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The Relationship between Aerobic Capacity, Anthropometric Characteristics, and Performance in the Yo-Yo Intermittent Recovery Test among Elite Young Football Players: Differences between Playing Positions

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Abstract: The objectives of this study were to investigate (a) the relationship between the Yo-Yo intermittent recovery test level 1 (YYIR1) and a laboratory test for measuring maximal oxygen uptake (VO_{2max}), (b) the relationships between anthropometric characteristics and variables of the two aerobic tests (field and laboratory), and (c) differences in performance and anthropometric characteristics among five different playing positions. The study involved 27 U17 young soccer players (16.0 ± 0.6 years). They randomly underwent a maximal laboratory treadmill test to measure VO_{2max} and the YYIR1 test. Pearson correlation was used to find potential correlations, and a one-way ANOVA was used to find differences between playing positions. Statistical significance was set at $p < 0.05$. The results showed that height was moderately negatively correlated (r = −0.455, p = 0.017) as well as body mass (r = −0.395, p = 0.042). Significant positive correlation was observed between vVO_{2max} and the distance covered in YYIR1 (r = 0.393, p = 0.042). Finally, no differences were observed between playing positions in any anthropometric characteristic or in any variable of the two aerobic tests (laboratory or field) ($p > 0.05$). In conclusion, the YYIR1 test is not suitable for estimating VO_{2max}. Additionally, the lack of differences between playing positions may be due to the limited specialization of the training load received by the players until this age.

Keywords: soccer; correlation; Yo-Yo intermittent recovery test level 1; VO_{2max}; position

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1. Introduction

The development of technology and the widespread use of the Global Positioning System (GPS) in soccer have allowed sports scientists to create profiles of the physical demands of young soccer players during matches. Recent studies report that U17 soccer players cover a total distance of 9000 to 11,000 m during a match [1–3]. Regarding the distance covered at speeds greater than 16 km/h, previous studies indicate it to be 10–12% [2,4], while distances above 19.8 km/h constitute 6–7% of the total distance [1,3]. Additionally, players execute various other actions during matches such as accelerations, decelerations, changes in direction, and jumps [5]. All these actions rely on the aerobic and anaerobic capacity of the players.

Aerobic capacity is particularly important for player performance. Average heart rate values during a match [6] highlight the aerobic nature of the sport. However, player performance and match outcome depend on the intense actions performed during the game. High aerobic capacity has been reported to aid in quicker recovery between sprints [7,8], faster resynthesis of phosphocreatine [9], and removal of fatigue-inducing factors such as hydrogen ions [8]. Recognizing its value, team coaches emphasize its development starting from adolescence.

Aerobic capacity is assessed through various indicators such as maximal oxygen uptake (VO_{2max}), anaerobic threshold, and velocity at anaerobic threshold and can also be estimated through other variables such as distance covered in running tests [10,11]. VO_{2max} refers to the maximum amount of oxygen an organism can uptake and utilize during maximal exertion. The gold standard for assessing VO_{2max} involves maximal laboratory tests using a treadmill [12]. During this assessment, other useful indicators for training purposes, such as speed and heart rate at VO_{2max}, maximum heart rate, speed at anaerobic threshold, heart rate at anerobic threshold, are also recorded. Laboratory measurement is highly reliable but has some drawbacks. It requires specialized equipment and personnel, and it is time-consuming when assessing a group of 25 individuals. These reasons led to the development of field tests aiming to estimate VO_{2max} and other indicators [10,13]. Field tests estimate VO_{2max} from other indicators such as exercise time or distance covered by players. Therefore, the assessment is less precise, but it does not require expensive equipment or specialized personnel, and large groups of athletes can be measured in a short time (~25 min).

Thus, for evaluating a soccer player's aerobic capacity, either laboratory tests or field tests can be used. It is logical to assume that since these tests assess the same physical capacity, their results should correlate. However, from the literature review, it appears that this relationship is not clear [14–16]. Specifically, in one study [15] on young soccer players comparing two field tests with laboratory tests, it was found that performance in the Yo-Yo intermittent endurance test (YYET) did not correlate with the VO_{2max} measured in the laboratory test. In contrast, performance in the 20m multistage shuttle run test correlated with VO_{2max}. Additionally, Metaxas et al. (2005) [16] observed that estimating VO_{2max} using the Yo-Yo endurance test differed significantly from its measurement in laboratory tests. However, Karakoc et al. (2012) [17] found moderate correlations between VO_{2max} and performance in Yo-Yo intermittent recovery level 1 and 2 (YYIRT) tests and weak correlation with performance in the Yo-Yo endurance test.

