ROL Spor Bilimleri Dergisi / *Journal of ROL Sports Sciences*
Cilt/Volume: 4, Sayı/No: 3, Yıl/Year: 2023, ss. / pp.: 964-980
E-ISSN: 2717-9508
URL: https://roljournal.com/

Comparing the maximal aerobic speed assessed with laboratory and field tests in soccer players

Erkan AKDOĞAN[1], Cihan AYGÜN[1],
Hayriye ÇAKIR ATABEK[1], Ali Onur CERRAH[1]

[1]Eskişehir Technic University, Sport Science Faculty, Eskişehir, Turkiye

Araştırma Makalesi/*Research Article*		**DOI:** 10.5281/zenodo.8354054
Gönderi Tarihi/*Received:* 28.04.2023	Kabul Tarih/*Accepted:* 15.08.2023	Online Yayın Tarihi/*Published*: 20.09.2023

Abstract

The aim of the study was to compare the maximal aerobic speed **(**MAS) obtained from the VAM-EVAL and Yo-Yo intermittent recovery test (YYIR1), with an incremental (1km.h^{-1} per min) treadmill test in soccer players. Eighteen amateur male soccer players, were evaluated with the following tests: a) a treadmill test to directly determine values of maximal oxygen uptake (VO_2max) and MAS (Treadmill); b) an indirect VAM-EVAL Test; c) an indirect YYIR1. The results demonstrated that the last speed, distance, and test duration values are significantly different among the tests ($p<0.05$)]. The highest MAS value was recorded during the treadmill test (17.10±1.38 km.h^{-1}) which was significantly different from YYIR1 and VAM-EVAL tests (15.82±0.66 and 14.33±0.69 km.h-1, respectively; $p<0.001$). The analysis also showed that treadmill MAS value was significantly correlated with YYIR1 MAS ($r=0.656$) and VAM-EVAL MAS values ($r=0.625$), also YYIR1 MAS value was significantly correlated with VAM-EVAL MAS value ($r=0.662$). It was concluded that the MAS and the VO_2max values are significantly different among YYIR1, VAM-EVAL and selected treadmill protocol, and support the idea that they should not be used interchangeably. From a practical perspective, MAS seems to be more important for coaches than VO_2max. Both laboratory and field tests can be useful for assessing MAS; however, field tests should be preferred for training purposes.

Keywords: Field tests, maximal aerobic speed**,** treadmill tests, VAM-EVAL test, YO-YO Test

Futbolcularda laboratuvar ve saha testleri ile değerlendirilen maksimal aerobik hızın karşılaştırılması

Öz

Bu çalışmanın amacı, futbolcularda VAM-EVAL ve Yo-Yo aralıklı toparlanma testinden (YYIR1) elde edilen maksimal aerobik hızı (MAS), şiddeti kademeli artan (dakikada, 1 km/s) koşu bandı testinden elde edilen MAS ile karşılaştırmaktır. On sekiz amatör erkek futbolcu (yaş:25,94±5,13 yıl, boy uzunluğu:177,77±4,89 cm, vücut ağırlığı:75,74±7,14 kg) aşağıdaki testlerle değerlendirilmiştir: a) maksimal oksijen tüketimi (VO_2maks) ve MAS (koşu bandı) değerlerini doğrudan belirlemek için, bir koşu bandı testi; b) dolaylı bir VAM-EVAL Testi; c) dolaylı YYIR1. Sonuçlar son hız, mesafe ve test süresi değerlerinin testler arasında önemli ölçüde farklı olduğunu göstermiştir [YYIR1-VAM-EVAL;YYIR1 - koşu bandı testi ve VAM-EVAL - koşu bandı testi arasında ($p<0,001$). Diğer taraftan, koşu bandı VO_2maks değeri, YYIR1 VO_2maks değeri ile önemli ölçüde ilişkili olduğu, ancak koşu bandı VO_2maks le VAM-EVAL VO_2maks değeri arasında ise anlamlı bir ilişki bulunmadığı tespit edilmiştir. Sonuç olarak, YYIR1, VAM-EVAL ve seçilen koşu bandı protokolünün MAS değerleri arasında istatistiksel açıdan ilişki bulunmasına rağmen, bulgularımız MAS ve VO_2maks değerlerinin YYIR1, VAM-EVAL ve seçilen koşu bandı protokolü arasında önemli ölçüde farklı olduğunu göstermekte ve birbirlerinin yerine kullanılmaması gerektiği fikrini desteklemektedir. MAS, antrenörler için VO_2max'ten daha önemli görünmektedir. MAS'ı değerlendirmek için hem laboratuvar hem de saha testleri faydalı olabilir; ancak antrenman amaçlarına yönelik olarak saha testleri tercih edilmelidir.

Anahtar Kelimeler: *Koşu bandı testleri, maksimal aerobik hız, saha testleri, VAM-EVAL testi, YO-YO Testi*

Sorumlu Yazar/ Corresponded Author: Erkan Akdoğan, **E-posta/ e-mail:** eakdogan@eskisehir.edu.tr
Genişletilmiş Türkçe Özet, makalenin sonunda yer almaktadır.

This study was presented as oral presentation at the 18. International Sport Sciences Congress.

INTRODUCTION

Soccer is an intermittent sport, which requires different physiological components (Stolen et al., 2005). The physiological demands of soccer require players to be competent in several aspects of fitness, which include aerobic and anaerobic power, muscle strength, flexibility and agility (Svensson & Drust, 2005). Therefore, to achieve the goals of the training, exercise individualization is a key factor in physical fitness improvement. For aerobic exercises, parameters such as percentage of maximal oxygen consumption (VO_2max), percentage of velocity at lactate / ventilatory thresholds, percentage of heart rate reserve (HRR), and percentage of maximal aerobic speed (MAS) have been mainly used to adapt exercises to the physiological features of each individual (Berthoin et al., 2006).

