RESEARCH ARTICLE

INTERNATIONAL JOURNAL OF KINANTHROPOMETRY

DOI: 10.34256/ijk2533

Relationship between Body Composition, Energy Availability, and Aerobic Fitness Across Playing Positions in Female Footballers

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DOI: https://doi.org/10.34256/ijk2533
Received: 04-07-2025; Revised: 21-11-2025; Accepted: 31-11-2025; Published: 07-12-2025

Abstract

Introduction: Football is a type of team sport in which physical and physiological characteristics play an important role in performance which differ across playing positions. Several international studies are carried out on body composition, aerobic fitness and energy availability in female football players but limited research was conducted on Indian players. Therefore, the aim of our study is to assess the relationship among body composition, energy availability, and aerobic fitness across playing positions in elite female football players from West Bengal. **Methods:** The study was carried out among 42 female football players. Anthropometric parameters such as height, weight, BMI etc. were measured according to standard protocols followed by ISAK manual. Energy intake was assessed using a 24-hour dietary recall, while exercise energy expenditure was estimated using MET-based activity values to calculate energy availability. Physiological assessments included flexibility, handgrip strength, back and leg strength, and VO_2 max (Yo-Yo IR2). **Results:** BMI showed a significant correlation with Body-fat % ($\rho = 0.449$, $p < 0.01$), and fat-free mass ($\rho = 0.390$, $p < 0.05$). No significant associations were found between VO_2 max and the assessed body-composition or energy-related variables. **Conclusion:** These findings highlight the importance of individualized conditioning and nutrition strategies to match positional demands and support optimal performance.

Keywords: Body composition, Energy availability, Female football players, VO_2 max

Resumen

Introducción: El fútbol es un deporte de equipo en el que las características físicas y fisiológicas desempeñan un papel importante en el rendimiento, y estas características varían según la posición de juego. Se han realizado varios estudios internacionales sobre la composición corporal, la aptitud aeróbica y la disponibilidad de energía en jugadoras de fútbol, pero la investigación en jugadoras indias es limitada. Por lo tanto, el objetivo de nuestro estudio es evaluar la relación entre la composición corporal, la disponibilidad de energía y la aptitud aeróbica en diferentes posiciones de juego en jugadoras de fútbol de élite de Bengala Occidental. **Métodos:** El estudio se llevó a cabo con 42 jugadoras de fútbol. Se midieron parámetros antropométricos como la estatura, el peso, el IMC, etc., según los protocolos estándar del manual ISAK. La ingesta de energía se evaluó mediante un registro dietético de 24 horas, mientras que el gasto energético durante el ejercicio se estimó utilizando valores de actividad basados en MET para calcular la disponibilidad de energía. Las evaluaciones fisiológicas incluyeron flexibilidad, fuerza de agarre, fuerza de espalda y piernas, y VO_2 máximo (Yo-Yo IR2). **Resultados:** El IMC mostró una correlación significativa con el porcentaje de grasa corporal ($\rho = 0{,}449$, $p < 0{,}01$) y la masa libre de grasa ($\rho = 0{,}390$, $p < 0{,}05$). No se encontraron asociaciones significativas entre el VO_2 máximo y las variables de composición corporal o relacionadas con la energía evaluadas. **Conclusión:** Estos hallazgos destacan la importancia de las estrategias individualizadas de acondicionamiento físico y nutrición para adaptarse a las exigencias de cada posición y favorecer un rendimiento óptimo.

Palabras Clave: Composición corporal, Disponibilidad de energía, Jugadoras de fútbol, VO_2 máximo

Introduction

Football is the most widely recognized team sport globally and Indian women's football has experienced significant growth lately. West Bengal women's football team significantly contributes to this achievement. The

Indian women's football team has made significant improvement in FIFA world rankings, moving from 70th to 63rd in 2025, and has successfully qualified for the women's Asia Cup for the first time. (Drishya, 2025) West Bengal is one of the top competitive states among national representatives, for the senior national football championship (NFC) organized by the All-India Football Federation (AIFF).

This rapid development of women's football highlights the need for scientific evaluation for a deep understanding of player profiles, performance determinants and training demands. In this context, studying various factors like body composition, energy availability, and aerobic fitness across playing positions in football plays a crucial role in promoting evidence-based training and long-term athlete development.