Furthermore, from the literature, it appears that the effect of anthropometric characteristics on aerobic tests such as the ones mentioned above is not clear. In a recent study [18], a negative correlation between body fat percentage and performance in the multistage shuttle run test was observed in professional soccer players. In contrast, Michailidis (2022) [19] found no correlation between anthropometric characteristics and performance in field tests (Yo-Yo intermittent endurance test and Yo-Yo intermittent recovery test) across various age groups and different levels of soccer players.

Moreover, it has been observed that the different tactical roles of playing positions affect players' running performance [6,20] in matches. In a recent review study [21], it was reported that Sporis et al. (2009) [22] observed midfielders to have higher VO_{2max} values than forwards and defenders. In contrast, Gil et al. (2007) [23] observed forwards to have higher VO_{2max} than midfielders and defenders. However, there are also studies that did not find significant differences in VO_{2max} between playing positions [24–26]. The researchers [21] suggested that the observed differences may be due to the different competitive levels of the participants.

Therefore, the aim of this study was to explore possible correlations between the results of a laboratory test measuring maximal oxygen uptake and the results of the Yo-Yo intermittent recovery test level 1 in elite youth football players. Additionally, the impact of anthropometric characteristics on player performance in the two tests (laboratory and field) was investigated. Finally, a comparison of player performance in the two tests across their playing positions was made. We assumed that (a) correlations would be observed between the two tests, (b) anthropometric characteristics would influence performance in the tests, and (c) differences between positions would be observed.

2. Methods

2.1. Subjects

This study involved 27 young high-level soccer players (16.0 $\pm$ 0.6 years; height, 1.7 $\pm$ 0.1 m; weight, 66.3 $\pm$ 5.8 kg). The players participated in four training sessions per week and one friendly game. The football players are members of an Under-17 team of a professional football club, and every year, they participate in the playoffs of their category (U17). The study was conducted during the preparation period, and in the five friendly matches the players participated in, they played for approximately the same amount of time. To participate in the study, the following criteria had to be met: (a) no injuries in the last month, (b) not taking any medication, (c) not using ergogenic aids, and (d) participating in 90% of their training sessions in the last two months. Participants and their guardians were informed about the purpose of the study and its benefits and potential risks, and they signed a consent form. The local Institutional Review Board approved the study, following the principles of the Helsinki Declaration.

To assess statistical power, G*Power software v.3.1 (University of Dusseldorf, Dusseldorf, Germany) was used [27]. Specifically, for calculating the power of the sample size, a post hoc correlation analysis (point biserial model) was selected with the following options: α err prob = 0.05, power $(1 - \beta$ err prob) = 0.85, and effect size = 0.5. The choice of effect size was based on previous studies reporting large and very large correlations between physiological variables in soccer players [28,29]. From the results, it was evident that with a sample of 27 individuals, the exact power was 89.8%.

2.2. Procedure

The study was conducted before the start of the competitive season over a period of 10 days. More specifically, the study began in the sixth week of preparation (the total duration of the preparation was eight weeks). The transitional period before the start of the preparation lasted five weeks, during which no training sessions were scheduled for the first two weeks, while in the following three weeks, the football players performed individual training sessions. During the first visit, anthropometric measurements were taken, and the players familiarized themselves with the treadmill test. Over the next 10 days, the players underwent a laboratory test to measure maximal oxygen uptake and the Yo-Yo intermittent recovery test level 1 in random order. The two tests were separated by approximately 7 days, and 48 h before each test, there was a light training session. A 15-min warm-up preceded each test, and after the conclusion of each test, a 10-min cool-down was conducted. During the measurements, participants were allowed to consume water ad libitum to ensure proper hydration.

2.3. Anthropometric Measurements

Body mass was measured with an accuracy of 0.1 kg using an electronic digital scale (Seca 220e, Hamburg, Germany). Players were weighed without shoes and wearing only their underwear. Standing height was measured using a stadiometer (Seca 220e, Hamburg, Germany) with an accuracy of 0.1 cm. The skinfold method was used to measure body fat percentage. Four skinfold measurements (biceps, triceps, suprailiac, subscapular) were taken using a Lafayette skinfold caliper (Lafayette, Ins. Co., Lafayette, IN, USA) on the right side of the players' bodies. Body fat percentage was calculated using the Siri equation (1956) [30].