Maximal aerobic speed is one of the most important training components used to develop soccer players' aerobic power and is defined as the minimal speed that elicits the maximal oxygen consumption (Di Prampero et al., 1986, Lacour et al., 1991). This parameter can be expressed as a velocity, it became a great tool for coaches to define percentages to train. Field tests such as VAM-EVAL and YO-YO, as well as various laboratory tests including the Astrand modified running, Submaximal discontinuous treadmill (SUBMAX) protocol, Oxygen Consumption till Exhaustion, VO_2 max, and Vsub%95, are employed for the determination of an individual's MAS level (Balasekaran et al., 2023). Laboratory performance tests are often time-consuming and require expensive equipment (Paradisis et al., 2014), for this reason, different field tests have been created to estimate MAS with sufficient accuracy. Shuttle run test, 5-minute running field test, Yo-Yo intermittent recovery test level 1 (YYIR1), University de Montreal Track-Test (UM-TT), and VAM-EVAL tests are the most known field tests used to determine MAS (Lacour et al., 1991; Berthoin et al., 1994; Berthon et al., 1997; Brocherie et al., 2008; Dupont et al., 2010).

Although there are sufficient studies in the literature comparing field tests and laboratory tests in terms of MAS, the results are conflicting. It has been reported that the MAS data of VAM-EVAL test was significantly lower than the MAS data of treadmill test (15.5 ± 0.9 $km.h^{-1}$ vs. 17.4 ± 1.4 $km.h^{-1}$, respectively) in professional soccer players (Brocherie et al., 2008). Consistent with these findings, in a study conducted on physical education students, it has been determined that the MAS value (13.1 ± 1 $km.h^{-1}$) of shuttle run test was significantly lower than running track and treadmill tests (15.8 ± 1.9 $km.h^{-1}$ and 15.9 ± 2.6 $km.h^{-1}$, respectively) (Berthoin et al., 1994). The differences in test methodologies may explain those different findings. On the other hand, Los Arcos et al. (2019) reported that the MAS value estimated by UM-TT (16.6 ±

0.8 km·h-1) was most likely greater than the MAS value determined by laboratory test (15.9 ± 0.9 km·h^{-1}), additionally, the VO_2max estimated by the UM-TT was most likely lower than the VO_2max determined on the treadmill.

Although previous studies (Lacour et al., 1991; Berthoin et al., 1994; Brocherie et al., 2008; Dupont et al., 2010; Los Arcos et al., 2019) have already presented some evidence relating to the MAS data, there is still need of knowledge about MAS determined by different procedures. In particular, the high validity and reliability of laboratory tests are essential; however, in practical settings, football teams may have limitations in terms of feasibility. Therefore, investigating the differences between field tests used in practice and laboratory tests is important for accurate performance assessment in soccer players. Therefore, this study aimed to compare MAS and VO_2max data gathered from the laboratory (incremental progressive protocol conducted on treadmill) and field tests (YYIR1 and VAM-EVAL) in amateur soccer players.

METHOD

Participant

Eighteen amateur male soccer players, (age 25.94 ± 5.13 years, height 177.77 ± 4.89 cm, weight 75.74 ± 7.14 kg, percent body fat (%) 17.73 ± 3.58) volunteered to participate in this study. All players were selected from amateur teams and had at least six years of competitive playing experience. A priori sample size was performed (G*Power, version 3.1.9.2, University of Kiel, Germany) for an ANOVA of repeated measurements, which a determined effect size = 0.35, power = 0.85, one group and three measures (YYIR1, VAM-EVAL, Treadmill), and that accordingly to these, the sample size should be seventeen participants. The study protocol adhered to the ethical guidelines of the 1975 Declaration of Helsinki, and written informed consents were obtained from all participants, who were completely informed about benefits, and risks. As for the ethical issues, the local Research Ethics Committee approved the research (Board approval numbers: 17052).

Procedures

The study was conducted on amateur soccer players during the preparation period of training season, for this reason no familiarization measurements were done. However, the day before the tests, there was no training the day before the tests to ensure that all players were rested. On the first, anthropometry and body composition were carried out at the Laboratory of Kinanthropometry at the Faculty of Sport Sciences, Eskişehir Technical University. Afterwards laboratory and field tests were conducted. Experimental sessions were carried out at the same time of day and were separated by one week. YYIR1, VAM-EVAL test, and laboratory test (incremental progressive exercise test) in order to determine MAS and VO_2max.

Anthropometric data collection

A stadiometer mounted on the wall (Holtain, UK) was utilized to measure the standing height of individuals without shoes, with measurements rounded to the nearest 0.1 cm. Body mass was determined using an electronic scale (SECA, Hamburg) with a precision of ± 0.1 kg. Moreover, the percentage of body fat (PBF) was evaluated using DXA technology (Lunar Prodigy Pro; GE Healthcare, Madison, WI, USA) with a precision of ± 0.1%. After collecting anthropometric data, the physiological variables were assessed under the three distinct conditions outlined below.

Yo-Yo intermittent recovery test level 1 (YYIR1)

The assessment involves performing shuttle runs over a distance of 2 x 20 meters, shuttling back and forth between the start, turning, and finish lines. The speed of the shuttle runs progressively increases and is controlled by auditory cues from a computer. After each running segment, there is a 10-second period of active rest, involving 2 sets of 5 meters of jogging. This particular test format includes 4 running segments covering speeds from 10 to 13 km/h (0 to 160 m), followed by 7 runs at 13.5 to 14 km/h (160 to 440 m). Subsequently, the speed increments by 0.5 km/h after every 8 running segments until the participant reaches exhaustion, following the protocol established by Krustrup et al. (2001) and Dupont et al. (2010). During the test, players receive verbal encouragement, and the test concludes if a participant fails to complete the shuttle run in time on two occasions. Recorded parameters include the total distance covered in meters, the time taken in minutes and seconds, and the maximum speed reached during the final completed shuttle run (Roe and Malone, 2016).

The Maximum Aerobic Speed (MAS) and VO_2max values for the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) are calculated using Equation 1 (Kuipers et al., 1985; Dupont et al., 2010) and Equation 2 (Bangsbo et al., 2008) as follows:

$$\text{YYIR1 MAS} = V + 0.5 \times (n/8) \text{ [Equation 1]}$$

Within the equation, V symbolizes the velocity attained during the penultimate stage, where the value 0.5 signifies the speed increment after each stage (in km/h), and n indicates the count of runs within each stage starting from 14.5 km/h (Dupont et al., 2010).

