Original Research Report

DIFFERENCES IN AEROBIC CAPACITY AND RUNNING SPEED ACROSS VARIOUS SOMATOTYPE STRUCTURES AND BODY FAT COMPOSITIONS AMONG PROFESSIONAL FOOTBALL ATHLETES IN INDONESIA

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ABSTRACT

This study investigates the effects of somatotype structure and body fat composition on aerobic capacity and running speed. This study used an analytical observational design with a cross-sectional approach. The subjects were 27 professional football athletes from Bhayangkara Football Club in Bekasi, Indonesia. This study measured several variables, namely age, playing position, somatotype structure assessed using the Somatotype Rating Form and Heath-Carter Somatochart, body fat composition measured using the Brozek and Siri formulas, aerobic capacities determined by the maximum rate of oxygen consumption (VO2 max) through the Yo-Yo Intermittent Recovery Test Level 2, and running speed over a 30 m distance. The data were presented as mean ± standard deviation (SD), frequency (n), and percentage. The Shapiro-Wilk test was used to determine the normality of the data distribution. The statistical analyses included one-way analysis of variance (ANOVA) followed by the post-hoc least significant difference (LSD) test, the Kruskal-Wallis test followed by the post-hoc Mann-Whitney test, as well as the independent t-test, the Mann-Whitney test, and Pearson's or Spearman's correlation tests. A p-value of less than 0.05 was considered statistically significant. The athletes predominantly exhibited a mesomorph-endomorph somatotype (88.9%). Significant correlations were found between mesomorph rating and running speed (r=-0.548; p=0.003), body fat composition and aerobic capacity (r=-0.448; p=0.019), as well as age and aerobic capacity (r=-0.515; p=0.006). Significant differences in aerobic capacity were observed among various age groups (p=0.031). There were also differences in body fat composition (p=0.003) and running speed (p=0.036) between the two somatotypes. These findings underscore the importance of individualized training and conditioning programs that take into account the unique body compositions and ages of athletes.

Keywords: Aerobic capacity; athletes; body fat composition; football; healthy lifestyle

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Highlights:
1. This study emphasizes the significance of understanding professional football players' various somatotype structures and body fat compositions as an important contribution to the area of sports science.
2. This study lays the groundwork for future research to better understand the intricate interactions between somatotype structures, body composition, and athletic performance.
3. Since a one-size-fits-all approach may not be successful, this study advocates for tailored evaluations of training regimens to cater to athletes' unique requirements and skills, which may lead to higher overall performance.

INTRODUCTION

Football involves intricate movements such as sprinting, jumping, ball control, and rapid acceleration and deceleration. Athletes have to maintain peak physical condition to optimize their performance. The physical attributes of football players encompass strength, endurance, speed, flexibility, muscle mobility, fundamental motor skills, coordination, agility, and responsiveness (Akenhead 2014, Scheunemann 2014). Sprinting is recognized as an essential skill for scoring goals and determining the outcome of a game. Previous studies have underscored the significant influence of an athlete's somatotype on running speed and endurance (Marangoz 2018, Ryan-Stewart et al. 2018). Somatotype refers to the classification of human body types or compositions based on anthropometric characteristics, which are further categorized into mesomorphy, ectomorphy, and endomorphy types. It has been demonstrated that ectomorph and mesomorph types of amateur soccer players exhibit faster running speeds compared to those of endomorph-type players (Primasoni 2012, Anggitasari et al. 2019).

Football players must possess high levels of endurance, a paramount attribute given the prolonged and strenuous nature of football matches. Aerobic endurance is the ability of the heart, lungs, and blood vessels to use oxygen as energy to carry out activities for a long period of time. VO2 max, which refers to the maximum rate of oxygen consumption, is a common way to gauge aerobic endurance. An average football player has a VO2 max of 55–65 mL/kg/min (Akenhead 2014, Modric et al. 2020). Young (2020) demonstrated that genetics, cardiovascular system, training habits, lifestyles, and body compositions can impact a player's VO2 max. Body composition is an important factor that must be considered when determining VO2 max. Body composition includes the amount and distribution of fat, muscle, and bone tissue. An excess of adipose tissue can impede the adequate circulation of blood throughout the body, diminishing the delivery of oxygen to muscle cells. Additionally, extra body fat can lessen pulmonary strain, disturbing the exchange of oxygen and carbon dioxide. It has been found that futsal players with a lower body fat percentage exhibit higher VO2 max or aerobic endurance (Jayanti et al. 2019, Damayanti & Adriani 2021). Excess fat can hasten tiredness, which affects an athlete's ability to maintain heart and lung endurance.

