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Original Article

Relationship between VO_2max and anthropometric measures in semiprofessional female soccer players

LORENA RODRÍGUEZ-GARCÍA[1,], BEATRIZ MORENO-VECINO[2], RICARDO MARTÍN-MOYA[3], JOSÉ ALFONSO MORCILLO LOSA[4], FRANCISCO TOMÁS GONZÁLEZ-FERNÁNDEZ[5]
[1,2]Department of Physical Activity and Sport Sciences, Pontifical University of Comillas. CESAG, 07013 Palma, SPAIN.
[3,5]Department of Physical Education and Sports, Faculty of Sport Sciences. University of Granada 18071, Granada, SPAIN.
[4]Department of Didactics of Corporal Expression, University of Jaén, Jaén, SPAIN.
[1,,2,] MOBhE Research Group, Pontifical University of Comillas, 07013 Palma, SPAIN

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Abstract.
Problem Statement: Soccer requires significant utilization of aerobic system, owing to the continuous energetic demands and high glycogen consumption. The optimal functioning of this system is crucial for energy efficiency, which may be influenced by various anthropometric factors. While research has extensively explored male players, there is a notable dearth of studies concerning female footballers. **Approach:** Optimal functioning of this system depends on enhanced energy efficiency, which may be influenced by variations in anthropometric parameters. Despite ongoing research focusing on male players, there remains a gap in understanding among female soccer players. **Purpose**: The purpose of the present study was to examine the potential correlation between estimated oxygen consumption and anthropometric metrics among female semi-professional soccer players. Twenty-five participants from the Balearic Islands, Spain, with an average age of 21.87 years, height of 163.93 cm, weight of 61.78 kg, and 6.55 years of experience, were included. Anthropometric measurements were initially conducted, followed by the Yo-Yo test to assess maximum oxygen consumption. Correlation analyses were performed between maximum oxygen consumption, fat mass percentage, muscle mass percentage, bone mass percentage, body weight percentage, body mass index (BMI), and visceral fat percentage. **Results:** A correlation analysis performed between maximum oxygen consumption, percentage of fat mass, percentage of muscular mass, percentage of bone mass, and percentage of body weight and body mass index did not revealed a significant correlation, r=-0.16, p=0.46, r=0.03, p=0.88, r=0.01, p=0.94, r=0.05, p=0.83, and r=0.17, p=0.29, respectively. Nevertheless, there was a large negative correlation between maximum oxygen consumption and body mass index (r=-.49, p=0.01) and maximum oxygen consumption and visceral fat (r=-.39, p=0.05). **Conclusions:** Maintaining a normalized BMI and reducing visceral fat are crucial for achieving higher maximal oxygen consumption in female soccer players, potentially enhancing their performance. Strategies for optimizing oxygen consumption and reducing visceral fat may include cardiovascular exercise, strength training, and proper nutrition.
Keywords: Soccer, VO_2max, female soccer players, anthropometrical measures, visceral fat.

Introduction

Soccer stands as one of the most globally recognized sports, with a notable surge in the popularity and professionalism of women's competitions in recent years, with 193 teams participating in the 2024 FIFA World Ranking (FIFA, 2024). However, compared to men's soccer, research and findings in the realm of women's soccer remain scant (Lockie et al., 2017). This team sport demands a diverse array of abilities and physical competencies, essential for adapting to the game's varying intensities and continuous, intermittent demands. The exertion required is contingent upon numerous factors, including the maximum strength and power of the neuromuscular system. This system's sustained engagement involves the utilization of various muscle fibers, tasked with generating explosive force rapidly. Additionally, the game's physiological demands are met through the utilization of both aerobic and anaerobic energy systems (Cometti et al., 2001; Ingebrigtsen et al., 2011; Lockie et al., 2017).

In soccer, characterized by prolonged exercise lasting at least 90 minutes and involving diverse activities of varying intensities, the proper development of the aerobic system is paramount. This metabolic pathway, chiefly through aerobic glycolysis, serves as the primary energy source during a match. Research has established a direct correlation between aerobic capacity and player performance in medium to high-intensity exercises, such as counterattacks or pressing against opponents (Gabrys et al., 2020; Rønnestad et al., 2011). Moreover, during phases of the game necessitating less intense activities, the aerobic system reliant on fatty

Corresponding Author: BEATRIZ MORENO VECINO, E-mail: bmoreno@cesag.org

acids facilitates energy conservation, thereby enhancing energy efficiency and facilitating quicker player recovery (Christensen et al., 2011; Gabrys et al., 2020).