The calculation for maximal oxygen consumption (VO_2max) in milliliters per kilogram per minute (ml.kg-1.min-1) is carried out using Equation 2 as follows:

$$VO_2max = (\text{YYIR1 distance in meters}) \times 0.0084 + 36.4 \text{ [Equation 2]}$$

The VAM-EVAL: Continuous multistage field test

The VAM-EVAL test commences at a running speed of 8 km/h, followed by a continuous increase in speed by 0.5 km/h each minute until the point of exhaustion. Participants adjusted their running pace according to auditory cues presented at 20-meter intervals, marked by cones placed along a 200-meter long athletics track. The test was concluded if a participant failed to reach the subsequent cone in time on two occasions. Throughout the test, researchers and coaches provided verbal encouragement to the players. Recorded data encompassed the total distance covered in meters, the time taken in minutes and seconds, and the highest speed achieved (the last recorded speed in km/h) during the final completed run. The maximum speed attained by players during the last 1-minute segment of the test was taken as their MAS in km/h (Mendez-Villanueva et al., 2010). In cases where the last phase was not completed in its entirety, the MAS was determined using the equation developed by Kuipers et al. (1985) as shown in Equation 3.

$$\text{VAM-EVAL MAS} = V + 0.5 \text{ x } (t/60) \text{ [Equation 3]}$$

In the provided equation, V denotes the velocity during the penultimate stage, while the value 0.5 signifies the incremental change in velocity between consecutive stages (in km/h). The variable "t" represents the duration in seconds for which the last stage was maintained, and "60" corresponds to the total seconds in the stage. This adjusted velocity achieved during the test was then utilized to calculate VO_2max using Equation 4, where "v" stands for the adjusted velocity (MAS) in km/h, referring to the work of Léger and Mercier (1983) and Brocherie et al. (2008).

The calculation for maximal oxygen consumption (VO_2max) in milliliters per kilogram per minute (ml.kg-1.min-1) is performed using Equation 4 as follows:

$$VO_2max = 1.353 + (3.163 \text{ x } v) + 0.0122586 \text{ x } v^2 \text{ [Equation 4]}$$

Laboratory test

The determination of MAS and VO_2max was conducted on a motor-driven treadmill (Cosmed T150, Italy) through an incremental progressive protocol adapted from Midgley et al. (2007). The test commenced with an initial running speed of 8 km/h (at 0% incline) and was subsequently subjected to a 1 km/h increment every minute. Throughout the test, the oxygen consumption (VO_2), carbon dioxide (VCO_2), and heart rate (HR) were continuously measured using the computerized breath-by-breath analysis system Master Screen-CPX (Care Fusion, Germany). The gas analyzer underwent calibration before each session according to the manufacturer's guidelines.

To ascertain the VO_2max value, the mean of the final 30 seconds of the test was taken. Likewise, the MAS value was derived from the mean speed recorded during the last 30 seconds. VO_2max was deemed to be achieved if two consecutive workloads demonstrated either no increase (< 2.1 $ml.kg^{-1}.min^{-1}$) in VO_2, or if at least two of the following criteria were met: i) the respiratory exchange ratio (RER) exceeded 1.10, or ii) the participants attained their age-predicted maximum heart rate (220 - age). Parameters recorded included total distance covered (in meters), time taken (in minutes and seconds), and the maximum speed achieved (the last recorded speed in km/h) at the final stage.

Statistical analyses

The statistical analysis was conducted using SPSS software (version 18, IBM, Chicago, USA), where statistical significance was set at $p < 0.05$. The normality of the data was assessed using the Shapiro-Wilk test, which indicated that all data followed a normal distribution. As a result, repeated measure ANOVA was employed to compare both the MAS and VO_2max data, with a Bonferroni correction employed for multiple comparisons. In the context of ANOVA, the partial eta-squared (η_p^2) was calculated as a measure of effect size. The interpretation of ηp2 effect sizes was as follows: 0.01 denoted a small effect, 0.06 signified a medium effect, and 0.14 indicated a large effect. For the presentation of results, all values were expressed as means ± standard deviation (SD). Furthermore, individual data for both MAS and VO_2max were visualized in figures.

RESULTS

Table 1 presents the physical performance data encompassing speed, distance, and test duration. The outcomes unequivocally illustrate notable variations in the last achieved speed (both in km/h and m/sec), covered distance (in meters), and test duration among the distinct experimental sessions ($p<0.001$). Specifically, the highest speed was attained during the treadmill test, while the longest distance was achieved in the VAM-EVAL test. Further pairwise comparisons indicate significant disparities across the investigated variables when comparing YYIR1 with VAM-EVAL tests, YYIR1 with treadmill tests, and also between VAM-EVAL and treadmill tests ($p<0.05$).

Table 1. The physical performance data of the soccer players

	YYIR1	VAM-EVAL	Treadmill	F	p value	1-β	η_p^2
Speed_last ($km.h^{-1}$)	16.08±0.62	14.50±0.64 ‡	17.39±1.42 **	82.683	p<0.001	1.000	0.83
Distance (m)	1604.44±425.51	2624.29±325.12 ‡	2069.39±386.06 **	85.799	p<0.001	1.000	0.84
Test duration (min and sec)	13 min 4 sec±3 min 20 sec (784.33±200.89 sec)	14 min 48 sec ± 1 min 34 sec (887.86±82.36 sec) #	9 min 54 sec±1 min 28 sec (594.17±78.28sec) **	41.914	p<0.001	1.000	0.71

Speed last: the speed at which the test ended; ** p<0.001 significantly different from YYIR1 and VAM-EVAL tests, # p<0.05 and ‡ p<0.001 significantly different from YYIR1 test.

