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Aerobic power across positions – an investigation into women's soccer performance

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A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

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Abstract

Objective. The aim of the study was to discern the disparities in the aerobic capacity of female athletes occupying various positions within a soccer team, and to understand the physical characteristics of the athletes in different positions. It is critical to understand that the physical demands for players vary depending on their positions on the field, a factor that greatly influences their training and gameplay.
Materials and method. The study engaged a sample of 25 female soccer players, average age of 22.72 (±2.69 SD), all of whom were active participants in the Chinese Women's Super League. The sample was distributed across several playing positions, including forwards, midfielders, and defenders. To gather pertinent data on oxygen uptake, a progressive load test was administered on a treadmill, coupled with a gas analyzer to amass respiratory indices (JAEGER, Germany).
Results. The study revealed that there was a notable variance in the maximum oxygen uptake among players in different positions. The midfielders exhibited the highest VO2 max at 63.24±7.04 ml/kg/min, followed by the forwards who averaged at 58.92±7.70 ml/kg/min, and finally the defenders who recorded the smallest average at 55.73±4.40 ml/kg/min.
Conclusions. The outcomes of this study indicate that the positional role of a player in a team correlates with their aerobic capacity. Therefore, the positional demands significantly shape the player's physical characteristics, influencing their training and gameplay. This understanding is vital for the optimal conditioning of athletes in different positions in the sport of soccer.

Key words
aerobic power, VO2 max, training, aerobic capacity, women's soccer, physical characteristics

INTRODUCTION

Soccer, also known as football, is a highly demanding sport that requires continuous physical activity and endurance during matches [1]. Aerobic capacity, commonly measured by the maximum amount of oxygen uptake during exercise (VO2 max), is a fundamental factor in assessing an athlete's fitness level and performance ability [2]. Soccer players are found to have higher aerobic capacities than the average person due to the nature of the sport [3]. However, studies show that there may be variations in position specific VO_2 max among soccer players, based on their roles on the field [4]. More than 4 million female soccer players are registered with soccer associations, and women's soccer is gradually gaining some influence in the world [5]. Women's soccer has the same complex structure as men's soccer, and many other factors influence the game. However, a good female soccer player should have the aerobic capacity, anaerobic capacity, speed, endurance, explosive power, coordination, and the ability to read the game [6, 7]. The physical and technical requirements of players in different positions in the game are also different [8].

In recent years, researchers have started to study the influence of soccer players' physiology and morphology on the playing position, which are factors that may influence the tactical arrangement by team coaches [9]. The literature suggests that there may be differences in VO_2 max levels between soccer players of different positions. One study found that midfielders have the highest VO_2 max levels among all positions, while defenders and forwards may have slightly lower measurements [10]. Most studies have focused on male soccer players and fewer studies have been conducted on female soccer players [11].

In normal game analysis, the dominant analytic item in women's soccer remains movement, which includes running distances, sprints, and direction changes throughout the game, or can be described as movement of different intensities [12]. In a regular game, female athletes run around 10,000 m in a 90-minute game, with an aerobic-to-anaerobic work ratio of 9:1 [2]. From a physiological point of view, during such long races, athletes do not maintain constant high-intensity exercise, but intermittent exercise alternating between aerobic and anaerobic [13], with some studies indicating a change in activity every 4–6 seconds [14]. This exercise pattern may occur in both sprint-rest or jog-rest situations, in which the athlete's organism changes with the duration of the race, and good aerobic capacity affects the exercise performance. For example, a series of physiological responses, such as decreased intramuscular PH, decreased ATP and PCr concentrations, aerobic metabolic depletion, and increased lactic acid [6]. While lactate clearance rate is related to aerobic capacity, athletes with a higher aerobic capacity have a shorter recovery time and a very strong regeneration of phosphocreatine. The average VO_2 level of

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a team will even determine the league standings, where the first-place team has the highest VO_2 and the second and third places ranked behind; therefore, good aerobic capacity is undoubtedly one of the factors in achieving results [15].

Different race levels mean different load intensities, and in physiological terms the essence of exercise load originates from the metabolic capacity of body functions to cope with the intensity of the race. Measuring VO_2 max is the maximum amount of oxygen a person utilizes per unit of time, and oxygen uptake can represent oxygen utilization and exercise capacity [16, 17].

Despite extensive research on aerobic capacity and variations in VO_2 max among soccer players, there remains a notable research gap in investigating female athletes. The existing studies predominantly focus on male soccer players, leaving a dearth of comprehensive research on position-specific aerobic capacities within women's soccer. Therefore, there is a compelling need to investigate the intricacies of the aerobic capacities of female soccer players in different positions.