Depending on the specific sport undertaken, variations in the cardiorespiratory system and aerobic capacity can manifest. Engaging in mixed sports such as soccer has been shown to enhance post-exercise recovery capacity in youth compared to other sports (Calleja-González et al., 2021; Tomlin & Wenger, 2002). Furthermore, it exerts a beneficial effect on the cardiorespiratory system, evidenced by improvements in maximum oxygen volume (VO_2max), with professional soccer players competing in higher-level categories exhibiting higher VO_2max levels (VO_2max) (Mandroukas et al., 2021). In this sense, VO_2max reflects the body's ability to utilize maximum oxygen at a given time, serving as a robust indicator of performance and an international standard for assessing athletes' physical capabilities (Papadakis et al., 2020; Ranković et al., 2010). Given soccer's dynamic nature, intermittent monitoring of this parameter is crucial. Indeed, numerous studies employ the intermittent Yo-Yo test to gauge VO_2max in soccer players (Bradley et al., 2014; González-Fernández et al., 2020; (Krustrup et al., 2005); Markovic & Mikulic, 2011; Papadakis et al., 2020;Gabryś et al., 2019; Schmitz et al., 2018).

The association between VO_2max and body weight has been established (Ranković et al., 2010), highlighting the significance of evaluating anthropometric variables and body mass index (BMI) to optimize the health and performance of soccer players (Nobari et al., 2021; Sutton et al., 2009). Performance outcomes are intricately linked to various anthropometric traits, including height, weight, body perimeter measurements, and skinfold thickness, as well as physiological factors such as body mass, skeletal muscle mass, heart mass, and lung mass (Nobari et al., 2021). Recent research advocates for the integration of performance metrics from training sessions and matches with assessments of body composition, offering a more comprehensive understanding tailored to individual players. Moreover, disparities in VO_2max parameters are associated with players' positional roles on the field, with midfielders typically demonstrating higher values compared to defenders. These positional discrepancies may also align with distinct anthropometric characteristics among players (Collins et al., 2021; Ingebrigtsen et al., 2011; Kammoun et al., 2020). In fact, the holistic assessment of physiological and morphological factors, including oxygen consumption, anthropometric measurements, and positional differences, offers valuable insights into the performance dynamics of female soccer players. Nevertheless, the limited research conducted thus far on female athletes has revealed significant heterogeneity among top-level soccer players, suggesting a need for further studies to determine whether certain anthropometric profiles are characteristic of specific playing positions (Randell et al., 2021). By understanding these multifaceted relationships, coaches, trainers, and sports scientists can tailor training programs and interventions to optimize the athletic potential and well-being of female athletes in soccer.

Body composition in general and anthropometric characteristics in particular, affect sporting performance in male soccer players (González-Fernández et al., 2023). It is well established that a higher muscle mass and a lower fat percentage are associated with higher VO_2max values. Consequently, it can be anticipated that men will achieve superior results in physical tests where oxygen consumption is a relevant factor compared to women (Martín-Moya et al., 2023).

Despite the significant rise in the involvement of women in sports over recent decades, there remains a notable scarcity of research focusing on female soccer players and their anthropometric characteristics, which are intricately linked to soccer performance (Ingebrigtsen et al., 2011; Lockie et al., 2017; Kammoun et al., 2020). Consequently, there exists a gap in understanding the relationship between oxygen consumption (VO_2max) and anthropometric measurements in female soccer players; even though the pivotal role these parameters play in assessing sports performance. Given the relevance of VO_2max and anthropometric measurements in gauging the athletic capabilities of soccer players and the dearth of conclusive evidence regarding their interplay in female athletes, this study aims to elucidate whether a relationship exists between oxygen consumption, anthropometric measurements, and performance in young female soccer players. By investigating these associations, we seek to contribute valuable insights into the physiological and morphological factors influencing the performance of female athletes in soccer.

Material & Methods

The research was carried out in February. The data collection was previously followed by 48 hours of rest. Yo-Yo test IR-Level 1 and anthropometrical measures was evaluated.

Participants

Twenty-five female semiprofessional soccer players (age= 21.87 ± 3.30 years; stature = 163.93 ± 7.02 cm, and body mass= 61.78 ± 9.20 kg; 6.55 ± 3.09 years of experience) from the region of Balearic Islands, Spain, were recruited in February 22nd and 23rd. The participants trained three times a week with a duration of 90 minutes per session. The training sessions were based on the development of technical and tactical content, improvement of technical skills and general physical condition. The training sessions were divided into a warm-up in a main part and a cool-down. Participants received information on the main objectives of the research and signed informed consent forms.