Figure 1 and Figure 2 display the physical performance data for MAS and VO_2max, respectively. The outcomes reveal significant disparities in both MAS (in km/h) and VO_2max (in ml.kg-1.min-1) values among the experimental sessions (F=78.423, p<0.001, η_p^2=0.82, 1β=1.000, and F=71.176, p<0.001, η_p^2=0.81, 1-β=1.000, respectively). The peak MAS value was achieved during the treadmill test (17.10±1.38 km/h), signifying a substantial difference from the MAS values in the YYIR1 and VAM-EVAL tests (15.82±0.66 and 14.33±0.69 km/h, respectively; p<0.001). Furthermore, the MAS value recorded in the VAM-EVAL test significantly differed from that in the YYIR1 test (p<0.001). Parallel to the MAS findings, the highest VO_2max value emerged from the treadmill test (60.58±6.10 ml.kg-1.min-1), indicating a significant discrepancy when compared to the VO_2max values in the YYIR1 and VAM-EVAL tests (49.88±3.57 and 49.19±2.42 $ml.kg^{-1.}min^{-1}$, respectively; p<0.001). No significant difference was observed between YYIR1 and VAM-EVAL tests in terms of VO_2max (p=0.884).

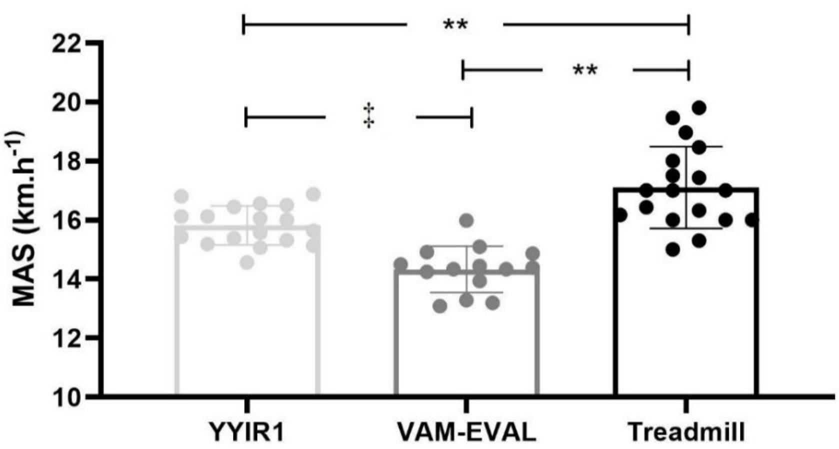

Figure 1. Maximum aerobic speed data of different experimental sessions.

MAS: maximum aerobic speed; ** $p<0.001$ significantly different from YYIR1 and VAM-EVAL tests, ‡ $p<0.001$ significantly different from YYIR1 test. The figure shows individual data points and mean ± SD values.

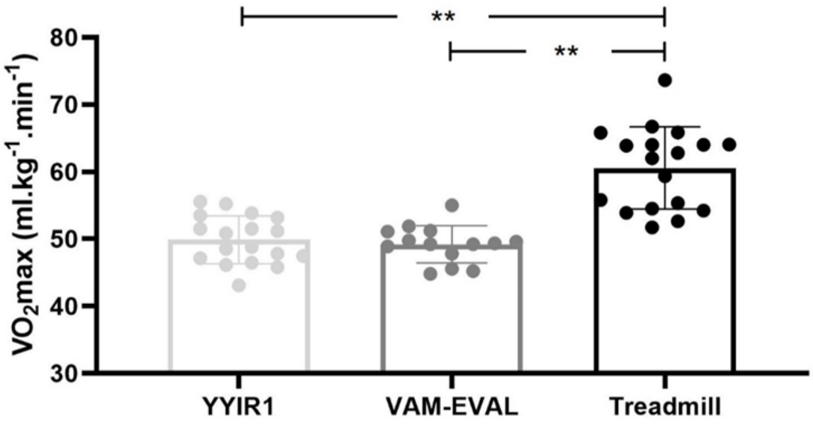

Figure 2. Maximum oxygen consumption data of different experimental sessions.

VO_2max: maximum oxygen consumption; ** $p<0.001$ significantly different from YYIR1 and VAM-EVAL tests. The figure shows individual data points and mean ± SD values.

Regarding the correlation coefficients among the three distinct experimental sessions, the results indicate several significant relationships. Specifically, the treadmill MAS value exhibited a significant correlation with YYIR1 MAS ($r=0.656$; $p<0.01$) and VAM-EVAL MAS values ($r=0.625$; $p<0.01$). Similarly, the YYIR1 MAS value demonstrated a significant correlation with the VAM-EVAL MAS value ($r=0.662$; $p<0.01$).

Conversely, the treadmill VO_2max value showed a significant correlation with YYIR1 VO_2max value ($r=0.632$; $p<0.01$). However, no significant correlation was identified between the treadmill VO_2max and VAM-EVAL VO_2max values ($r=0.368$; $p>0.05$). Notably, a robust correlation coefficient of $r=0.661$ ($p<0.01$) was observed between the VAM-EVAL VO_2max value and YYIR1 VO_2max value.

DISCUSSION AND CONCLUSION

The aim of this study was to analyze and contrast the MAS and VO_2max data acquired from three distinct tests: VAM-EVAL, YYIR1, and an incremental treadmill test (with a speed increase of 1 km/h per minute) in soccer players. The key outcomes of this investigation demonstrate noteworthy disparities in terms of the last achieved speed, covered distance, and overall test duration among the various tests. These differences were observed when comparing YYIR1 versus VAM-EVAL, YYIR1 versus treadmill tests, and VAM-EVAL versus treadmill tests ($p<0.001$). Moreover, a significant correlation was identified between the MAS value attained during the treadmill test and the MAS values obtained from the field tests. On the other hand, the VO_2max value determined by laboratory test significantly correlate with YYIR1 VO_2max value, but do not significantly correlate with VAM-EVAL VO_2max value. A study involving professional soccer players established a significant difference in test duration between VAM-EVAL and the treadmill test (16±1.8 minutes vs. 10.4±1.4 minutes, respectively; $p<0.01$), as reported by Brocherie et al. (2008). In line with these findings, the present study also reveals that the test duration for field tests is notably longer than that of the treadmill test (13 minutes 4 seconds and 14 minutes 48 seconds vs. 9 minutes 54 seconds, respectively). Conversely, Brocherie et al. (2008) found that the MAS derived from the VAM-EVAL test was significantly lower than the MAS determined through the treadmill test (15.5±0.9 km/h vs. 17.4±1.4 km/h, respectively; $p<0.01$). However, Ahmaidi et al. (1992) demonstrated that the MAS value of the 20-meter shuttle run test (20-MST) was lower compared to both the treadmill test (16.3%) and the UM-TT (19.3%). One can argue that the disparities in the literature's results can be attributed to factors such as the comparison of direct and indirect measurement methodologies and variations in the formulas employed for estimating indirect measurements