Football is a complex and dynamic team sport that requires physical, psychological, technical and tactical skills like sprinting and jumping during defence and attack to achieve successful performance (Dey *et al.,* 2010). The performance of a whole team depends on the interaction and cooperative approach between the players of different playing positions (Aquino *et al.,* 2020). In football, there are four major playing positions: Forwards or strikers, Midfielders, defenders, and Goalkeepers. In recent years, there have been many players noticed in the Indian women's football team as wingers who cover the highest number of sprint distances, even more than midfielders. The physical and physiological characteristics of these different playing positions may vary (Reilly *et al.,* 1990). A single Football match lasts more than one and a half hours, thus the energy mostly produced by aerobic metabolism (Silva *et al.,* 2011 and Garcia-Tabar *et al.,* 2019). Despite being an aerobic dependent game, it also involves short duration activities like sprint, jump, etc. through the entire game, thus both the aerobic and anaerobic capacities play significant roles to exhibit better performance (Dey *et al.,* 2010 and Matkovic *et al.,* 1993).

Being a team sport, footballers can be differentiated based on their physique, body composition, physiological demands and overall conditioning that provide positional advantage (Bale, 1986). Indian Forwards (include wingers) had lower body fat with higher agility, whereas the midfielders were strongest with higher aerobic fitness in comparison to other positions (Amrindera *et al.,* 2013). In football, body composition and energy availability are indispensable for maintaining performance, promoting recovery, and minimizing risk of injury. Female athletes are prone to low energy availability (LEA) due to the high demands of training, competition, and physiological factors that influence energy balance (Heikura *et al.,* 2022). LEA impacts metabolic, hormonal, and physiological functioning in female athletes, contributing to Female Athlete Triad and Relative Energy Deficiency in Sport. Female football players demand varying energy requirements due to different training intensities across training cycles, making it important to examine energy availability within the period. Including positional differences may help identify groups at higher risk. The variations in playing positions may contribute to different body fat percentage, energy expenditure, and overall energy availability (EA). Understanding differences in energy availability across positions can help in strategizing individualized nutrition plans that support optimal performance and reduce injury.

Although several research studies have been conducted globally that examine the physical and physiological characteristics of football players, a very limited research study was found in the Indian football context. However, there has been a lack of research studies for female footballers, especially in India. This article aims to observe the energy availability of football players according to their different playing positions, showing how body composition, energy availability, and aerobic fitness interrelate with playing positions among female football players**.**

Material and Methods

Study Design

A cross-sectional study was conducted on female football players, aged 17–21 years (19.0±1.3 years) from five local football clubs of West Bengal to find out the relationship between body composition, aerobic fitness, and energy availability across different playing positions in female football players.

Participants

42 female football players were included in this study. All the players were divided according to their playing positions into four groups: forwards (n=12), defenders (n=9), goalkeepers (n=6), midfielders (n=9), and wingers (n=6). Only the state and national women's football players are included in the study, whereas any recreational or ex-players were excluded from the study. All the subjects were given their written consent, and the test procedure, purpose, and risks and benefits were explained.

Protocol

Anthropometric Measurements and Body Composition Analysis

All the anthropometric measurements were conducted following the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK) protocol (ISAK 20219). Height and weight were measured according to the standardized method of ISAK with a stadiometer and electronic weighing scale. Body mass index (BMI) was calculated from the standardized formula of BMI = body mass in kg / (height in meters) 2 (Slaughter *et al.,* 1988). The body fat percentage was calculated from skinfold measurements in biceps, triceps, subscapular, and suprailiac sites (Weiner et al., 1969) with the use of the Harpenden skinfold calliper (UK). Body fat percentage was calculated using the Siri equation, i.e. Body fat% = (495 / Body density) – 450 (Siri, W.E. 1961). Body fat mass was calculated by multiplying body fat percentage with total body mass, and fat free mass (FFM) was obtained by subtracting fat mass from total body mass.

Energy Availability (EA)

Energy availability (EA) is defined as the amount of dietary energy remaining for the body's physiological functions after accounting for the energy expended during exercise. It reflects available energy to support essential processes such as metabolism, immune function, growth and reproductive health. Energy Availability was computed from the standardized formula: EA = Energy Intake – Exercise Energy Expenditure / Fat-Free Mass (FFM), and typically measured in kcal/kg FFM/day (Palazzo *et al.,* 2024). EA can be categorised according to established standards, i.e. Optimal EA: >45 kcal/kg FFM/day, Suboptimal EA: 30–45 kcal/kg FFM/day, Low EA (LEA): <30 kcal/kg FFM/day (Loucks *et al.,* 2011). This classification of EA allowed us to evaluate the prevalence of LEA across playing positions. Dietary intake was calculated using the 24-hour dietary recall method and measured with Dietcal software version 13 for windows. Exercise Energy Expenditure (EEE) calculated by using a minute-by-minute movement profile and corresponding metabolic equivalent (MET) based on standardized sport-specific activity tables (Compendium, 2021). Individualized energy cost was calculated using the formula: EEE (kcal/min) = MET value × body weight (kg) × duration of play (Herrmann *et al.,* 2024).