Numerous researchers, such as Cinarli et al. (2022) and Marangoz (2018), have examined the relationship between athletes' somatotype and running speed. However, there is a scarcity of research concerning professional football players.

To our knowledge, the existing research on the somatotypes of professional football players still primarily focuses on the variations among them according to the playing positions, whether it is a striker, midfielder, defender, or goalkeeper. Furthermore, a noticeable gap exists in the literature, as no prior studies have endeavored to elucidate the impact of body fat percentage on maximal oxygen uptake (VO2 max). This study aimed to fill this void by scrutinizing the influence of somatotype structures and body fat composition on professional football athletes' aerobic capacities and running speed.

MATERIALS AND METHODS

This study employed an analytical observational design and specifically utilized a cross-sectional approach (Probandari et al. 2020). The study was conducted in November 2021 at the home base of Bhayangkara Football Club (FC) in Bekasi and the Universitas Sebelas Maret Stadium in Surakarta, Indonesia. This study obtained ethical clearance from the Health Research Ethics Committee of Dr. Moewardi Regional General Hospital, Surakarta, Indonesia, under reference No. 895/IX/HREC/2021 on 21/9/2021. This study included professional football athletes from Bhayangkara FC who played in the Indonesian League 1 during the 2021/2022 season. The criteria for inclusion in this study were limited to male players between the ages of 18 and 35 who followed a routine training program provided by the coaching team. Meanwhile, the exclusion criteria were players who were sick or injured and those training for the Indonesian national team at the time, so they could not participate in this research until its completion. Additionally, athletes who refused to participate in this study were also excluded. Potential bias in this study was minimized through total sampling, standardized measurements using calibrated instruments, and ethical clearance. This research used a total sampling technique (Sumardiyono et al. 2020), which resulted in the selection of a sample consisting of 27 athletes who agreed to participate and provided informed consent.

This study measured several variables of the players, including age, playing position (i.e., goalkeeper, back, midfielder, and forward), somatotype structures, body fat composition, aerobic capacity, and running speed. The somatotype of all subjects was assessed by measuring their body height, body weight, skinfold (i.e., triceps, subscapular, supraspinal, and calf), bone diameter (i.e., width of elbow and knee joints), and muscle size (i.e., biceps and calf circumference). Each measurement was performed three times prior to calculating the average values. The calculation results were then

entered into the Somatotype Rating Form, and the final results were calculated on the Heath-Carter Somatochart according to the dominant somatoplots (Carter & Heath 1971). The somatoplot results were divided into four categories depending on the chief points: central, endomorph, mesomorph, and ectomorph.

The body fat percentage was measured according to the skinfold thickness at seven locations: the triceps, subscapular, mid-axilla, pectoral, abdomen, supra-iliac, and thigh. The average was calculated after conducting the measurements three times using a slim guide caliper. Data from the skinfold thickness measurements were entered into the seven-location Jackson-Pollock formula to determine body density values (Jackson & Pollock 1978). The body density values were then entered into the Brozek and Siri formulas to obtain body fat percentages (Brožek et al. 1963, Siri 1993). Following that, the aerobic capacities were assessed by measuring the VO2 max using the Yo-Yo Intermittent Recovery Test Level 2 (Bangsbo et al. 2008). The measurements were carried out in the field using a 25-meter track for each test participant. Lastly, the running speed was determined by observing the time a participant took to run quickly over a distance of 30 m. The running speed was calculated by dividing the running distance by the time taken to finish the run.

The data obtained were analyzed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, N.Y., USA). The data were reported in the form of mean ± standard deviation (SD), frequency (n), and percentage. The normal distribution of the data was determined using the Shapiro-Wilk test. In the statistical analyses, the one-way analysis of variance (ANOVA) followed by the post-hoc least significant difference (LSD) test were employed. Furthermore, we employed the Kruskal-Wallis test followed by the post-hoc Mann-Whitney test, as well as the independent t-test, the Mann-Whitney test, and Pearson's or Spearman's correlation tests. Finally, we conducted a path analysis by utilizing multiple linear regression. The statistical significance was indicated by a value of $p < 0.050$ (Sumardiyono et al. 2020).