Furthermore, it has been documented that the peak velocity in the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) is notably lower than the peak velocity in a standard treadmill protocol (Castagna et al., 2008). Consistent with similar studies mentioned above conducted on soccer players, our study's results indicate that the MAS from the treadmill test is significantly higher than the MAS derived from field tests. In our study, the laboratory test commenced at a speed of eight km/h, identical to the VAM-EVAL test's starting speed. Additionally, to maintain uniform conditions, a protocol with zero slope was adopted. However, unlike the field tests, the speed increment was set at one km/h per minute instead of 0.5 km/h per minute. This difference in speed increment may contribute to the laboratory test concluding earlier and yielding a higher maximum speed result. Furthermore, in the current study the MAS value recorded for the YYIR1 test was significantly higher than the VAM-EVAL test's MAS value ($p<0.001$). This is probably because of the ten-second rest intervals, which are thought to provide recovery, after every 40-meter shuttle run (Bangsbo et al., 2008). These recovery periods, additionally the stops and the returns after every 20 meters may be the main reasons of different physiological responses. A study comparing the intermittent (YYIR1) and the continuous (UM-TT) exercise protocols has been indicated that the peak velocities of the YYIR1 and UM-TT tests should not be used interchangeably (Dupont et al., 2010). However, contrasting outcomes to those aforementioned studies have also surfaced (Berthoin et al., 1996; Silva et al., 2011) wherein no significant distinctions between the tests were observed. Berthoin et al. (1996) reported that maximal speeds achieved on both the treadmill and the track were not significantly divergent; the comparable speed increments possibly contributing to this result. Notably, a potential elevation in the energy expenditure during treadmill testing, especially when set at a 3% incline, might have led to the MAS treadmill being lower than the MAS UM-TT. Similarly, Silva et al. (2011) found no noteworthy differences between peak running velocity in Carminatti's test and the VO_2max test conducted on the treadmill.

Brocherie et al. (2008) reported that the MAS data from the VAM-EVAL test did not correlate with the treadmill velocity at VO_2max. Conversely, research conducted on amateur soccer players revealed a significant correlation between the MAS derived from the Université de Montréal Track Test (UM-TT) and the YYIR1 MAS value (Dupont et al., 2010). Similarly, Los Arcos et al. (2019) reported a strong correlation ($r>0.67$) between the MAS measured on the UM-TT and the MAS measured on a treadmill in young soccer players. Furthermore, Lacour et al. (1991) found that while the velocity corresponding to the last stage of the UM-TT was slightly higher than the intermittent graded treadmill test performed on well-trained runners, these two velocities were highly correlated ($r=0.92$, $p<0.001$). Consistent with the studies mentioned above, the findings of our present study results were correlated among the MAS data obtained from the treadmill, YYIR1, and VAM-EVAL tests ($r>0.620$). The results of this study, particularly in similarity to the recent study by Los Arcos et al. (2019), are noteworthy for their correlation coefficient.

Similar to the MAS data, the highest recorded VO_2max value in our current study was obtained during the treadmill test (60.58 ± 6.10 ml.kg^{-1}.min^{-1}), which significantly differed from the VO_2max values of the YYIR1 and VAM-EVAL tests (49.88 ± 3.57 and 49.19 ± 2.42 ml.kg^{-1}.min^{-1}, respectively; $p<0.001$). These results align with previous research findings. For example, Brocherie et al. (2008) indicated that the VO_2max estimated from the VAM-EVAL test was notably lower (-7.3%) than the VO_2max measured during the treadmill test among professional soccer players. Additionally, Los Arcos et al. (2019) demonstrated that the VO_2max estimated by the UM-TT was likely lower than the VO_2max measured on a treadmill.

In a study by Alemdaroğlu et al. (2012), direct measurement of VO_2max using a portable breath-by-breath system was compared with VO_2max estimates from three different performance tests: YYIR1, 20-meter multistage fitness test (MST), and Bruce treadmill test

(BTRT). The results showed no significant differences in measured VO_2max values among the tests. However, VO_2max values estimated from the YYIR1 test were significantly lower than those estimated from the MST and BTRT. In contrast to this study, our present study's results indicate no significant differences between the VO_2max values estimated from the YYIR1 and VAM-EVAL tests. It can be stated that one of the reasons for this is the non-identical nature of the test procedures used in the mentioned study and the differences in the formulas utilized for estimation.

Darendeli et al. (2021) demonstrated that the final scores obtained from the Yoyo IRT1, 20-meter shuttle run test (20-MST), and 5-minute time trial (5 min-TT) did not align with the speed of VO_2max (sVO_2max) when considered individually. However, the final speed values achieved during Yoyo IRT1 and 20-MST correlated well with the speed of VO_2max values derived from The Université de Montréal Track Test (UMTT) in our population of regional-level amateur soccer players. This suggests that the equation models of Yoyo IRT1 and 20-MST could be utilized for predicting sVO_2max values. Benhammou et al. (2021) compared the performance and physiological responses obtained from a new intermittent field test (Test3L) with those from a standard continuous test (TestVAM) and examined its reproducibility. They have demonstrated that the three-level test enabled the acquisition of a reproducible MAS, comparable to that of a traditional test like VAM-EVAL. Consequently, both MAS and the maximum heart rate derived from Test3L could be employed in the design of training programs. It is mentioned that practitioners can use sVO2max to prescribe a 10-minute HIIT session consisting of 15-second work and passive recovery intervals (Bok et al., 2023). Additionally, it has been indicated that when prescribing short-format HIIT, the 30-15 intermittent fitness test, which takes into account the portion of the anaerobic speed reserve (ASR) in the final test speed, leads to a more homogeneous cardiopulmonary response compared to prescribing based solely on MAS (Buchheit et al., 2021).