Physiological Assessment

Flexibility, isometric handgrip strength, back and leg strength, and the maximal aerobic capacity or VO2 max test were conducted in this study to investigate the positional variation in body composition and aerobic capacity of female football players. Flexibility was measured in centimetres by using a standardized sit and reach box (Cranlea, UK). The players were instructed to sit on the floor in front of the box by removing their shoes and extending their legs. The participants were asked to stretch their hands in front of the box by placing one hand over another and stretch slowly forward till maximum and hold for 3 seconds (Nieman, 1990). The upper body strength was measured in kilograms through isometric handgrip strength in left and right hands by using a Jamar hydraulic hand dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA). The participants were instructed to stand in an erect posture with the hand straight at a 90-degree angle respective from the body (Koley *et al.,* 2012). The subjects were asked to press the handle of the dynamometer as hard as possible and hold for 3 seconds to assess the maximum grip strength (España-Romero *et al.,* 2010). Isometric back and leg strength were measured in kilograms by using a back-leg-chest dynamometer (Sener *et al.,* 2016). All the participants performed the Yo-Yo intermittent recovery level – 2 test to assess the maximum aerobic capacity or VO_2 max (Bangsbo *et al.,* 2008).

Data Analyses

All data was presented as means ± standard deviation (SD). To assess the relationships among body composition, energy availability, and aerobic fitness in female football players, Spearman correlation coefficients (ρ) was performed where Differences across playing positions were analysed using the Kruskal–Walli's test. An exploratory multiple regression was conducted to determine whether body fat %, fat-free mass, energy availability, and playing position predicted VO_2 max. The Statistical Program for the Social Sciences (SPSS) version 25.0 for Windows (SPSS Inc., Chicago, II, USA) was used for data analysis. The value of $p< 0.05$ was considered to be statistically significant.

Results

Our current study involved 42 female football players aged 17-21 years (19.0±1.3 years) from the local private football club of West Bengal. All the players were divided according to their playing position into five groups, forwards (n=12), defenders (n=9), goalkeepers (n=6), and midfielders (n=9), winger (n=6). These findings are summarized in Figure 1.

Descriptive analysis for physical, anthropometric, physiological, and nutritional variables of players according to their playing position are presented in Table 1. It has been observed goalkeepers were the tallest (164.8 ± 4.7 cm) and heaviest (54.3 ± 4.1 kg), whereas midfielders were shorter. Forwarder players had the highest body-fat values (21.3 ± 3.7%), while midfielders and wingers had the lowest (17.6 ± 5.4% and 17.1 ± 6.5%) respectively. The average energy availability was 43.5± 2.7 kcal/day which falls under the recommended range for female athletes. Midfielders and wingers had slightly higher VO_2 max (53.5±2.9 ml/kg/min, 54.4±3.0 ml/kg/min) compared to forwarders (50.9±2 ml/kg/min).

Table 1. Representation of Selected Parameters of female football players by playing position (n=42)