RESULTS

A total of 27 professional football athletes were involved in this study. The study subjects had a mean age of 26.519±4.611 years and a mean body mass index (BMI) of 23.258±1.555 kg/m². The majority of the subjects exhibited a somatotype structure that was predominantly mesomorph-endomorph (88.9%). Furthermore, the mean body fat composition was 9.461±2.381% when measured using the Brozek formula and 7.949±2.622%

according to the Siri formula. The subjects had an average aerobic capacity (VO2 max) of 56.467±3.616 and a running speed of 26.300±1.213 km/hour. Table 1 presents the overall characteristics of the sample.

Table 1. Characteristics of the entire study participants (n=27).

Characteristic	Mean±SD	n (%)
Age [years]	26.519±4.611	
18–20		4 (14.8%)
21–25		7 (25.9%)
26–30		9 (33.3%)
31–35		7 (25.9%)
Body mass index [kg/m²]	23.258 ± 1.555	
Position		
Goal Keeper		3 (11.1%)
Back		10 (37.0%)
Midfielder		11 (40.7%)
Forward		3 (11.1%)
Somatotype structures		
Mesomorph-endomorph		24 (88.9%)
Mesomorph-ectomorph		3 (11.1%)
Somatotype rating		
Endomorphy rating	3.389±0.725	
Mesomorphy rating	4.796±0.880	
Ectomorphy rating	2.278±0.641	
Body fat compositions (Brozek formula)	9.461±2.381	
Body fat compositions (Siri formula)	7.949±2.622	
Aerobic capacity (VO2 max)	56.467±3.616	
Running speed [km/h]	26.300±1.213	

Legend: Nominal data are presented as frequencies and percentages. Numerical data are presented as means ± standard deviations (SD).

There were differences in aerobic capacity (VO2 max) among various age groups (p=0.031). Significant differences were observed between the 18–20 and 31–35 age groups (mean difference=5.897; p=0.017) and between the 26–30 and 31–35 age groups (mean difference=4.204; p=0.041). However, the 18-20 and 26–30 age groups had a higher average than the 31–35 age groups. Apart from that, there were also significant differences in body fat composition measured using the Brozek formula (mean difference=4.113; p=.003) as well as running speed (mean difference=1.536; p=0.036) among the study subjects with different somatotype structures. Specifically, the mesomorph-endomorph group exhibited higher body fat composition and running speed than the mesomorph-ectomorph group. All results of differences in body fat composition, aerobic capacity, and running speed across different age groups, playing positions, and somatotype structures are presented in Table 2.

Table 2. Differences in body fat composition, aerobic capacity, and running speed between various age, position, and somatotype structure groups.

	Body fat compositions (Brozek formula)	Body fat compositions (Siri formula)	Aerobic capacity (VO2 max)	Running speed [km/h]
Age (years)	p=0.070[a]	p=0.376[a]	p=0.031*[a]	p=0.252[a]
18–20 years	7.710±3.349	6.416±2.342	59.200±1.289	26.099±1.643
21–25 years	8.704±1.961	7.474±2.341	56.734±3.496	25.577±1.051
26–30 years	9.451±1.930	8.232±2.099	57.507±3.924	26.750±1.171
31–35 years	11.232±1.945	8.935±3.550	53.303±2.168	26.561±1.038
Positions	p=0.895[a]	p=0.595[b]	p=0.318[a]	p=0.658[a]
Goal Keeper	10.302±2.129	9.800±2.306	53.123±0.822	25.753±1.228
Back	9.634±2.799	8.148±3.170	56.342±4.128	26.073±1.199
Midfielder	9.128±2.303	7.491±2.242	57.572±2.897	26.559±1.101
Forward	9.268±2.355	7.109±2.473	56.180±5.191	26.655±1.961
Somatotype structures	p=0.003*[c]	p=0.084[d]	p=0.747[c]	p=0.036*[d]
Mesomorph-endomorph	9.918±2.044	8.226±2.630	56.386±3.751	26.471±1.162
Mesomorph-ectomorph	5.805±1.772	5.732±1.219	57.120±2.721	24.935±0.675

Legends: [a]One-way ANOVA, [b]Kruskall-Wallis test, [c]independent t-test, and [d]Mann-Whitney test were utilized. An asterisk (*) signifies any statistical significance (p<0.050).

There was a significant correlation between mesomorphy rating and running speed (r=-0.548; p=0.003). Additionally, negative correlations were observed between body fat composition (measured using the Brozek formula) and aerobic capacity (r=-0.448; p=0.019) as well as between age and aerobic capacity (r=-0.515; p=0.006). Meanwhile, there was no relationship found between other variables. All correlation results between variables are presented in Table 3.