2.4. Laboratory VO_{2max} Measurement

The laboratory measurements were conducted in the morning hours from 9 a.m. to 12 p.m. The temperature in the laboratory space was controlled and stable at around 20 °C, and the relative humidity was approximately 40–55 mmHg. The measurement of maximum oxygen uptake was performed on a motorized treadmill (Pulsar; h/p/Cosmos, Nussdorf-Traunstein, Germany) using a continuous exercise protocol consisting of seven stages of 2 min each. The initial treadmill incline was set at 0% at speeds of 8, 10, and 12 km/h. Then, the incline was increased to 2%, and every 2 min, the speed was increased by 2 km/h until exhaustion. O_{2max} values and cardiorespiratory indices were measured using a breath-by-breath automated pulmonary–metabolic gas exchange system (Oxycon Pro; Jaeger, Wurzburg, Germany). Prior to each test, the gas analyzer was calibrated using a 2.0 L calibration syringe and known certified gas concentrations. The maximum VO_{2max} value was taken as the highest value recorded after it stabilized for at least 5 measurements (steady state). During the measurement, heart rate was also recorded using a heart rate monitor (10 Hz Polar Team Pro, Kempele, Finland).

The measurement of VO_{2max} was considered complete when 3 of the following 5 criteria were observed: (a) heart rate during the last minute exceeding 95% of the expected maximum heart rate (220-age); (b) the leveling off (plateau) of VO_{2max} occurred despite increasing treadmill speed, with VO_2 < 150 mL O_2 [31]; (c) a respiratory gas exchange ratio (VCO_2/VO_2) equal to or higher than 1.1 being reached [32]; and (d) subjects no longer being able to continue running despite verbal encouragement.

2.5. Yo-Yo Intermittent Recovery Test Level 1

The YYIR1 test was conducted on a soccer field with synthetic turf. The test took place at 9 a.m. with the temperature ranging between 20–22 °C and the relative humidity around 45–60 mmHg. In the YYIR1, the soccer player must run two shuttle runs of 20 m each, following an auditory signal from an mp3 that determines the running speed. After completing these runs, there is a 10 s rest period during which the participant must cover a distance of 10 m (2 × 5 m) behind the starting line and prepare for the next repetition. These actions are repeated until the player cannot maintain the pace set by the auditory signal for two consecutive runs. The first time the sound is heard and the participant fails to reach the line, a warning (yellow card) is given, and the test is terminated on the second occasion (red card). The player's performance in the last completed shuttle run constitutes their performance in this specific test [33]. The test starts at a running speed of 10 km/h, increasing by 2 km/h at the next level and by 1 km/h at the following one. In all subsequent levels, increases were by 0.5 km/h. According to the researchers [10] who proposed the test, VO_{2max} can be estimated from the players' performance in the test according to the following equation: VO_{2max} prediction (mL/kg/min) = Yo-Yo IR1 distance (m) × 0.0084 + 36.4. The researcher who conducted the data collection during the YYIR1 test had extensive experience (more than 15 years) in athlete assessments (ICC 0.99).

2.6. Positions

The playing positions into which the soccer players were categorized were central defenders (CD, n = 5), side defenders (SD, n = 7), central midfielders (CM, n = 6), side midfielders (SM, n = 5), and forwards (F, n = 4). Goalkeepers were excluded from the study.

2.7. Statistical Analysis

The data are presented as means ± standard deviation. Initially, the 1-sample Kolmogorov–Smirnov test was conducted to determine whether the data followed a normal distribution. From the test results, it was found that parametric tests could be used. Pearson correlation coefficient was applied to assess correlations between the variables of the two aerobic tests as well as between anthropometric characteristics and aerobic test variables. According to Hopkins [34], the magnitude of the correlation coefficient was categorized as 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 ($r = 1.0$). A one-way ANOVA was used to compare the performance of the soccer players in the two aerobic tests. In case differences were observed, the Bonferroni test was applied. The level of statistical significance was set at $p < 0.05$. SPSS version 28.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

3. Results

In anthropometric characteristics, correlations were observed between height and body mass with VO_{2max} measured in the laboratory. Specifically, a negative moderate correlation was observed with height ($r = -0.455$, $p = 0.017$), and a negative moderate correlation was also observed with weight ($r = -0.395$, $p = 0.042$). Significant correlations are presented in Figure 1, while Table 1 displays the statistical indices of all correlations.