Selected Parameters	Total (n=42)	Defenders (n=9)	Forwards (n=12)	Goalkeepers (n=6)	Midfielders (n=9)	Wingers (n=6)
Physical Parameters						
Age (years)	19.0±1.3	18.2±1.0	19.3±1.8	18.8±1.2	19.0±1.3	19.5±0.8
Height (cm)	159.1±6.5	161.9±7.6	157.9±6.0	164.8±4.7	154.8±6.0	157.8±2.8
Weight (kg)	50.6±4.8	50.4±4.6	51±5.5	54.3±4.1	49.1±4.6	48.6±3.1
BMI (kg/m^2)	20.0±1.7	19.2±1.4	20.4±2.0	19.9±1.0	20.5±2.2	19.5±0.7
Anthropometrical Parameters						
Body fat (kg)	10.1±3.2	10.4±3	11±2.8	11.4±2.9	8.8±3.5	8.4±3.4
Body Fat %	19.6±4.9	20.3±4.6	21.3±3.7	20.9±4.4	17.6±5.4	17.1±6.5
Fat free mass (kg)	40.5±2.8	40±2.6	40±3.2	42.9±3.0	40.3±2.2	40.2±2.7
FFM %	80.4±4.9	79.7±4.6	78.7±3.7	79.1±4.4	82.4±5.4	82.9±6.5
Nutritional Parameters						
EEE	1306.4±58.5	1297±53.4	1296±66.7	1355.4±62.7	1301.8±45.7	1299.6±55.5
TDEE	2998.2±150.9	2965.7±143.4	2968.5±173.2	3151.2±159.6	2989.4±96.2	2966.4±118.7
Energy Availability	43.5±2.7	44±1.7	42.3±1.3	42.4±2.7	44.7±3.5	44.3±3.8
Energy Intake [Kcal/day]	3061.6±160.5	3053.6±128.2	2985.1±200.4	3167.7±155.1	3094.7±109.3	3070.9±153.3
kcal/kg	60.8±4.6	60.8±3.8	58.8±3.6	58.5±3.9	63.5±5.0	63.4±5.7
Physiological Parameters						
Flexibility (cm)	41.2±4.5	42.5±2.6	40±5.4	44.7±4.0	39.6±4.2	40.6±4.3
Handgrip (Right Hand)	46.9±10.1	52.2±10.3	45.2±6.7	48.5±9.8	46.8±12.8	40.5±9.8
Handgrip (Left Hand)	45.7±11.5	51.2±13.8	44.8±8.4	49.2±11.0	43.5±13.6	39±9.0
Back Strength (kg)	67.7±9.9	65.8±5.0	64±11.0	77.7±4.0	69.5±10.0	65.3±12.2
Leg Strength (kg)	71.4±12.6	66.9±5.8	70.9±12.5	77.5±10.2	75.7±18.1	66.3±11.1
VO_2 max (ml/kg/min)	52.6±3.1	50.9±2	52±3	53.3±4.2	53.5±2.9	54.4±3.0

Values are shown in (mean ± standard deviation)

Table 2 represents correlation analysis among selected anthropometric parameters, energy availability and aerobic fitness of football players. It was observed that Body-fat % positively correlated with BMI ($\rho = 0.449$, $p < 0.01$), and BMI also demonstrated a positive relationship with fat-free mass ($\rho = 0.390$, $p < 0.05$). In contrast, fat-free mass exhibited a significant negative correlation with energy availability ($\rho = –0.458$, $p < 0.01$), suggesting that athletes with higher lean mass may experience relatively lower energy availability due to increased metabolic

demand. No significant associations were found between VO_2 max and the assessed body-composition or energy-related variables ($p > 0.05$).Table 3 shows the group comparisons for body-composition, energy-availability, and aerobic-fitness variables across the five playing positions. No statistically significant differences were observed for BMI, body-fat %, fat-free mass, energy availability and aerobic fitness ($p > 0.05$).

Table 2. Correlation Coefficients (ρ) among Body Composition, Energy Availability, and Aerobic Fitness Variables in Female Football Players (n=42)

Variables	BMI (kg/m^2)	Fat free mass (kg)	Energy Availability (kcal/day)	VO_2 max (ml/kg/min)
Body Fat %	0.449**	0.042	-0.086	0.080
BMI (kg/m^2)	_	0.390*	-0.100	0.119
Fat free mass (kg)		_	-0.458**	-0.021
Energy Availability (kcal/day)			_	0.127

ρ = Spearman's correlation coefficient; (*) denotes significant at $p < 0.05$; (**) denotes significant at $p < 0.01$

Table 3. Group Comparisons of Body Composition, Energy Availability, and Aerobic Fitness Variables of Female Football Players by Playing Position (n=42)

Variables	Defenders (n=9)	Forwards (n=12)	Goalkeepers (n=6)	Midfielders (n=9)	Wingers (n=6)	p-value
BMI (kg/m^2)	19.2±1.4	20.4±2.0	19.9±1.0	20.5±2.2	19.5±0.7	0.389
Body Fat %	20.3±4.6	21.3±3.7	20.9±4.4	17.6±5.4	17.1±6.5	0.270
Fat free mass (kg)	40±2.6	40±3.2	42.9±3.0	40.3±2.2	40.2±2.7	0.298
Energy Availability (kcal/day)	44±1.7	42.3±1.3	42.4±2.7	44.7±3.5	44.3±3.8	0.163
VO_2 max (ml/kg/min)	50.9±2	52±3	53.3±4.2	53.5±2.9	54.4±3.0	0.063