Table 3. Correlation between somatotype structure, body fat compositions, aerobic capacity, and running speed.

		Correlation coefficient	p
Endomorphy rating	Aerobic capacity (VO2 max)	-0.243	0.222[a]
	Running speed	0.239	0.230[a]
Mesomorphy rating	Aerobic capacity (VO2 max)	0.141	0.484[b]
	Running speed	-0.548	0.003*[b]
Ectomorphy rating	Aerobic capacity (VO2 max)	-0.033	0.872[b]
	Running speed	-0.074	0.713[b]
Body fat compositions (Brozek formula)	Aerobic capacity (VO2 max)	-0.448	0.019*[a]
	Running speed	0.230	0.249[a]
Body fat compositions (Siri formula)	Aerobic capacity (VO2 max)	-0.347	0.076[b]
	Running speed	0.525	0.525[b]
Age	Aerobic capacity (VO2 max)	-0.515	0.006*[a]
	Running speed	0.346	0.077[a]
Body mass index	Aerobic capacity (VO2 max)	-0.299	0.130[a]
	Running speed	-0.010	0.960[a]

Legend: [a]Pearson correlation test and [b]Spearman correlation test were utilized. An asterisk (*) signifies any statistical significance (p<0.050).

DISCUSSION

The highest rate at which oxygen can be carried up and used by the body during intense activities is referred to as VO2 max. Aerobic capacity, defined as the highest level of oxygen consumption during intense activities that use large muscle groups, is a measure of aerobic fitness. A spike in VO2 max implies that aerobic capacity has increased. A prior study has established an association between maximum aerobic capacity and improved match performance and team achievement (Modric et al., 2020). Enhanced aerobic capacity would enable a player to reach and sustain a higher work rate, thus exerting a more significant influence during a game. Various factors, such as genetics, the cardiovascular system, training habits, lifestyle, and body composition, can impact a player's VO2 max (Akenhead 2014, Young 2020).

Our research indicated significant differences in aerobic capacity (VO2 max) between various age

groups. Individuals in the age groups of 18–20 and 26–30 years had a higher average aerobic capacity than those in the 31–35 age group. According to prior research, the consequences of aging are particularly identified in the context of fitness (Wickramarachchi et al. 2023). The consistent decrease in VO2 max, notably appearing at the ages of 20–30 and diminishing by around 10% every decade, demonstrates a significant decline in the capacity to exercise. On top of that, the pace of this reduction intensifies with age. It indicates that the present research's findings are in line with the previous study.

A previous cross-sectional study conducted by King & Lowery (2024) revealed that VO2 max diminishes nearly 50% on average throughout the ages of 20 and 80. This decline must be attributed to either or both cardiac output and arterial-venous oxygen concentration. Cardiac output and arterial-venous oxygen concentration have been shown to fall by 25% with age. Because stroke volume has been predicted to be preserved throughout life, the vast majority of cardiac output reduction tends to be attributed to the decrease in maximum heart rate. The decline in VO2 max results from an alteration in the arterial-venous oxygen concentration, which illustrates changes in oxygen efficiency and balance. This implies the critical role of mitochondrial and muscle mass performance. On the other hand, the decrease in cardiac function is accounted for by a variety of mechanisms, including increased circulation afterload, arterial-ventricular load mismatching, diminished intrinsic contractility of the myocardium, disrupted autonomic control, and physical deconditioning (King & Lowery 2024).

This current study discovered significant differences in body fat composition, as measured using the Brozek formula, among football players with varied somatotype structures. Individuals in the mesomorph-endomorph group exhibited higher body fat compositions compared to individuals classified in the other somatotype category. Football players are constantly exposed to extensive physical exercises and matches. Hence, their body composition becomes a significant factor affecting their performances. Body fat composition has been measured using numerous techniques, one of which is the Brozek formula. The formula estimates body density through observations of skinfold thickness. The Brozek formula might represent a more reliable alternative than the Siri formula for measuring body density as a percentage of body fat composition. Additionally, it is widely recognized that somatotype variations obviously impact athletic performance and are considered one of the most significant considerations in athlete recruitment. Somatotype determines a person's physical form on the basis of three elements: endomorphy (related to adiposity), mesomorphy (related to musculoskeletal development), and ectomorphy (related to linearity or slenderness) (Almeida et al. 2021, Cinarli et al. 2022).