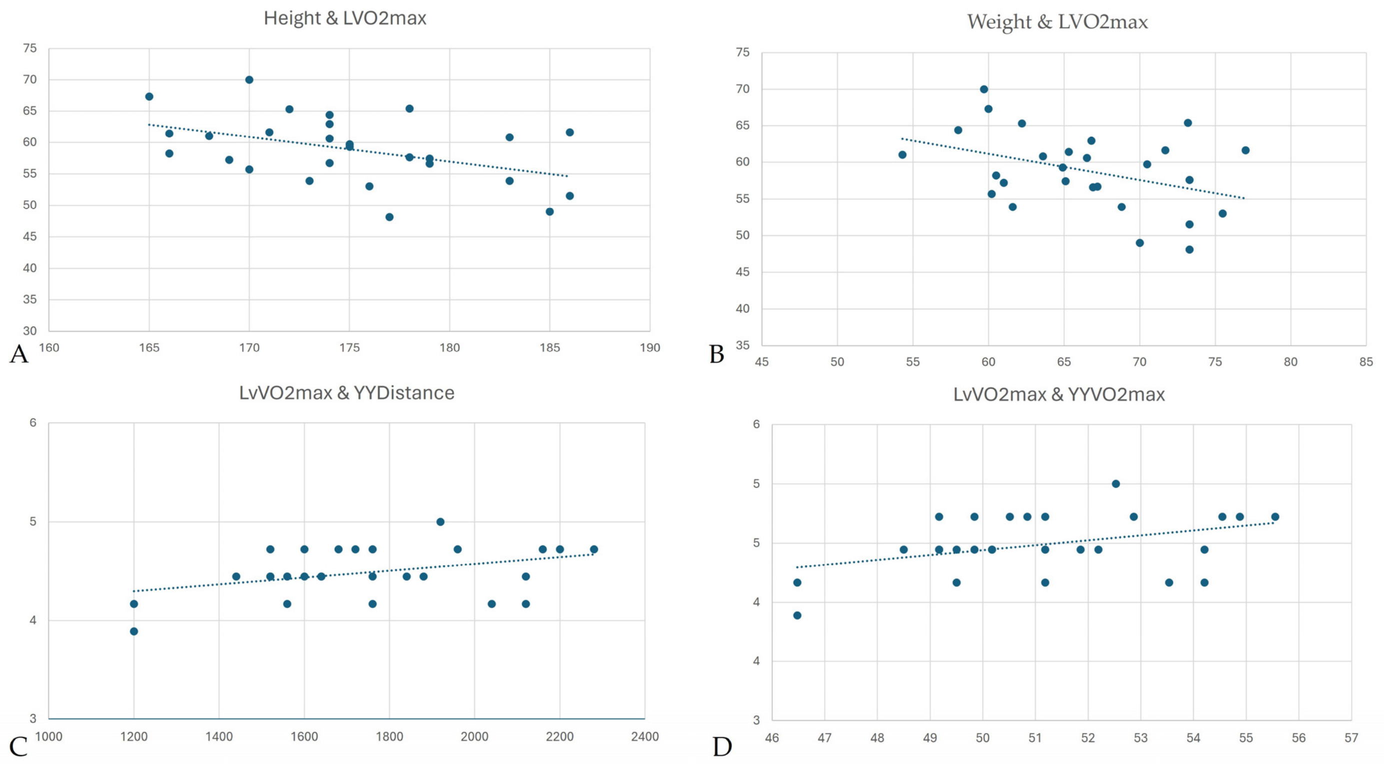

Figure 1. Significant correlations between variables. (**A**) Correlation between Height and LVO_{2max}. (**B**) Correlation between Weight and LVO_{2max}. (**C**) Correlation between $LvVO_{2max}$ and YYDistance. (**D**) Correlation between $LvVO_{2max}$ and $YYVO_{2max}$.

Table 1. Correlation matrix for anthropometric characteristic and aerobic performance indexes.