The results of the current study demonstrate a significant correlation between the VO_2max values obtained from the treadmill test and those from the YYIR1 test, whereas no significant correlation was observed between the treadmill VO_2max value and the VAM-EVAL VO_2max value. A study involving young soccer players found a strong correlation between VO_2max values derived from treadmill and shuttle run tests (r=0.69) (Higino et al., 2017). However, Higino et al. (2017) highlighted that, despite this strong correlation, the VO_2max determination they employed the shuttle run test did not appear to be a robust predictor of aerobic fitness among young soccer players. Contrary to the current study's findings, studies conducted on soccer players have reported no significant correlations among VO_2max values determined from different tests [e.g. between YYIE2 test, shuttle run test, and treadmill test (Aziz et al., 2005); between YYIR1 and treadmill tests (Castagne et al., 2006)]. The differences in results in the literature can be attributed to factors such as participant characteristics, variations in measurement methods, especially the comparison of direct and indirect measurement methodologies, and differences in the formulas used for estimation.

Limitations

We acknowledge that certain facets of the study's design and execution could potentially constrain the interpretation of our results. Firstly, we estimated the VO_2max from performance of the field tests instead of measure directly the VO_2 during the field tests. Second, we did not monitor the heart rate simultaneously during the field tests, which may limit our findings. Third, the treadmill protocol selection may have affected the results.

Practical application

Although a strong relationship exists between the measured VO_2max and the estimated VO_2max from the YYIR1 test, coaches in practical settings are likely to prioritize the absolute performance in the field tests specifically, the distance covered during the tests. This directly reflects a player's endurance level, which holds more relevance than their oxygen uptake rate.

In summary, while a significant correlation is evident among the MAS values of YYIR1, VAM-EVAL, and the selected treadmill protocol, our findings emphasize that the MAS and VO_2max values substantially differ across YYIR1, VAM-EVAL, and the chosen treadmill protocol. This underscores the notion that these values should not be used interchangeably. Furthermore, the direct comparison between field tests and laboratory tests does not appear to be a reasonable approach.

Recommendations

In summary, while a significant correlation is evident among the MAS values of YYIR1, VAM-EVAL, and the selected treadmill protocol, our findings emphasize that the MAS and VO_2max values substantially differ across YYIR1, VAM-EVAL, and the chosen treadmill protocol. This underscores the notion that these values should not be used interchangeably. Furthermore, the direct comparison between field tests and laboratory tests does not appear to be a reasonable approach.

GENİŞLETİLMİŞ ÖZET

GİRİŞ

Futbolun fizyolojik ihtiyaçları, oyuncuların aerobik ve anaerobik güç, kas kuvveti, esneklik ve çeviklik gibi birkaç fitness yönünde yeterli olmalarını gerektirir (Svensson & Drust, 2005). Bu nedenle, antrenmanın hedeflerine ulaşmak için egzersiz bireyselleştirilmesi, fiziksel fitness gelişiminde kilit bir faktördür. Aerobik egzersizler için, maksimal oksijen tüketiminin yüzdesi (VO_2maks), laktat / ventilasyon eşiklerinde hızın yüzdesi, kalp atış hızı rezervinin yüzdesi (HRR) ve maksimal aerobik hızın yüzdesi (MAS), egzersizleri her bireyin fizyolojik özelliklerine uyarlamak için başlıca kullanılan parametrelerdir (Berthoin ve ark., 2006).

Son zamanlarda, MAS (Maksimal Aerobik Hız), futbol oyuncularının aerobik güçlerini geliştirmek için kullanılan en önemli antrenman bileşenlerinden biridir ve maksimal oksijen tüketimini en üst düzeye çıkaran minimal hız olarak tanımlanır (Di Prampero ve ark., 1986; Lacour ve ark., 1991). Bu parametre hız olarak ifade edilebilir ve antrenörler için yüzde değerlerini belirlemek için büyük bir araç haline gelmiştir. Birçok laboratuvar ve saha testi bireysel MAS seviyesini belirlemek için kullanılır. Laboratuvar performans testleri genellikle zaman alıcı ve pahalı ekipman gerektirir (Paradisis ve ark., 2014); bu nedenle, yeterli doğrulukla MAS'ı tahmin etmek için farklı saha testleri oluşturulmuştur.

Önceki çalışmalar (Lacour ve ark., 1991; Berthoin ve ark., 1994; Brocherie ve ark., 2008; Dupont ve ark., 2010; Los Arcos ve ark., 2019), MAS verileri ile ilgili bazı kanıtlar sunmuş olsa da, farklı yöntemlerle belirlenen MAS hakkındaki bilgiye hala ihtiyaç vardır. Bu nedenle, bu çalışma amatör futbol oyuncularında laboratuvar (koşu bandında artan ilerleyici protokol) ve saha testleri (YYIR1 ve VAM-EVAL) ile toplanan MAS ve VO_2maks verilerini karşılaştırmayı amaçlamıştır.

YÖNTEM

Çalışmaya 18 amatör erkek futbolcu gönüllü olarak katılmıştır. Boy uzunluğu ve vücut ağırlığı iki kez alınmış ve iki ölçümün ortalaması, ölçüm sonucu olarak kaydedilmiştir (Lohman ve ark., 1988). Vücut kompozisyon parametreleri Dual enerji X-ışını absorptiometrisi (DEXA) cihazı ile belirlenmiştir. Tüm katılımcıların MAS ve VO_2maks'ını belirlemek için YYIR1 testi, VAM-EVAL testi ve laboratuvar testi (kademeli şiddeti artan) yapılmıştır. Üç farklı test, birer hafta arayla, ayrı günlerde ve günün aynı saatinde gerçekleştirilmiştir. Çalışma, antrenman sezonunun hazırlık döneminde yapılmıştır. Testlerden bir gün önce, tüm oyuncuların antrenman yapmadığı ve dinlendirildiği bir gün sağlanmıştır.

BULGULAR

İstatistiksel analizler sonucunda son hız, mesafe ve test süresi değerlerinin testler arasında önemli ölçüde farklı olduğunu göstermiştir. En yüksek son hız değeri, YYIR1 ve VAM-EVAL testlerinden anlamlı olarak farklı olan koşu bandı testi (17,10 ±1,38 km / saat) sırasında kaydedilmiştir (sırasıyla 15,82±0,66 ve 14,33 ± 0,69 km / saat; p <0,001). En fazla mesafe vameval testinde, test süresi olarak en kısa koşu bandında görülmüştür.

