009). The number of high-intensity accelerations and decelerations was conducted as > ±2 m·s2 (Illa et al., 2021). HR was continuously monitored during the entire game, and PL was calculated using Banister's training impulse (TRIMP) (Banister, 1991) with the following formula:

Banister's TRIMP: [Duration (min)](HRex – HRrest) / (HRmax – HRrest) 0.64e1.92x where HRex = average HR during exercise, HRrest = HR at rest, HRmax = predetermined maximal HR = 2.712, and x = (HRex – HRrest) / (HRmax – HRrest).

Data analysis

Descriptive statistics were used as the initial step in data analysis. Descriptive analysis was presented as median (Med) and interquartile range (IQR). The normality of the data was tested using the Shapiro–Wilk test, allowing parametric statistical analysis. The relationships between laboratory test parameters (VO2max and WAnT) and activities during the game (TD, LIRD, MIRD, HIRD, SD, ACC, DEC, and PL) were verified using Pearson's linear correlation and linear regression analysis. The coefficient of correlation was classified as very weak to negligible (0 to 0.2), weak (0.2 to 0.4), moderate (0.4 to 0.7), strong (0.7 to 0.9), and very strong (0.9 to 1.0) (Papageorgiou, 2022). The level of significance was set at $p < 0.05$. All statistical analyses were performed using IBM SPSS Software version 22.0.

Results

Table 1 presents the aerobic and anaerobic parameters in the laboratory tests and the activity profiles of the futsal players in the simulated game.

Table 1. Descriptive statistics for laboratory tests and activity profile of futsal players.

CPET test	Mean ± *SD*
VO_{2max} (mL·kg·min^{-1})	52.86 ± 3.72
RER (CO_2·VO_2^{-1})	1.24 ± 0.08
HR_{max} (beat·min^{-1})	191.37 ± 4.50
HR_{AT} (beat·min^{-1})	172.75 ± 6.10
V_{AT} (km·h^{-1})	13.75 ± 0.69
V_{VO2max} (km·h^{-1})	16.88 ± 0.79
WAnT test	**Mean ± *SD***
Peak power (watt)	659.30 ± 93.63
Relative peak power (watt·kg^{-1})	9.43 ± 1.10
Mean power (watt)	505.68 ±72.83
Relative mean power (watt·kg^{-1})	7.24 ± 0.95
Minimum power (watt)	364.18 ± 90.19
Relative minimum power (watt·kg^{-1})	5.24 ± 1.34
RPM_{max} (n)	161.45 ± 16.47
Fatigue index (%)	55.10 ± 9.74
Activity profile – Simulated game	**Mean ± *SD***
Standing/walking (m)	1203.81 ± 82.31
Low intensity running distance (m)	1213.88 ± 106.65
Medium intensity running distance (m)	1076.06 ± 242.67
High intensity running distance (m)	467.75 ± 73.98
Sprinting (m)	106.19 ± 15.35
Total distance (m)	4065.13 ± 350.24
Acceleration (n)	103.88 ± 20.70
Deceleration (n)	88.75 ± 17.21
PL (TRIMP, u.a.)	197.56 ± 28.89
Maximal speed (km·h^{-1})	27.50 ± 1.83
HR_{max} (beat·min^{-1})	191.38 ± 4.35

CPET: cardiopulmonary exercise test; WAnT: Wingate Anaerobic Test; HR_{max}: maximum heart rate; AT: anaerobic threshold; V_{AT}: Velocity at Anaerobic Threshold; V_{VO2max}: Velocity at VO_{2max}; RER: respiratory exchange ratio; RPM: repeat per minute; PL: Player Load from Training Impulse (TRIMP).

Correlation between laboratory test and activity profile of a simulated game

A Pearson product-moment correlation was run to determine the relationship between VO2max and WAnT parameters and the activity profiles of futsal players during a simulated game. The main variables from the VO2max test, VO2max, and VAT correlated significantly with most of the different displacement velocities in the game. VO2max was strongly correlated with LIRD, MIRD, TD, and PL and moderately correlated with ACC and DEC. Concurrently, VAT was strongly correlated with MIRD and PL and moderately correlated with LIRD and TD (Table 2). Peak and mean powers correlated with HIRD, SD, and ACC (moderate to very strong correlations); the minimal power significantly correlated with MIRD, SD, PL, ACC, and DEC (moderate to strong correlations); and the mean power moderately correlated with DEC (Table 2).