(*) denotes significant at $p < 0.05$; (**) denotes significant at $p < 0.01$

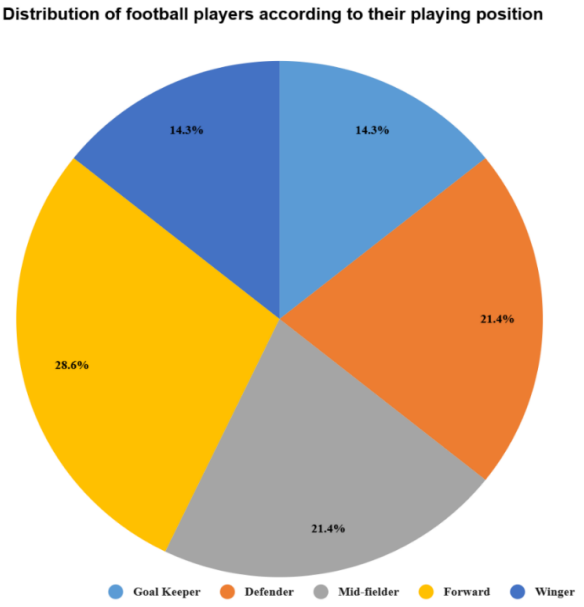

Figure 1. Distribution of football players according to their playing position

Discussion

The study aimed to explore how body composition, energy availability, and aerobic fitness interrelate with playing positions among female football players. In addition to body composition, energy availability, and aerobic

fitness, other factors such as age, height, and body mass can also impact sports performance in football. Our study found that goalkeepers or defenders are usually taller and physically stronger players, which aligns with previous research. (Łuszczki *et al.,* 2025) Our study found that the average height of female football players aligns with previous research, thereby supporting the consistency of somatic parameters across different studies. (Igiri *et al.,* 2008 and Ransone *et al.,* 2004) It was observed in the present study that goalkeepers were taller and heavier than midfielders, which is similar to other research's findings as well. (Ingebrigtsen *et al.,* 2011 and Sedano *et al.,* 2009) Body composition, which plays an important role in achieving optimal physical performance in football, varies based on the players' position on the field. (Cavia *et al.,* 2019) Our study showed no significant differences in the body composition of players regarding BMI, body fat %, and fat-free mass by playing position. The current study showed a significant positive correlation between BMI, body fat %, and fat-free mass. Our findings are consistent with other studies that report a relationship between higher BMI and increased body fat percentage, indicating a link between adiposity and BMI in athletes. (Ramírez-Muñera *et al.,* 2023) The study observed a significant inverse correlation between fat-free mass and energy availability. This finding is consistent with the previous research indicating that players with higher lean mass may experience lower energy availability due to increased metabolic cost and total energy expenditure. (Loucks *et al.,* 2011).

Regarding VO_2max, there were no significant differences observed among the playing positions. Hence, midfielders and wingers demonstrated a trend toward higher VO_2max values ($p = 0.063$). These findings align with the previous research that Midfielders demand greater total and high-intensity running during match play requiring superior aerobic capacity to sustain both offensive and defensive contributions. (Datson *et al.,* 2014) These results are in line with previous study carried out by Villaseca-Vicuña *et.al.* 2021, where significant differences were found between positions of Chile Women's Senior National Football players. The VO_2max values in this study are higher than those observed in the Chilean national team during the season. The lack of statistical significance in the current dataset may relate to the relatively small sample size of 42 female players within positions. This impacted the statistical power of the findings, particularly for positions such as goalkeeper. These findings highlight that aerobic performance in female football players is largely shaped by training load, tactical role, and positional movement demands rather than static anthropometric parameters. Still, maintaining adequate energy availability remains crucial for optimizing performance, recovery, and long-term athlete health. (Thomas *et al.,* 2016)

Conclusion

Our current study examined the relationship between body composition, energy availability, and aerobic fitness in female football players across different playing positions. A strong positive correlation was observed between BMI, body-fat percentage and fat-free mass. Contrarily, fat free mass was negatively correlated with energy availability. However, none of these variables demonstrated a significant relationship with VO_2 max. Although positional differences were not statistically significant, midfielders and wingers demonstrated slightly higher aerobic fitness values. Overall, these findings highlight the importance of individualized conditioning programs and adequate energy availability to support optimal performance. This current research depicts that position-specific training demands should also be considered to ensure that players develop specific attributes required for their on-field roles and positional adaptation.

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Funding

There is no external funding to declare

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

All the athletes included in the study provided written informed consent.

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