Variable	YYDistance	$YYVO_{2max}$	LVO_{2max}	$LvVO_{2max}$
Height	r = 0.062 p = 0.758	r = 0.062 p = 0.758	r = −0.455 p = 0.017 *	r = −0.024 p = 0.906
Weight	r = −0.183 p = 0.360	r = −0.183 p = 0.360	r = −0.395 p = 0.042 *	r = 0.065 p = 0.747
BMI	r = −0.291 p = 0.140	r = −0.291 p = 0.140	r = −0.059 p = 0.770	r = 0.104 p = 0.604
% BF	r = −0.344 p = 0.079	r = −0.344 p = 0.079	r = −0.123 p = 0.542	r = −0.245 p = 0.217
LVO_{2max}	r = 0.183 p = 0.360	r = 0.183 p = 0.360		
$LvVO_{2max}$	r = 0.393 p = 0.042 *	r = 0.393 p = 0.042 *		

BMI, body mass index; % BF, percentage of body fat; YYDistance, performance on Yo-Yo intermittent recovery test; $YYVO_{2max}$, VO_{2max} predicted from the performance on Yo-Yo intermittent recovery test level 1; LVO_{2max}, VO_{2max} measured in the laboratory test; $LvVO_{2max}$, velocity measured during the laboratory test. * denotes significant correlation at $p < 0.05$.

Among the variables of the two aerobic tests, a significant positive correlation was observed between vVO_{2max} and the distance covered in YYIR1 (r = 0.393, p = 0.042), as well as between VO_{2max} estimated from performance in YYIR1 (r = 0.393, p = 0.042). Significant correlations are presented in Figure 1, while Table 1 displays the statistical indices of all correlations.

YYDistance refers to performance on Yo-Yo intermittent recovery test; $YYVO_{2max}$, VO_{2max} predicted from the performance on Yo-Yo intermittent recovery test level 1; LVO_{2max}, VO_{2max} measured in the laboratory test; and $LvVO_{2max}$ velocity measured during the laboratory test. The level of significance set at $p < 0.05$.

From the results of the one-way ANOVA analysis, no differences were observed between playing positions in any anthropometric characteristics or variables of the two aerobic tests (laboratory and field). The means of anthropometric characteristics in relation to position are presented in Figure 2, while the means in the variables of the aerobic tests are presented in Figure 3. The statistical indices for anthropometric characteristics and aerobic tests are presented in Table 2.

Table 2. Statistical indexes of the differences between positions.

			Height	Weight	BMI	%BF	LVO_{2max}	$LvVO_{2max}$	YYDistance	$YYVO_{2max}$
CI 95%	CD	Upper	189	77.9	25.2	16.5	77.7	5.68	2233	55.2
		Lower	171	62.2	17.9	5.2	36.6	3.57	1233	46.8
	SD	Upper	181	70.9	22.4	12.7	61.8	4.60	2087	53.9
		Lower	170	59.9	20.4	9.9	54.4	4.22	1493	48.9
	CM	Upper	180	72.2	23.2	14.3	65.6	4.70	1800	51.5
		Lower	166	60.3	20.9	9.6	53.9	4.43	1537	49.3
	SM	Upper	175	67.7	22.1	14.2	67.8	4.74	2268	55.5
		Lower	168	55.4	19.4	9.6	52.6	4.37	1396	48.1
	F	Upper	184	78.2	26.9	19.9	64.9	4.88	2314	55.8
		Lower	168	62.4	18.7	8.8	52.5	3.73	1205	47.7
F(Anova)			1.103	1.771	1.205	1.388	0.228	1.245	0.273	0.273
p			0.380	0.171	0.337	0.271	0.920	0.321	0.892	0.892
η^2			0.167	0.244	0.180	0.201	0.040	0.185	0.047	0.047

CD, central defender; SD, side defender; CM, central midfielder; SM, side midfielder; F, forward; YYDistance, performance on Yo-Yo intermittent recovery test; $YYVO_{2max}$, VO_{2max} predicted from performance on Yo-Yo intermittent recovery test level 1; LVO_{2max}, VO_{2max} measured in the laboratory test; $LvVO_{2max}$, velocity measured during the laboratory test; BMI, body mass index; %BF, percentage of body fat; CI 95%, confidence interval 95%.