Table 2. Pearson product-moment correlation between variables of aerobic and anaerobic power tests and the activity profile of futsal players.

Aerobic variables		LIRD	MIRD	HIRD	SD	TD	PL	ACC	DEC
VO_{2max}	*r*	.90**	.97**	.02	.12	.94**	.94**	.57*	.61*
	p	.001	.001	.940	.660	.001	.001	.022	.012
V_{AT}	*r*	.60*	.81**	.25	.22	.66**	.84**	.48	.48
	p	.015	.001	.357	.411	.005	.001	.061	.059
V_{VO2max}	*r*	.72**	.94**	.30	.34	.82**	.89**	.79**	.87**
	p	.002	.000	.257	.193	.000	.000	.000	.000
Anaerobic variables		LIRD	MIRD	HIRD	SD	TD	PL	ACC	DEC
Peak power	*r*	.12	.25	.76**	.92**	.19	.42	.55*	.48
	p	.659	.340	.001	.001	.492	.108	.027	.0657
Mean power	*r*	.17	.30	.82**	.84**	.254	.415	.51*	.51*
	p	.526	.250	.001	.001	.343	.110	.042	.044
Drop power (FI)	*r*	.30	.51*	.37	.66**	.42	.64**	.72**	.57*
	p	.257	.042	.158	.005	.103	.007	.002	.020

VO_{2max}: Maximal oxygen uptake; V_{AT}: Velocity at Anaerobic Threshold; V_{VO2max}: Velocity at VO_{2max}; LIRD: Low Intensity Running Distance; MIRD: Moderate Intensity Running Distance; HIRD: High Intensity Running Distance; SD: Sprint Distance; TD: Total Distance; PL: Player Load from Training Impulse (TRIMP); ACC: Acceleration; DEC: Deceleration; FI: Fatigue Index.

Relationship between VO2max and peak anaerobic power with the activity profile

Simple linear regression was used to assess whether VO2max and peak anaerobic power significantly predicted the displacement activity profiles of the futsal players (Table 3). Linear regression analysis established that VO2max could predict most of the analysed displacement parameters (MIRD, LIRD, TD, PL, ACC, and DEC) (Table 3 and Figure 2). The results suggested that VO2max accounted for 81% of the explained variability of LIRD ($r2 = .082$, $F = 63.275$, $p < .001$), 94% of MIRD ($r2 = .94$, $F = 237.733$, $p < .001$), 89% of TD ($r 2 = .89$, $F =115.802$, $p < .001$), 88% of PL ($r2 = .88$, $F =105.656$, $p < .001$), 32% of ACC ($r2 = .32$, $F =6.675$, $p < .050$), and 37% of DEC ($r2 = .37$, $F = 8.376$, $p < .050$). Regarding peak anaerobic power, the results of the regression indicated 59% ($r2 = .59$, $F =19,766$, $p < .001$) and 84% ($r2 = .85$, $F = 78,796$, $p < .001$) of the variance for high-intensity running distance and sprint distance, respectively (Table 3 and Figure 2).

Table 3. Linear regression between VO_{2max} and peak anaerobic power with displacement variables from a simulated game.

Profile	Unstandardized β	Standardized β	r	r^2	p
		VO_{2max}			
LIRD	25.908	.905	.90	.81	.001
MIRD	63.308	.972	.97	.94	.001
HIRD	.403	.020	.02	.00	.940
SD	.492	.119	.12	.01	.660
TD	88.808	.945	.94	.89	.001
PL (TRIMP)	7.287	.940	.94	.88	.001
ACC	3.157	.568	.57	.32	.022
DEC	2.827	.612	.61	.37	.012
		Peak anaerobic power			
HIRD	.60	.77	.77	.59	.00
SD	.15	.92	.92	.85	.00

LIRD: Low Intensity Running Distance; MIRD: Moderate Intensity Running Distance; HIRD: High Intensity Running Distance; SD: sprint distance; TD: Total Distance; PL: Player load from Training Impulse (TRIMP); ACC: Acceleration; DEC: Deceleration.

Figure 2. Simple linear regression curve for the relationship between VO2max and (a) Low Intensity Running Distance, (b) Medium Intensity Running Distance, (c) Total Running Distance, (d) TRIMP: Training impulse, (e) Acceleration, (f) Deceleration. Coefficient of explanation (r2) is presented.