OBJECTIVE

The aim of the study is to investigate the gap in knowledge about female aerobic capabilities in the game of soccer:
1) to meticulously assess and compare female soccer players' aerobic capacities, as measured by VO_2 max across distinct positions, including forwards, midfielders, and defenders;
2) to scrutinize and discover any significant disparities in the aerobic capacities exhibited by athletes occupying diverse positions within the female soccer team;
3) to discern and understand the implications and ramifications of position-specific aerobic capacities regarding training regimens and overall game performance among female soccer players;
4) to provide invaluable insights into the multi-faceted physical characteristics and individual demands inherent on different positions within women's soccer.

A flowchart depicting the schematics of the study is shown in Figure 1. Flowchart demonstrating the schematics of current study.

MATERIALS AND METHOD

Participants. Cardiorespiratory fitness testing was performed on 25 female soccer players (age = 22.72 ± 2.69 SD): 5 forwards, 10 midfielders, and 10 defenders (Table 1. Basic information of participants. 1, Fig. 2). All players had participated in the Chinese Women's Super League and were active players at the time of the study. The testing of the players took place at the Shandong Sports Science Research Center, China. All tests were conducted during daytime hours. According to the terms of the study, the results of the data collected were anonymous. All participants were informed about the purpose of the study and approved by both the club and individual players. The study was approved by the Gdańsk University of Physical Education and Sport and the local Ethics Committee, and conducted according to the provisions of the 1964 Declaration of Helsinki.

Table 1. Basic information of participants

Category	No. of people	Age
Forward	N=5	24.2±2.31
Midfield	N=10	23.3±2.72
Fullback	N=10	21.4±2.2
Total	N=25	22.72±2.69

Sample variables. During all tests, a heart rate belt was used to monitor each athlete's heart rate (HR) at 5s intervals. The GPS sampling frequency of this device is 10Hz, and the accelerometer is 200Hz and 1,000Hz for HR. Athletes were not permitted to exercise before the test to achieve a resting heart rate (HRrest). The entire test was carried out on a professional sports treadmill (hp/cosmos GmbH, Nussdorf-Traunstein, Germany). Oxygen uptake (VO_2) and heart rate were measured by a spirometer (Oxytone Alpha, Jaeger, Germany); calibration was performed before and after each test according to the During the test, the spirometer measured VO_2 every five seconds. To attain VO_2 max, the following conditions must be met:
1) test subject's heart rate reaches 180 beats/min;
2) respiratory quotient is greater than 1;
3) oxygen uptake has a relatively stable plateau with the increase in exercise.

After the best effort, the participant could not exercise under load [18,19].

After the test, the data was uploaded and exported to the Microsoft Excel table. The athlete always wears a breathing mask connected to the gas. The gas analyzer measured the athlete's oxygen uptake and VE ventilation. A polar heart rate belt was used to monitor the athlete's real-time heart rate and heart rate reserve, and a HP treadmill used for the treadmill test.

Testing process. The athletes did not exercise vigorously the day before the experiment and had no injuries. The test process consisted of 2 parts: a preparation phase and an incremental load phase. The purpose was to change the load intensity so that the athletes receive a certain amount of strong stimulus in advance; preparation phase 3 speed 4km/h, slope 0% for 6 minutes; the purpose was to change the load intensity so that the athletes received a certain amount in advance of strong stimulus; preparation phase 3 speed 4km/h, slope 0% hold for 1 minute, the purpose was to adjust the athlete's state and prepare for an incremental load test. Incremental load stage: Level 1: speed 8.5km/h, gradient 0.4%, hold for 2 minutes; Level 2: speed 9km/h, gradient 0.8%; LEVEL3: speed 9.5km/h. gradient 1.2%; and so on every 2 minutes with speed increasing the slope by 0.5km/h, and increased by 0.4% until the athlete could no longer continue, gradient 1.2%; and so on every 2 minutes, speed increasing the slope by 0.5km/h, increased by 0.4% until the athletes could no longer continue.