En yüksek MAS değeri, YYIR1 ve VAM-EVAL testlerinden anlamlı olarak farklı olan koşu bandı testi (17,10±1,38 km / saat) sırasında kaydedilmiştir (sırasıyla 15.82 ± 0.66 ve 14,33±0,69 km / saat; p<0,001). Ayrıca analizler sonucunda, koşu bandı MAS değerinin YYIR1 MAS ve VAM-EVAL MAS değerleri ile anlamlı düzeyde korelasyon gösterdiğini, ayrıca YYIR1 MAS değerinin VAM-EVAL MAS değeri (r>0,62) ile anlamlı korelasyon gösterdiği bulunmuştur.

MAS verilerine benzer şekilde, en yüksek VO_2maks değeri, YYIR1 ve VAM-EVAL testlerinden (49,88±3,57 ve 49,19±2,42 ml) önemli ölçüde farklı olan koşu bandı testi sırasında (60,58 ± 6,10 ml.kg^{-1}.dak^{-1}) kaydedilmiştir. Öte yandan, koşu bandı VO_2maks değeri, YYIR1 VO_2maks değeri ile önemli ölçüde korelasyon göstermiştir, ancak koşu bandı VO_2maks ile VAM-EVAL VO_2maks değeri arasında anlamlı bir korelasyon saptanmamıştır

TARTIŞMA VE SONUÇ

Bu çalışmanın amacı, üç farklı testten elde edilen Maksimal Aerobik Hız (MAS) ve maksimal oksijen tüketimi (VO_2maks) verilerini analiz etmek ve karşılaştırmaktır. Bu araştırmanın temel sonuçları, farklı testler arasında son ulaşılan hız, katedilen mesafe ve genel test süresi açısından dikkate değer farklılıklar göstermektedir. Bu farklılıklar, YYIR1 ile VAM-EVAL, YYIR1 ile koşu bandı testleri ve VAM-EVAL ile koşu bandı testleri arasında karşılaştırıldığında gözlenmiştir (p<0,05).

Ayrıca, koşu bandı testi sırasında elde edilen MAS değeri ile saha testlerinden elde edilen MAS değerleri arasında anlamlı bir korelasyon belirlenmiştir. Diğer taraftan, laboratuvar testiyle belirlenen VO_2maks değeri YYIR1 VO_2maks değeri ile anlamlı bir şekilde ilişkili olduğu, ancak VAM-EVAL VO_2maks değeri ile anlamlı bir ilişki göstermemiştir.

Sonuç olarak, futbolcularda VO_2maks belirlemek için koşu bandı testleri, VAM-EVAL testine göre daha doğru bir yöntem gibi görünse de pratik bir bakış açısıyla MAS, antrenörler için VO_2maks 'dan daha önemli görünmektedir. MAS'ı incelemek için hem laboratuvar hem de saha testleri yararlı olduğunda, saha testleri antrenman amacıyla seçilmelidir.

REFERENCES

Ahmaidi, S., Collomp, K., Caillaud, C., & Prefaut, C. (1992). Maximal and functional aerobic capacity as assessed by two graduated field methods in comparison to laboratory exercise testing in moderately trained subjects. *International Journal of Sports Medicine*, *13*(03), 243-248.

Aziz, A. R., Tan, F. H., & Teh, K. C. (2005). A pilot study comparing two field tests with the treadmill run test in soccer players. *Journal of Sports Science & Medicine*, *4*(2), 105.

Alemdaroğlu, U., Dündar, U., Köklü, Y., & Aşcı, A. (2012). Evaluation of aerobic capacity in soccer players: comparison of field and laboratory tests. *Biology of Sport*, *29*(2), 157-161.

Balasekaran, G., Loh, M. K., Boey, P., & Ng, Y. C. (2023). Determination, measurement, and validation of maximal aerobic speed. *Scientific Reports*, *13*(1), 8006.

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

Benhammou, S., Mourot, L., Mokkedes, M. I., Bengoua, A., & Belkadi, A. (2021). Assessment of maximal aerobic speed in runners with different performance levels: Interest of a new intermittent running test. *Science & Sports, 36*(5), 413-e1.

Berthoin, S., Gerbeaux, M., Turpin, E., Guerrin, F., Lensel-Corbeil, G., & Vandendorpe, F. (1994). Comparison of two field tests to estimate maximum aerobic speed. *Journal of Sports Sciences*, *12*(4), 355-362.

Berthoin, S., Pelayo, P., Lensel-CorbeiP, G., Robin, H., & Gerbeaux, M. (1996). Comparison of maximal aerobic speed as assessed with laboratory and field measurements in moderately trained subjects. *International journal of Sports Medicine*, *17*(07), 525-529.

Berthon, P., Fellmann, N., Bedu, M., Beaune, B., Dabonneville, M., Coudert, J., … et al. (1997). A 5-min running field test as a measurement of maximal aerobic velocity. *European Journal of Applied Physiology and Occupational Physiology*, *75*(3), 233-238.

Berthoin, S., Baquet, G., Dupont, G., & Van Praagh, E. (2006). Critical velocity during continuous and intermittent exercises in children. *European Journal of Applied Physiology*, (98), 132-138.

Bok, D., Gulin, J., Škegro, D., Šalaj, S., & Foster, C. (2023). Comparison of anaerobic speed reserve and maximal aerobic speed methods to prescribe short format high-intensity interval training. *Scandinavian Journal of Medicine & Science in Sports*, *33*(9).

Brocherie, F., Racinais, S., Chatard, J. C., & Grantham, J. (2008). Comparison of maximal aerobic velocity assessed with laboratory and field measurements in elite soccer players. *Medicine and Science in Sports and Exercise*, *40*(5 (Supp. 1), S386-S386.

Buchheit, M., Dikmen, U., & Vassallo, C. (2021). The 30-15 Intermittent Fitness Test—Two decades of learnings. *Sport Performance & Science Reports*, *1*(148), 1-13.

Castagna, C., Impellizzeri, F. M., Chamari, K., Carlomagno, D., & Rampinini, E. (2006). Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: acorrelation study. *The Journal of Strength & Conditioning Research*, *20*(2), 320-325.