The study was conducted in accordance with the ethical principles of the Helsinki declaration for human research and was approved by the Research Ethics of University of Granada, registered No. 3570/CEIH/2023.

The inclusion criteria for the participants were (i) to report normal vision and no history of any neuropsychological disorder that could affect the results of the experiment, (ii) to have an active player's federative license, (iii) not to have any injury during the previous two months, and (iv) to give their consent.

Table 1. VO_2max Assessment Norms through the Yo-Yo Test for Woman

Ratings	Levels	Value Range
Ellite	>17.5	>49.8
Excelent	16.6-17.5	47.5-49.8
Good	15.6-16.5	44.8-47.2
Average	14.6-15.5	42.1-44.5
Below average	13.1-14.5	39.1-41.7
Poor	<13.1	<39.1

Source: Hardinata et al. (2023)

Procedure

Twenty-five female semiprofessional soccer players were enrolled in this study to collect data in two days. Body composition measurement was performed in one day and VO_2max estimation test was carried out two days later. These measurements were conducted in the locker room of the soccer field where the participants usually train, and the Yo-Yo test was conducted on the soccer field.

Anthropometric measurements

Height (cm) was measured with a stadiometer (type SECA 225, Hamburg, Germany) with an accuracy of 0.1 cm. Body weight (kg) and the rest of the body composition parameters analysed were measured by using a bioelectrical impedance analysis (BIA) device (Tanita BC-602) with an accuracy of 0.1 kg. Body mass index was computed as mass (in kilograms) divided by the square of height (in meters). Firstly, the height of the participants was measured and then, the BIA data were collected.

The instructions for participants to consider when collecting body composition data were: not to have eaten within the last 3 hours, to urinate immediately previous to data collection, not to have consumed alcohol and/or drugs during the 12 hours prior to data collection and not to have performed strenuous exercise 12 hours previously.

Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT Level 1)

The test was performed following the guidelines of González-Fernández et al. (2020).The YYIRT Level 1 consists of 4 initial out-and-back runs (from 0 to 160 m) at 10-13 km/h and 7 runs (from 160 to 440 m) at 13.5-14 km/h. Afterwards, the running speed increases gradually by 0.5 km/h every 8 runs until the participant is unable to reach the finish line in time on two attempts. Finally, at the end of the test, the number of levels reached and the total metres completed were recorded.

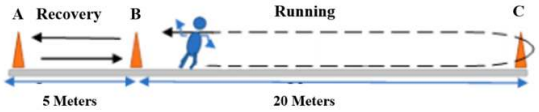

Figure 1. The Yo-Yo intermittent recovery test instrument.

Statistical analysis

Descriptive statistics were computed for each variable, followed by tests for normal distribution and homogeneity (Kolmogorov–Smirnov and Levene's tests, respectively) on all metrics. Subsequently, Pearson's correlation coefficient (r) was employed to explore the association between VO_2max and various anthropometric measures, including percentage of fat mass (%FM), percentage of muscle mass (%MM), bone mass (BM), body mass index (BMI), kilocalories (kcal), percentage of total body water (%BW), and visceral fat (VF). The magnitude of these correlations was interpreted based on the following criteria: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, moderate; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect. All analyses were conducted using the statistical software Statistical (version 13.1; Stat soft, Inc., Tulsa, OK, USA), with the significance level set at $p < 0.05$.

Results

Descriptive statistics were calculated for each variable (Table 2).

Table 2. Anthropometrical measures and physical VO_2max in the experiments (mean ± SD).

	Young soccer players (*n*=25)			
	Mean (SD)	**Minimum**	**Range**	**Maximum**
Anthropometrical measures				
Age (years)	21.87± 3.30	18.57	6.6	25.17
Height (cm)	163.93±7.02	150.00	29.00	179.00
Weight (kg)	61.78±9.20	46.10	33.90	80.00
%MG	29.50±5.09	21.70	20.20	41.90
%MM	40.98±4.20	33.20	17.40	50.60
BM (kg)	2.20±0.23	1.80	0.90	2.70
BMI	22.98±3.31	18.40	13.60	32.00
kcal	2232.58±204.35	1847.00	829.00	2676.00
% BW	52.28±3.57	43.20	14.50	57.70
VF	2.21±1.76	1.00	8.00	9.00
Physical fitness parameters				
VO_2max (mL/min/kg)	47.76±3.49	37.76	14.43	52.19

Note: VO_2max was estimated by the next equation: Yo-Yo IR1 test: VO_2max (mL/min/kg) = IR1 distance (m) × 0.0084 + 36.4 (Bangsbo et al., 2008).