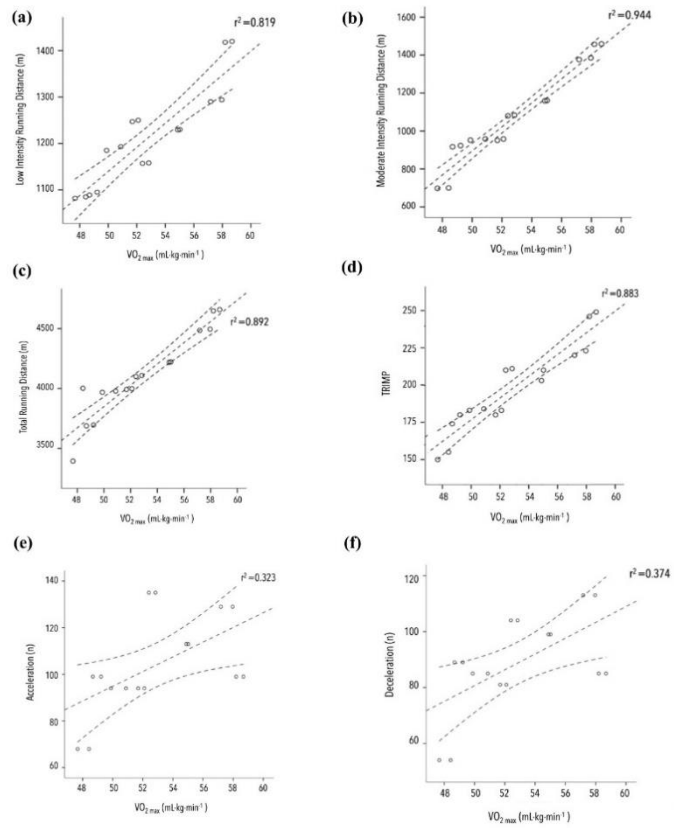
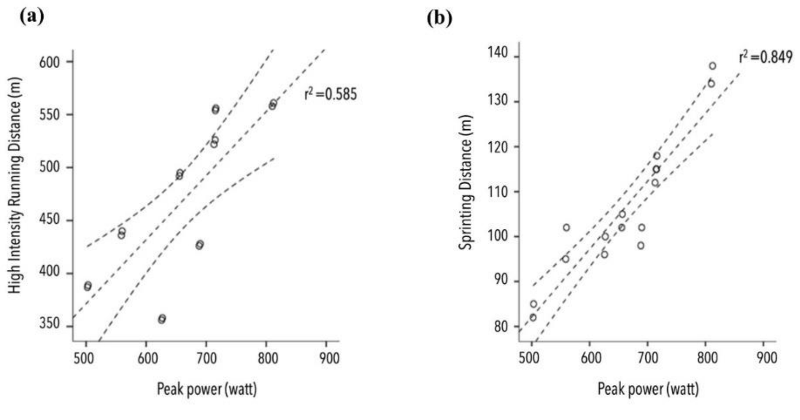


Figure 3. Simple linear regression curve for the relationship between Peak Power and (a) High Intensity Running Distance, (b) Sprint Distance. The coefficient of explanation (r2) is presented.



Discussion

This study is the first to explore how aerobic and anaerobic power test parameters correlate with the activity profiles of elite futsal players during a game. The main results determined that the VO2max correlation was very strong with LIRD, MIRD, TD, and PL, and moderately correlated with ACC and DEC, whereas VAT strongly correlated with MIRD and PL, and moderately correlated with LIRD and TD. Peak and mean powers were correlated with HIRD, SD, and ACC (moderate to very strong correlations); the minimum power was significantly correlated with MIRD, SD, PL, ACC, and DEC (moderate to strong correlations); and the mean power was moderately correlated with DEC.

VO2max presented a high explanatory power for the physical variables in the game (MIRD = 94%, LIRD = 81%, TD = 89%, and PL = 88%). MIRD, LIRD, and TD were parameters with aerobic predominance characteristics in contrast to HIRD and SD, which did not significantly correlate with VO2max. Similar to our results, VO2max was also correlated with TD, but not HIRD, during men's soccer matches (Krustrup et al., 2003). Corroborating these results, VO2max was not correlated with repeated-sprint ability determined in the game in elite male soccer players (Da Silva et al., 2018). Results of associations between VO2max and different intensity zones in soccer games are contradictory. For example, in female soccer players, TD was not correlated with VO2max, but HIRD was (Krustrup et al., 2005), and moderate correlated with low, high, and very high-intensity running during the game in female players (Savolainen et al., 2023). Moreover, no significant correlation was found between VO2max and game running performance at any velocity (Metaxas, 2021). These results contradict our results with futsal players and the aforementioned study findings on soccer players and may be related to the type and accuracy of the equipment used, as well as the global fitness level of players, i.e., how the aerobic and anaerobic power are developed together or each one.