Castagna, C., Impellizzeri, F. M., Rampinini, E., D'Ottavio, S., & Manzi, V. (2008). The Yo–Yo intermittent recovery test in basketball players. *Journal of Science and Medicine in Sport*, *11*(2), 202-208.

Darendeli, A., Vitiello, D., Billat, V. L., Diker, G., & Cuğ, M. (2021). Comparison of different exercise testing modalities to determine maximal aerobic speed in amateur soccer players. *Science & Sports*, *36*(2), 105-111.

Da Silva, J. F., Guglielmo, L. G., Carminatti, L. J., De Oliveira, F. R., Dittrich, N., & Paton, C. D. (2011). Validity and reliability of a new field test (Carminatti's test) for soccer players compared with laboratory-based measures. *Journal of Sports Sciences*, *29*(15), 1621-1628.

Di Prampero, P. E., Atchou, G., Brückner, J. C., & Moia, C. (1986). The energetics of endurance running. *European Journal of Applied Physiology and Occupational Physiology*, *55*(3), 259-266.

Dupont, G., Defontaine, M., Bosquet, L., Blondel, N., Moalla, W., & Berthoin, S. (2010). Yo-Yo intermittent recovery test versus the Universite de Montreal Track Test: relation with a high-intensity intermittent exercise. *Journal of Science and Medicine in Sport*, *13*(1), 146-150.

Higino, W. P., Souza-Sorroche, A., de Mattos-Falqueiro, P. G., Lima, Y. C. S., & Higa, C. L. (2017). Determination of aerobic performance in youth soccer players: Effect of direct and indirect methods. *Journal of Human Kinetics*, *56*(1), 109-118.

Krustrup, P., & Bangsbo, J. (2001). Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. *Journal of Sports Sciences*, *19*(11), 881-891.

Kuipers, H., Verstappen, F. T. J., Keizer, H. A., Geurten, P., & Van Kranenburg, G. (1985). Variability of aerobic performance in the laboratory and its physiologic correlates. *International Journal of Sports Medicine*, *6*(04), 197-201.

Lacour, J. R., Padilla-Magunacelaya, S., Chatard, J. C., Arsac, L., & Barthelemy, J. C. (1991). Assessment of running velocity at maximal oxygen uptake. *European Journal of Applied Physiology and Occupational Physiology*, *62*(2), 77-82.

Léger, L., & Mercier, D. (1983). Coût énergétique de la course sur tapis roulant et sur piste. *Motricité Humaine*, (2), 66-69.

Los Arcos, A., Vázquez, J. S., Villagra, F., Martín, J., Lerga, J., Sánchez, F., ... et al. (2019). Assessment of the maximal aerobic speed in young elite soccer players: Université de Montréal Track Test (UM-TT) vs. treadmill test. *Science & Sports*, *34*(4), 267-271.

Mendez-Villanueva, A., Buchheit, M., Kuitunen, S., Poon, T. K., Simpson, B., & Peltola, E. (2010). Is the relationship between sprinting and maximal aerobic speeds in young soccer players affected by maturation?. *Pediatric Exercise Science*, *22*(4), 497-510.

Midgley, A. W., McNaughton, L. R., & Carroll, S. (2007). Time at V· O2max during Intermittent Treadmill Running: Test Protocol Dependent or Methodological Artefact?. *International Journal of Sports Medicine*, 934-939.

Paradisis, G. P., Zacharogiannis, E., Mandila, D., Smirtiotou, A., Argeitaki, P., & Cooke, C. B. (2014). Multi-stage 20-m shuttle run fitness test, maximal oxygen uptake and velocity at maximal oxygen uptake. *Journal of Human Kinetics*, (41), 81.

Roe, M., & Malone, S. (2016). Yo-Yo intermittent recovery test performance in subelite gaelic football players from under thirteen to senior age groups. *Journal of Strength and Conditioning Research*, *30*(11), 3187-3193.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, *18*(9), 669-683.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Medicine*, (35), 501-536.

Svensson, M., & Drust, B. (2005). Testing soccer players. *Journal of Sports Sciences*, *23*(6), 601-618.

KATKI ORANI *CONTRIBUTION RATE*	**AÇIKLAMA** *EXPLANATION*	**KATKIDA BULUNANLAR** *CONTRIBUTORS*
Fikir ve Kavramsal Örgü *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak *Form the research hypothesis or idea*	Erkan AKDOĞAN Ali Onur CERRAH
Tasarım *Design*	Yöntem ve araştırma desenini tasarlamak *To design the method and research design.*	Erkan AKDOĞAN Ali Onur CERRAH
Literatür Tarama *Literature Review*	Çalışma için gerekli literatürü taramak *Review the literature required for the study*	Erkan AKDOĞAN Ali Onur CERRAH Cihan AYGÜN Hayriye ÇAKIR ATABEK
Veri Toplama ve İşleme *Data Collecting and Processing*	Verileri toplamak, düzenlemek ve raporlaştırmak *Collecting, organizing and reporting data*	Erkan AKDOĞAN Cihan AYGÜN Hayriye ÇAKIR ATABEK Ali Onur CERRAH
Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların değerlendirilmesi *Evaluation of the obtained finding*	Erkan AKDOĞAN Cihan AYGÜN Hayriye ÇAKIR ATABEK Ali Onur CERRAH

Destek ve Teşekkür Beyanı/ *Statement of Support and Acknowledgment*

Bu çalışmanın yazım sürecinde katkı ve/veya destek alınmamıştır.

No contribution and/or support was received during the writing process of this study.

Çatışma Beyanı/ *Statement of Conflict*

Araştırmacıların araştırma ile ilgili diğer kişi ve kurumlarla herhangi bir kişisel ve finansal çıkar çatışması yoktur.

Researchers do not have any personal or financial conflicts of interest with other people and institutions related to the research.

Etik Kurul Beyanı/ *Statement of Ethics Committee*

Bu araştırma, Eskişehir Teknik Üniversitesi Etik Kurulunun Kabul numarası 17052 sayılı kararı ile yürütülmüştür.

This research was conducted with the decision of Eskisehir Technical University Ethics Committee numbered 17052.