Sample variables. SPSS26 software was used for data processing (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY, USA), and statistical differences between the oxygen intakes of female soccer players were calculated using the Sh*apiro-Wilk test for normal distribution – $p>0.05$, conforming to normal distribution; $p\leq0.05$, not conforming to normal distribution; ANOVA using Levene test – $p<0.05$

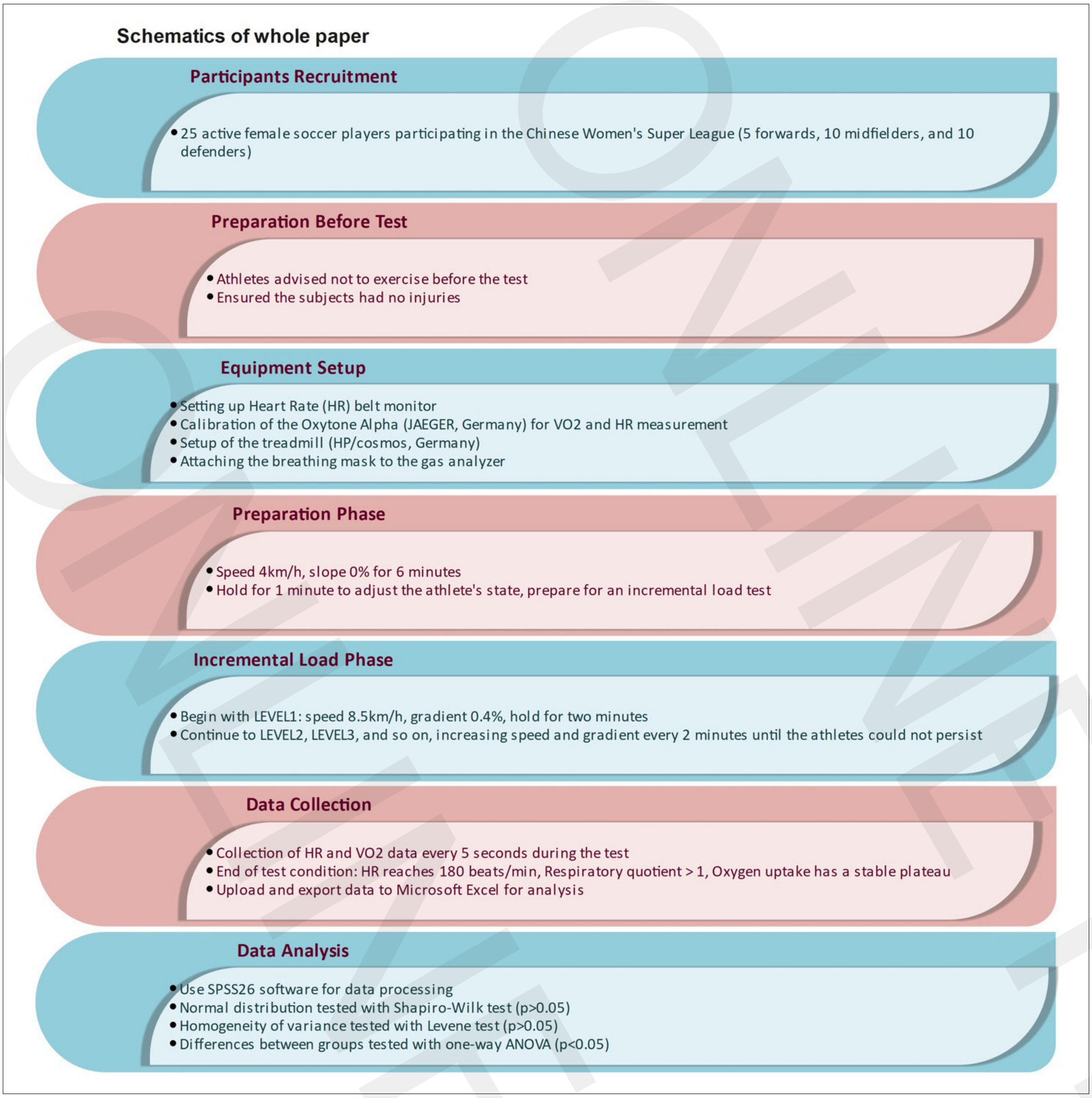

Figure 1. Flowchart demonstrating the schematics of current study

hypothesis not valid; p>0.05 -hypothesis is valid; one-way ANOVA, p<0.05 indicates significance.

RESULTS AND DISCUSSION

The coefficients of variation (CV) for height (170.04±5.42 cm), weight (58.64±6.06 kg), VO_2 max (59.37±7.27 ml/kg/min) and speed corresponding to VO_2 max (13.26±0.39 km/h) of female soccer players were less than 0.15, and the absolute values of sk less than 4, and the absolute value of Kurt less than 10 (Tab. 2). This indicates that athletes in different positions are homogeneous, and can be considered comparable in the same test, although in different positions.