Analysing the relationship between aerobic fitness (VO2max estimated by Yoyo test level-1 [YYIR-1]) and in small-sided games of different pitch sizes, the results showed that small-sided games for 4vs4 and 3vs3 in larger pitches led to a greater impact of aerobic capacity (total distance), and in the 2vs2 relationship, the opposite was observed, with more correlations appearing on smaller pitches, while in the SSG of 1vs1 the correlations with VO2max, total distance, and speed, were observed only on the larger pitch (Michailidis, 2024). These results demonstrate the high impact of the number of players and the pitch size on the relationship between aerobic fitness and physical performance in the game. Some controversy between our results with futsal and studies on soccer can be explained by the difference between the two; futsal is a soccer game adapted for a smaller court and presents higher intensity (Barbero-Alvarez et al., 2008; Dos-Santos et al., 2020). Comparisons of our results with official games and SSG of soccer are inevitable due to the similarity between the actions of both sports, and this study is unique in comparing the results of physical performance of the game with laboratory tests.

Within the futsal domain, VO2max serves as a discriminative variable (Alvarez et al., 2009) because of its association with elevated aerobic power, facilitating enhanced recovery such as improved phosphocreatine recovery during and after intense exertions, or even following exhaustion (Tomlin & Wenger, 2001). The assessment of VO2 from the game demonstrated that individuals engaged in professional futsal must operate within a mean of 48.6 mL·kg·min-1 (Castagna et al., 2009). The intensity level observed in both championship and training futsal matches was determined to be 75–80% of VO2max and 85-90% of maximum HR (Castagna & Alvarez, 2010). Silva et al. (2021) determined that the energy contribution from metabolic pathways during a futsal match comprised primarily aerobic (93%), followed by alactic (5%) and lactic (2%) pathways. Our results exhibited strong congruence with these findings, revealing a correlation between VO2max and futsal players' aerobic-based activity profiles (LIRD, MIRD, TD, and PL), highlighting the significance of considering VO2max as a crucial parameter during futsal matches. However, no significant correlation was observed between the VO2max HIRD and sprinting, as these variables exhibited a higher correlation with futsal players' anaerobic capacities. Given the potential for enhanced rapid recovery, we anticipated a correlation between VO2max and SD (Tomlin & Wenger, 2001). However, our findings did not substantiate this correlation. These findings may be partially explained by Silva et al. (2021), who explored the association between the VO2max assessed during a futsal game and the estimated VO2max derived from continuous treadmill running. Their study revealed no significant correlation between the estimated VO2max during treadmill running and the measured VO2max during the futsal game. The high-intensity and intermittent nature of futsal matches likely contributed to the dissociation in the HR–VO2 relationship. Considering the use of a continuous treadmill running test for VO2max measurement, correlations among VO2max, HIRD, and sprinting activity were not observed. Similarly observed in soccer players, Metaxas (2021) also identified no significant correlation between VO2max measured through laboratory tests and players' high-intensity running, fast running, and sprinting. However, some studies have indicated a correlation between aerobic capacity assessed through field tests, aligned with the dynamics of soccer gameplay, and the players' activity profiles (Bradley et al., 2011; Castagna & Alvarez, 2010; Castagna et al., 2009), as well as the official game intensity measured by the HR (TRIMP and time at 90% of HRmax) correlated with a field test, YYIR-1, in soccer young players (Moura et al., 2024).