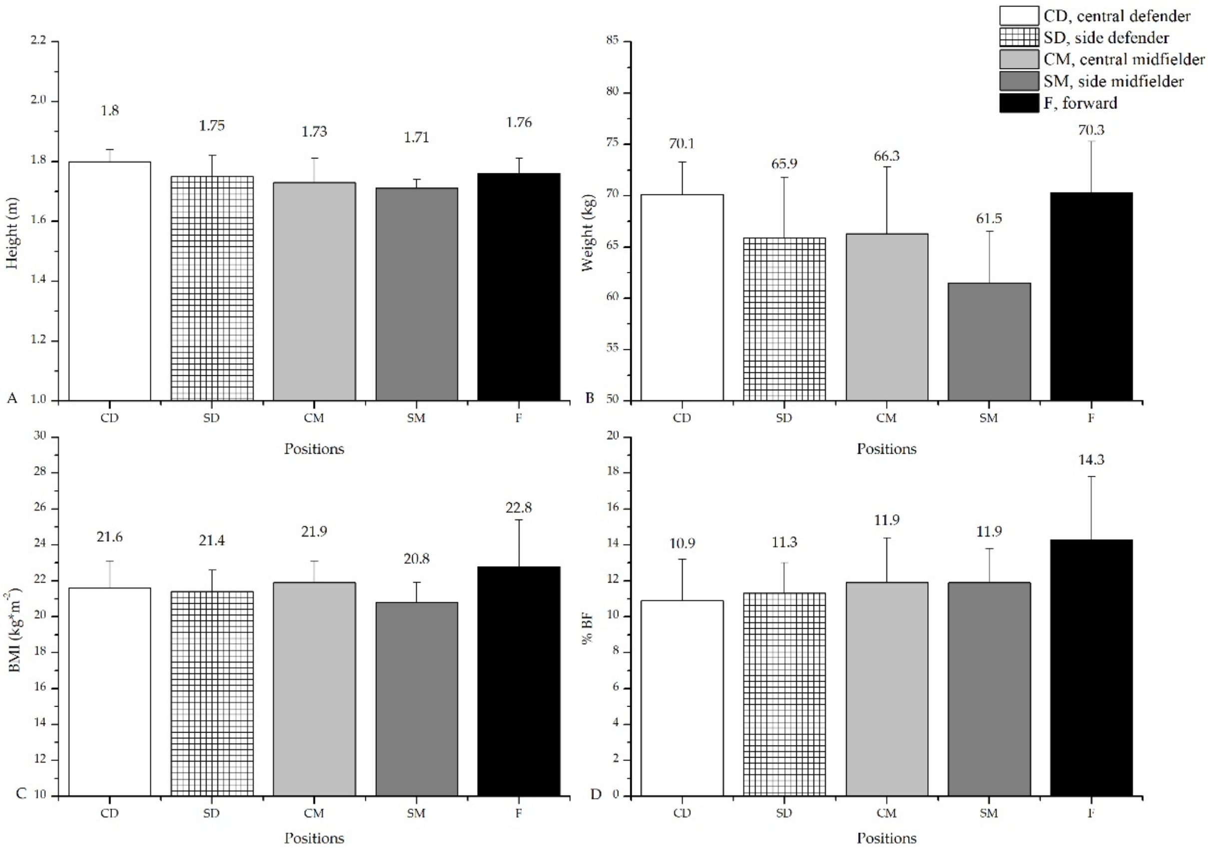

Figure 2. (**A**) Differences in height. (**B**) Differences in weight. (**C**) Differences in body mass index. (**D**) Differences in % of body fat.