Initially, a correlation analysis was conducted to explore the relationship between VO_2max and several anthropometric variables, including percentage of muscular mass (%MG), percentage of muscular mass (%MM), percentage of bone mass (%BM), calorie intake (kcal), and percentage of body weight (%BW). The results did not unveil any significant correlations, with correlation coefficients (r) and associated p-values of -0.16 (p=0.46), 0.03 (p=0.88), 0.01 (p=0.94), 0.05 (p=0.83), and 0.17 (p=0.29), respectively. However, a noteworthy finding emerged from the analysis, revealing a substantial negative correlation between VO_2max and body mass index (BMI) (r=-0.49, p=0.01), as well as between VO_2max and visceral fat (VF) (r=-0.39, p=0.05). Further details regarding these correlations are provided in Figure 2.

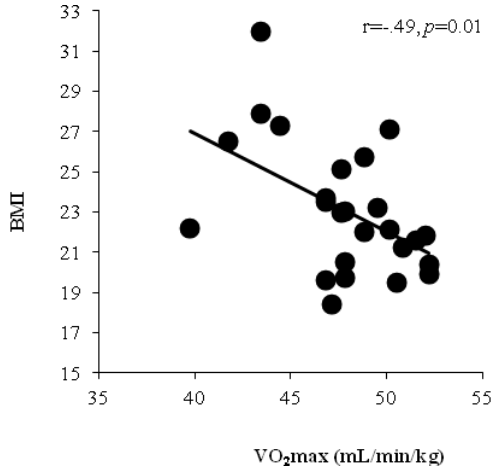

Figure 2.1. Correlations analysis between VO_2max and BMI.

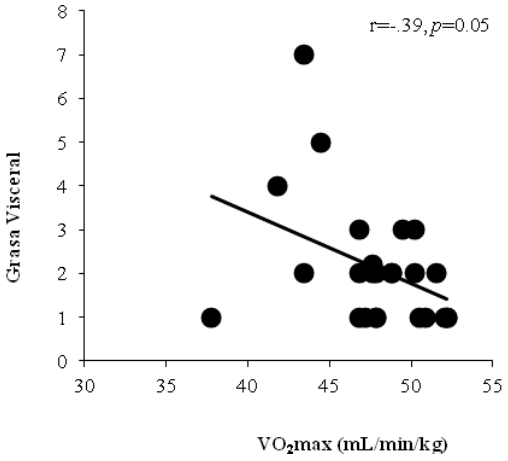

Figure 2.2. Correlations analysis between VO_2max and VF.

Finally, a multiple regression analysis was conducted to ascertain which fitness-related anthropometric variables, as identified through the correlation analysis, could offer a more comprehensive explanation of the significance of VO_2max. The multiple regression analysis for BMI revealed significant effects (r = -0.49, r^2= 0.24, adjusted r^2= 0.21, *F*= 7.37, *p*=0.01 and standard error= 2.88). On Similarly, the multiple regression analysis for visceral fat (VF) demonstrated significant effects (r = -0.49, r^2= 0.15, adjusted r^2= 0.12, *F*= 4.18, *p*=0.05 and standard error= 1.36). These findings indicate the potential of BMI and VF as predictors of VO_2max, offering valuable insights into the interplay between anthropometric measurements and aerobic capacity.

Discussion

The main aim of this investigation was to evaluate VO_2max using the Yo-Yo intermittent test among female soccer players and explore potential associations with anthropometric measurements, such as BMI and VF. A notable finding from the study is the significant correlation between VO_2max and body mass index (BMI)

(r=-.49), indicating an inverse relationship between the two variables. This suggests that individuals with lower BMI values exhibit greater oxygen utilization capacity during physical exertion. Consequently, a lower BMI may imply enhanced respiratory efficiency to sustain exercise intensity and duration. This observation aligns with previous research by Mohammed et al., (2018), who linked lower BMI within healthy ranges to optimized VO_2max attainment. Within this context, the term "aerobic fitness," denoting VO_2max, is frequently employed and typically improves with increased physical activity levels. Nonetheless, it's essential to recognize that VO_2max is influenced by various factors, including genetics, age, sex, training status, and cardiovascular and respiratory health (Lee & Zhang, 2021).