In Table 3, P>0.05 in the values of the Shapiro-Wilk test indicates normality in the distribution of variables for all

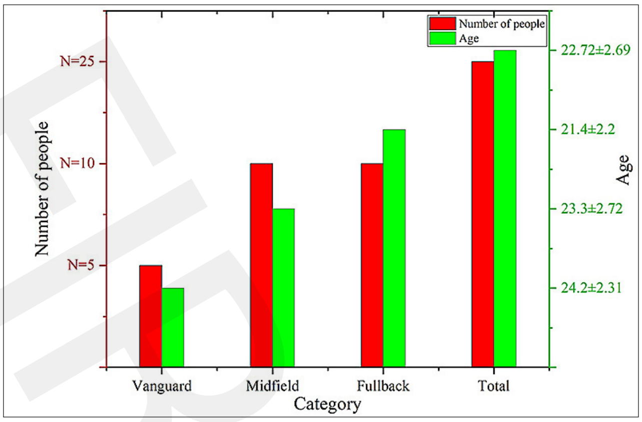

Figure 2. Graphical representation of the basic information for analysis. Vanguard – Forward

Table 2. Parameters and their values using in analysis

Category	Unit	Max	Min	AS	SD	CV	Sk	Kurt
Height	cm	186	160	170.04	5.42	0.03	1.15	2.423
Body weight	Kg	75	52	58.64	6.06	0.10	1.27	1.09
VO_2max		69.9	46.1	59.37	7.27	0.12	-0.12	-1.06
Speed	Km/h	14	12.5	13.26	0.39	0.03	-0.07	-0.13
Category	Unit	Max	Min	AS	SD	CV	Sk	Kurt
Height	cm	186	160	170.04	5.42	0.03	1.15	2.423
Body weight	Kg	75	52	58.64	6.06	0.10	1.27	1.09
VO_2max		69.9	46.1	59.37	7.27	0.12	-0.12	-1.06
Speed	Km/h	14	12.5	13.26	0.39	0.03	-0.07	-0.13
Category	Unit	Max	Min	AS	SD	CV	Sk	Kurt
Height	cm	186	160	170.04	5.42	0.03	1.15	2.423
Body weight	Kg	75	52	58.64	6.06	0.10	1.27	1.09
VO_2max		69.9	46.1	59.37	7.27	0.12	-0.12	-1.06

Max – maximum value; Min – minimum value; As – mean; SD – standard deviation; CV – coefficient of variation; Sk – skewed; Kurt – kurtosis. |skewed|<4, |kurtosis|<10

analyses. In contrast, in the one-way ANOVA, the F and P values also identify significant differences in height, weight, VO_2 max and maximum oxygen uptake corresponding to VO_2 max among the players in different positions. Also, Levene's test (P>0.05) further determined the homogeneity of the variances.

Table 3. Basic information about soccer players in different positions

Variables	Location	AS	SD	Swp	Lev	F	P
Height	Vanguard	172.8	4.79	P>0.05	0.525	1.73	0.02
	Midfield	170.9	6.25	P>0.05			
	Fullback	167.8	3.22	P>0.05			
Body weight	Vanguard	60.8	7.19	P>0.05	0.217	0.60	0.02
	Midfield	59	6.20	P>0.05			
	Fullback	57.2	4.4	P>0.05			
VO_2	Vanguard	58.92	7.70	P>0.05	0.199	3.16	0.02
	Midfield	63.24	7.04	P>0.05			
	Fullback	55.73	4.40	P>0.05			
$V(VO_{2)}$	Vanguard	13	0.32	P>0.05	0.696	2.86	0.01
	Midfield	13.45	0.35	P>0.05			
	Fullback	13.2	0.33	P>0.05			

Shapiro-Wilk test for normal distribution: p>0.05 – consistent with normal distribution; p≤0.05 – inconsistent with normal distribution. Levene test for ANOVA: p<0.05 – hypothesis not valid; p>0.05 – hypothesis valid. One-way ANOVA with ANOVA: p<0.05 – hypothesis valid

In Table 4. One-way ANOVA comparison of player information at different positions., in the data description of the different positions of players, all players' positions were grouped in a one-way analysis of variance (ANOVA). There was no significant difference in weight between of different positions of players; however, there was a significant difference (p<0.05) between the height of the forwards (172.8±4.79 cm) and the defenders (167.8±3.22 cm), while there was no significant difference between the height of the forwards and the midfielders (170.9±6.25 cm). In the comparison of VO_2max, there was a significant difference (p<0.05) between the 3 positions of players with a significantly different in the VO_2max comparison (P<0.05); the speed corresponding to VO_2 also showed significant differences between each position (P<0.05).