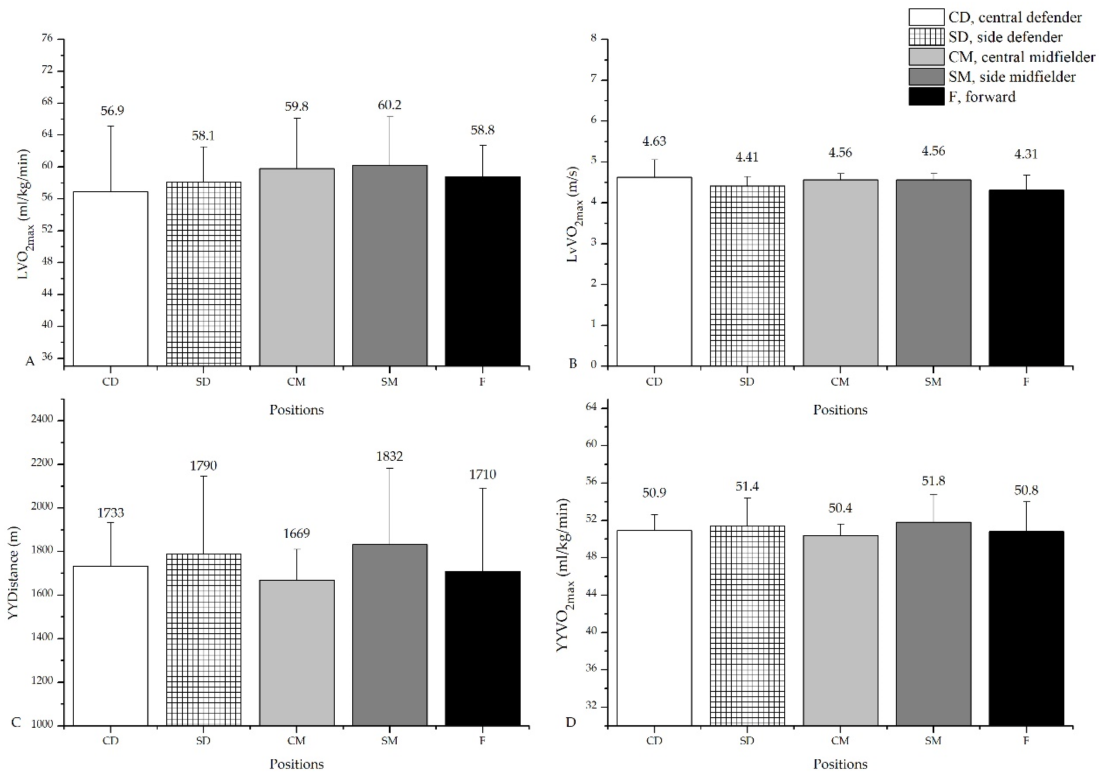

Figure 3. (**A**) Differences in VO_{2max} measured with laboratory test. (**B**) Differences in velocity of VO_{2max} measured with laboratory test. (**C**) Differences in performance on Yo-Yo intermittent recovery test level 1. (**D**) Differences in VO_{2max} predicted from the performance of Yo-Yo intermittent recovery test level 1.

4. Discussion

From the results, a moderate positive correlation was observed between the vVO_{2max} of the laboratory test and the distance in the YYIR1 and estimated VO_{2max} using the YYIR1 test. Among the anthropometric characteristics, only height and weight were negatively correlated with LVO_{2max}. Lastly, no differences were observed between playing positions in any variable.

Aziz et al. (2005) [15] in their study did not observe correlations between the VO_{2max} measured on the treadmill and the VO_{2max} measured with the Yo-Yo intermittent endurance test. Similar findings are reported by other researchers who used the YYIR1 test [33]. According to the researchers, the lack of correlations indicates the difference between the two tests. Specifically, the laboratory test was designed to measure the participant's aerobic capacity (VO_{2max}) and is a continuous test. In contrast, the YYIE was designed to assess the participant's ability to perform repeated efforts with intervals [35] and not to measure VO_{2max}. In a subsequent study [17], the researchers observed moderate correlations of VO_{2max} with the distances covered by football players in the YYIR1 and YYIR2 tests and weak correlations with the distance in the YYET. The literature also includes studies on football players that found strong correlations. Specifically, Krustrup et al. (2003) [36] in their study examining the physiological response of YYIR tests, found, among other things, a strong positive correlation of VO_{2max} with the distance in the YYIR1 test ($r = 0.71$), as did Rampinini et al. (2010) [37] a few years later ($r = 0.74$). From the presentation of the results of the above studies, it appears that the relationship between VO_{2max} and the YYIR1 field test is not clear. These differences between the studies may be due to the characteristics of the participants. Such characteristics may include age and level. We observed high correlations in studies involving adults and professional football players [36,37]. Another variable to consider when evaluating the results of studies with correlations is the sample size of each study. In the present study, 27 young football players participated; in the study of Aziz et al., [15] 21 young football players from a U18 team participated; in the study of Castagna et al. [33] 24 adult football players took part; in the study of Karakoc et al. [17] there were 12 young football players under 15; in the study of Krustrup et al. [36] there were 17 adults and 37 professional football players; and in the study of Rampinini et al. [37] 13 professional football players. These differences make it difficult to generalize the results. Previous studies report that a lack of correlations between tests leads to the conclusion that the tests have different physiological demands. However, this conclusion is not confirmed by studies showing large correlations.