Our findings revealed that the peak power explained 59% and 84% of the variance in high-intensity running and SDs, respectively. The Wingate test demands more anaerobic energy, preponderantly from the glycolysis pathway, explaining 83% and 81% of the variance of WAnT peak and mean power, respectively (Beneke, et al., 2002). Blood lactate concentration can rise to 8.0 mmol·L-1 in the game (Dos-Santos et al., 2020). A futsal match involves numerous high-intensity intermittent actions that require a high rate of energy production from an anaerobic system (Yustika, 2019). The critical phase in a futsal match is identified by high-intensity and rapid running, characterised by alterations in movement patterns occurring every 3.3 seconds, on average (Barbero-Alvarez et al., 2008). Elite futsal players allocate approximately 5% and 12% of their total game duration to high-intensity sprints and runs, respectively, as reported in the literature (Barbero-Alvarez et al., 2008; Castagna et al., 2009). Therefore, the crucial significance of intermittent physical endurance in sustaining high-intensity activity during training sessions or matches is emphasised for futsal players. The activity patterns observed in futsal indicate the requirement for both aerobic and anaerobic energy systems. Dal Pupo et al. (2020) explored the physical capacities associated with the physical match performance of young futsal players during simulated matches and reported similar observations. They found correlations between match-related performance variables such as relative distance covered per minute and the ability to engage in high-intensity running. These correlations were identified using metrics associated with the aerobic and anaerobic systems and maximal sprinting speed. They employed a high-intensity intermittent field test, the FIET, introduced by Barbero et al. (2005). This test was designed based on an analysis of futsal matches and was aimed at evaluating specific endurance. The peak speed achieved in the FIET accounted for 73% of the variability in distance covered per minute. The FIET requires engaging both aerobic and anaerobic energy systems to evaluate an individual's capacity to recover from progressive intermittent exercise. Notably, the peak velocity achieved during the FIET is a crucial factor influencing the ability to recover from such exercises, specifically impacting physical performance in futsal matches, particularly the distance covered at high intensity.

Regarding the FI from WAnT, we observe positive significant correlations between FI (power drop) and high-intensity activity (DEC > 2 m·s2, PL and SD, r = 0.51 to 0.66, moderate correlations), mainly ACC (r = 0.72, strong correlation). However, despite the FI from WAnT demonstrating sensitivity to discrimination between senior and younger futsal players (Nikolaidis et al., 2019) and between elite and non-elite futsal players (Farhani et al., 2019), it did not show an interrelationship with any of the metabolic measurements made (VO2 and lactate accumulation) to the estimation of aerobic, alactic, and lactic anaerobic pathways (Beneke, et al., 2002). The specificity and validity of FI from WAnT are not so evident for high-intensity, since in our results, players with higher ACC, DEC, and SD scores presented higher FI. In contrast to our results, Dal Pupo et al. (2020) evaluated futsal players with intermittent test (8 × 40-m shuttles), and discovered that the fatigue index in repeated sprints accounted for 40% of the distance covered at high-intensity, placing substantial strain on the anaerobic pathway, as a predictor negative of high-intensity running and sprint (r = -0.70 and -0.69). In addition, comparing the WAnT test with a repeated curve sprint test on the field in futsal players, IF from Wingate was not significantly correlated with IF from the repeated curve sprint test (Parnow et al., 2022), and it has not presented a significant correlation with isometric and explosive leg strength in sedentary and regular physical activity groups, together with men and women (Arslan, 2005). The difference between our results and those from Dal Pupo et al. (2020) can be attributed to the differences in the type of exercise and test specificity, specifically, the intermittent running test in the field versus the continuous cycling test in the laboratory. Furthermore, the FI WAnT is calculated as a percentage of variation of the peak power minus the minimum power, while the FI of the fast running anaerobic test (RSA) considers the ratio between the sum of all the real times obtained in the test and the best time of the races to be hypothetically considered for all the other races (decrement from best).

Some practical applications can be highlighted in the present study. Field tests that correlate with VO2max can help estimate physical performance in games since cost and access to the laboratory are often limited to small teams, and FI results from the WAnT test should be considered a precaution for predicting anaerobic actions in the game. Our study had some limitations. Primarily, it analyses a simulated futsal match to replicate official conditions; however, motivational factors may also impact performance. Because of the team's schedule, only one match could be evaluated. The small sample size may affect the strength of the regression model despite the precautions taken, such as considering the number of independent variables and addressing collinearity (Dal Pupo et al., 2020). Future studies should include official matches at various competitive levels to address these limitations, as well as verify the time intervals between high-intensity actions (density) in the game since the tests have a total duration in seconds, with or without pauses between the bouts, and different test protocols must be employed in comparison with players' physical actions in the game to verify the validity of the tests.

Conclusions

In conclusion, our findings suggest that VO2max effectively indicates long-duration, low-intensity activities in futsal players, including PL (TRIMP), total distance covered, and low-to-moderate-intensity running. Conversely, anaerobic peak power is a reliable indicator of high-intensity running distance and a significant predictor of sprinting ability. Overall, the physical capacities associated with aerobic and anaerobic aspects predicted match-related performance in young futsal players.

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Disclosure statements

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