To the best of the authors' knowledge, this is the first study to examine the relationship between different positions and VO_2 max in Chinese female professional soccer players. In the study, the results of maximal oxygen uptake by female soccer players in different positions showed that midfielders had the highest oxygen uptake; midfielders had 6.8% higher maximal oxygen uptake than forwards, and 11.9% higher maximal oxygen uptake than defenders. This is essentially the same as the study by Haugen et al. [20]. Players with a higher VO_2 max will have more rushes and often play a key role in the game; such players with high VO_2 max also prolong lactate buildup. Players with high VO_2 max theoretically also have a higher lactate threshold, which means that such players do not accumulate lactate during high-intensity activities [21].

In the 2019 Women's World Cup, midfielders ran an average of 11,210 m, forwards, an average of 10,979 m, and defenders an average of 10,369 m [22]. In addition to team injuries and athletes' skills in the tournament, fitness was an important factor that affected the game. If the team's average VO_2 max was higher than the other team, the result was equivalent to adding one more player to the game than the opponent [23]. This is one of the reasons why VO_2 max is important for women's soccer.

In terms of speed corresponding to maximal oxygen uptake, it is still the midfielders who are the fastest; midfielders are 3.3% faster than strikers and 1.9% faster than defenders. Vescovi et al. performed the '20-meter beep test' for endurance assessment of female college soccer players, and found that players in different positions ran a distance that still showed a large gap [24]. VO_2 max is an important factor in the repetitive sprinting ability and total distance run [25]. VO_2 max is also necessary for recovery after short periods of intense exercise [26]. This contrasts with the current study on the speed of different players at maximal oxygen uptake, where midfielders were also faster than other position players under maximal oxygen uptake conditions or where midfielders were more economical in their running exertion during the game. As a result, midfielders also cover the greatest area of the pitch during the game [27].

In terms of actual competition and training, the speed corresponding to the maximum oxygen uptake is a factor that determines the performance of the game. vVO_2 max represents the athlete's aerobic capacity, and there is also a relationship between the athlete's speed and the maximum oxygen uptake [28–30].

There was no significant difference in the weight comparison, which may be caused by the female athletes' fear of being too strong due to training and reduced diet intake [31, 32]. However, there were significant differences in body weight among male soccer players in different positions [33].

CONCLUSIONS

Evaluating the physical abilities of athletes at different positions is a key aspect of targeted training and identifying the potential of athletes. This study assess the maximum amount of oxygen uptake during exercise (VO_2 max) and vVO_2 max, as well as height and weight. Some of the data are similar for female professional athletes at different positions, but there were significant differences in VO_2 max and vVO_2 max, although in most cases they performed the same training in the same training programme, and the

Table 4. One-way ANOVA comparison of player information at different positions.

	W1	W2	W3	H1	H2	H3	V1	V2	V3	S1	S2	S3
W1		0.65	0.29									
W2	0.65		0.49									
W3	0.29	0.49										
H1					0.59	0.04						
H2				0.59		0.203						
H3				0.04	0.203							
V1								0.03	0.02			
V2							0.03		0.01			
V3							0.02	0.01				
S1											0.04	0.32
S2										0.04		0.14
S3										0.32	0.14	

1 – Forward; 2 – Midfield; 3 – Defender; Weight – W; Height – H; V – Oxygen uptake; S – Speed; One-way ANOVA: P<0.05 hypothesis holds.

division of positions led to more differences in oxygen uptake and speed. There are obviously differences in the height and weight between female and male athletes, and male training methods cannot directly follow many training methods.

Evaluation of maximal oxygen uptake in soccer players facilitates the organization of training programmes. It is part of the future direction of the player, and maximal oxygen uptake is the key to success in soccer. In the current study, patterns were found in the VO_2 max of players in different positions; VO_2 max ranked in the order of midfielders – 63.24 ± 7.04 ml/kg/min, forwards – 58.92 ± 7.70 ml/kg/min, and defenders – 55.73 ± 4.40 ml/kg/min. The conclusion is that midfielders, who combine both offense and defense in the match, have more tasks to accomplish in 90 minutes; therefore, the midfielders also had higher running distances. The defenders, on the other hand, have fewer tasks to perform during the game, and therefore have the lowest oxygen uptake requirement of the whole team. This is a good indication that different positions in the team have different requirements for the players, as a result of training and games.

Future research based on this study could include developing position-specific training programmes for soccer players, given the varied aerobic capacities observed across different roles. Additional research could also examine physiological differences between male and female athletes, track players' VO_2 max changes over time, and study other physical characteristics for comprehensive performance insights. The findings could potentially be applied to other team sports with position-specific roles, maximizing player performance through tailored training strategies.

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