As mentioned above, of the anthropometric characteristics, only height and weight were negatively correlated with LVO_{2max}. In the football players of the present study, it was observed that the value of VO_{2max} decreased as the weight or height of the athletes increased. In a recent review study [38], a moderate negative correlation of VO_{2max} with body mass was reported. In an earlier study [18] conducted on professional football players, a negative moderate correlation was observed between body fat and the distance covered in the multistage test. The different field tests used do not allow us to compare the results of the studies. In a recent study, Michailidis (2022) [19] did not observe a correlation of performance in the YYIR1/YYIE1 with any anthropometric characteristic at various age and playing levels. Specifically, he studied young football players from U10, U12, and U14 teams as well as adult amateurs and professionals. These results confirm the findings of the present study, where no correlations of anthropometric characteristics with the indices of YYIR1 were found.

Regarding the differences in VO_{2max} between playing positions, no difference was observed. It should be noted that goalkeepers were not included in the study. Similar findings were reported by other studies [24–26,39]. However, in an earlier study, it was reported that midfielders had higher VO_{2max} values than forwards and defenders [22]. Additionally, Lago-Penas et al. (2011) [40] reported that midfielders and forwards had higher VO_{2max} values than goalkeepers and defenders. Furthermore, Gil et al. [39] observed that forwards showed the highest values among all other playing positions. The differences presented in the results of the studies are likely due to the different characteristics of the participants. In professional football, players in midfield positions, as well as positions on the sides, which exhibit the greatest external load during matches [20], tend to show higher VO_{2max} values [22]. Studies in developmental ages show greater differentiation in their results, possibly because football players have not been influenced by specialized positional coaching.

Regarding the variables from the YYIR1 test, no differences were observed between playing positions. In a study conducted on young football players aged U13–U19, it was observed that central defenders had significantly lower performance than central midfielders, wide midfielders, and forwards (but not lower than side defenders). In another study [29] conducted on elite young football players (U15), it was observed that goalkeepers had the lowest VO_{2max} value and differed from all other playing positions both before and after the competitive period. The findings of the present study are consistent with those of the above study (if goalkeepers are not included).

In the present study, no differences were observed between playing positions in any of the anthropometric characteristics. Nobari et al. (2021) [41] observed that goalkeepers were taller, heavier, and had a higher percentage of body fat compared to players in other positions. Wingers had the lowest percentage of body fat, and central defenders had the least lean body mass among all positions. Similar results are reported by other studies where only goalkeepers differed in body mass and height [39,42], while forwards showed the lowest percentage of body fat [39]. Nobari et al. (2022) [29] in their recent study observed that central defenders and forwards were heavier compared to central midfielders. Additionally, central and side midfielders were shorter compared to those in other playing positions. The lack of differences in the anthropometric characteristics of football players in different playing positions may be due to the criteria used to select the players. Specifically, these players were chosen for the team, and the selection criteria may lead to a specific profile of anthropometric characteristics. Another reason may be the lack of specialized training for specific positions, which would result in specific adaptations in the players' bodies.

The present study has some limitations. The sample of the study may be considered limited, and the results cannot be generalized. Additionally, the small sample resulted in a small number of football players in each playing position. Additionally, the participating football players were members of the same team, limiting the representativeness of football players of this age group.

5. Conclusions

Performance in the YYIR1 test is not correlated with VO_{2max} but with vVO_{2max}. The YYIR1 is an intermittent test that essentially evaluates the player's ability to carry out repeated efforts with short rest periods and stresses different physiological mechanisms (aerobic and anaerobic) compared to the continuous test for measuring VO_{2max} in the laboratory. vVO_{2max} is used to determine the required intensity for implementing high-intensity interval training. This intensity for each player burdens the anaerobic metabolism, a fact that may account for the relationship observed with the YYIR1 test. So from a practical perspective, the YYIR1 test should not be used to estimate VO_{2max} but rather for measuring maximal aerobic speed for the purpose of using it in high-intensity interval training.

To conclude, elite young football players (U17) did not show differences between playing positions in the variables studied. This is likely due to limited specialization regarding the position-specific training load they received until this age.

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Institutional Review Board Statement: The Ethics Committee of the School of Physical Education and Sport Science at Thessaloniki approved this study (Ap.n. 188/2024).

Informed Consent Statement: Informed consent was obtained from all parents of subjects involved in the study.

Data Availability Statement: Data are available upon request from the corresponding author. The data are not publicly available due to privacy.

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Conflicts of Interest: The author declares no conflict of interest.

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