While excessive body weight or obesity may potentially impede VO_2max due to heightened cardiovascular strain, possessing a lower BMI does not necessarily guarantee superior VO_2max levels (Roso-Moliner et al., 2022). It's crucial to acknowledge individual physiological variations and exercise responses. Some athletes with higher BMI may exhibit exceptional cardiovascular fitness and VO_2max, while others with lower BMI may demonstrate lower fitness levels (Nikolaidis et al., 2019; Roso-Moliner et al., 2022)). Optimal physical performance results from a multifaceted interplay of numerous factors and should not solely rely on BMI or body composition assessments (Islam et al., 2020). To assess and improve an individual's capacity to process oxygen during exercise, it is important to consider a comprehensive approach that includes proper training, nutrition, and overall physical fitness.

Another significant finding in this study pertains to the notable relationship observed between visceral fat (VF) values and VO_2max levels among female soccer players. The results indicate that lower levels of VF correspond to greater cardiorespiratory capacity, as evidenced by higher VO_2max consumption. Existing evidence suggests a link between reduced VF levels and enhanced cardiovascular fitness, including elevated VO_2max levels, particularly in athletes (Ross et al., 2020; Ubago-Guisado et al., 2016)). VF specifically refers to adipose tissue stored around internal organs within the abdominal cavity, and this excessive accumulation has been associated with heightened risks of cardiovascular diseases and metabolic disorders (Myers et al., 2019) such as insulin resistance, inflammation, and dyslipidaemia, which can impair cardiovascular function (Asian-Clemente et al., 2022). When athletes exhibit lower levels of visceral fat, it often indicates a healthier body composition and a reduced susceptibility to certain health conditions. This favorable composition can positively impact cardiovascular function and overall fitness, potentially leading to augmented VO_2max values (Ross et al., 2020; Ubago-Guisado et al., 2016). However, it's crucial to acknowledge that VO_2max is influenced by a multitude of factors beyond VF alone, including genetic predisposition, training status, cardiovascular health, respiratory function, and overall body composition (Asian-Clemente et al., 2022; Lee & Zhang, 2021). Research comparing athletes with non-athletes often shows athletes as having lower VF levels and higher VO_2max values, suggesting that regular intense physical training is effective at reducing VF and enhancing cardiovascular fitness (López-Fuenzalida et al., 2016). However reduced levels of VF may contribute, they do not singularly determine an athlete's VO_2max (Asian-Clemente et al., 2022; (Santisteban et al., 2022).

Nevertheless, this study faces several limitations, with the primary constraint being the sample size. Additionally, the study's scope is limited by the number of variables examined, particularly with regards to nutrition and strength training, which are known to influence improvements in VO_2max. It is imperative to broaden the scope of study variables to comprehensively analyze the intricate relationships between anthropometric variables, training regimens, and aerobic capacity in female soccer players. Another limitation of the study and aspects for improvement could be the establishment of a specific physical exercise program in women's soccer to verify the improvement in aerobic capacity with data collection of the variables before and after. Regular monitoring of VF and BMI can help in assessing a female player health and fitness levels, guiding training, and nutrition plans to optimize performance. Research on the correlations between BMI, VF, and VO_2max can inform female soccer clubs about the physical fitness of their players in a simple and accessible way in any context.

Conclusions

The results of this study show that maximal oxygen uptake and VF and their BMI, are inversely related. A minimum and proper BMI and visceral fat is essential to accomplish a higher VO_2max. These results demonstrate the potential of BMI and VF as predictors of VO_2max and provide valuable insights into the interaction between anthropometric measurements and aerobic capacity. Therefore, to increase VO_2max, it is necessary to be at the right weight to minimize BMI and VF and be able to achieve greater improvements over VO_2max. Female soccer players with a well-rounded approach to training, including cardiovascular exercise, strength training, and proper nutrition, are more likely to optimize their VO_2max levels. It's important to focus on overall fitness, rather than solely targeting visceral fat reduction or BMI, to achieve optimal performance and cardiovascular health. Consulting with a healthcare or sports professional can provide personalized guidance and strategies for improving VO_2max and overall athletic performance.

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Conflicts of interests. The authors declare that they have no conflicts of interest relevant to the content of this manuscript.

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