The endomorphy component of somatotype, which is associated with adiposity, exhibited a positive correlation with body fat percentage as determined by the Brozek formula. Individuals with a higher endomorphy component might be more likely to have a greater body fat percentage, reflecting a predisposition towards increased adipose tissue (Galić et al. 2016). On the contrary, the mesomorphy component, which is linked to musculoskeletal development, showed an inverse correlation with body fat percentage. Higher mesomorphy scores might be associated with increased lean muscle mass and decreased body fat, indicating a potential protective effect against adiposity. In addition, higher mesomorphy scores indicate strength and power-to-weight ratio, potentially leading to reduced body fat percentage (Sukanta 2014, Bertuccioli et al. 2022). Individuals with the ectomorphy component, which is related to linearity, might demonstrate lower body fat due to a slender body build. However, this could vary depending on factors such as muscle mass and overall fitness.

Running speed is a fundamental attribute in football since it influences an athlete's ability to execute offensive and defensive maneuvers. Athletes with different somatotype structures may demonstrate varying running speeds due to variations in their body compositions. This research revealed a significant difference in running speed between various somatotype structures, with the mesomorph-endomorph group exhibiting a higher running speed than the mesomorph-ectomorph group. A higher level of mesomorphic features contributes to a larger amount of muscle mass. It may benefit athletes who face significant physical challenges throughout competition and training. In contrast, the endomorphy component showed that having greater body fat mass might be advantageous for absorbing and releasing power, resulting in faster running speed compared to individuals in other somatotype variations (Bujak et al. 2016).

The mesomorphy component is more likely to exhibit a positive correlation with running speed. This is because athletes with higher mesomorphy scores may benefit from increased muscle mass and strength, contributing to improved sprinting abilities. However, this research found a negative correlation between mesomorphy rating and running speed. The negative correlation is consistent with several possible explanations. Individuals with a mesomorphic feature are associated with a higher proportion of muscle mass. While muscle mass

contributes to strength and power, it also adds to body mass (Gutnik et al. 2015). In terms of running, particularly when endurance is necessary, individuals with a larger body mass may require more energy to move. Therefore, they may face challenges in achieving maximum running speeds compared to individuals with a lower body mass.

Individuals exhibiting mesomorphy often have a higher percentage of fast-twitch muscle fibers, which are beneficial for short bursts of power. However, they may also experience fatigue more quickly during prolonged endurance activities such as running (de la Iglesia et al. 2020). According to Sanders et al. (2017), running speed is strongly influenced by aerobic capacity, which is the ability of the cardiovascular system to supply oxygen to muscles during sustained physical activity. While individuals with mesomorphy may prioritize strength training over cardiovascular training, it potentially leads to lower endurance and running speed. However, it is essential to note that other factors, such as training regimens, cardiovascular fitness, or individual variations, could also contribute to running speed.

This study found a correlation between the body fat composition of professional football athletes, as measured using the Brozek formula, and their aerobic capacity (VO2 max). The negative correlation between body fat composition and aerobic capacity (r=-0.448; p=0.019) indicated that higher body fat levels are associated with lower aerobic capacity. Aerobic capacity, as determined by VO2 max, is influenced by various factors, including body composition, cardiovascular system efficiency, and muscle oxygen utilization during exercise. On the other hand, body fat composition is a crucial determinant of overall health, with implications for metabolic function and cardiovascular well-being (Frank et al. 2019, Young 2020). Prior studies conducted by Green et al. (2018) and Littleton & Tulaimat (2017) have identified several mechanisms that contribute to the observed correlation. One of which is the physiological impact of body fat on the cardiovascular and respiratory systems. Excessive body fat can lead to decreased lung function, resulting in reduced lung compliance and impaired efficiency in oxygen uptake and utilization during aerobic activities. Moreover, excessive body fat slows the dynamic responses of the VO2 max during cycling and delays the phase of vasodilation in muscle contraction. Adipose tissue secretes bioactive substances known as adipokines, which may negatively affect the cardiovascular system, further compromising aerobic capacity as measured by VO2 max (Clemente-Suárez et al. 2023).

Strength and limitations

This study highlights the importance of recognizing athletes' diverse somatotype structures and body fat compositions as a valuable contribution to the field of sports science. It provides a foundation for further research to enhance our understanding of the complex interplay between somatotype structures, body composition, and athletic performance. We also consider incorporating individualized assessments to optimize training programs for professional football athletes since a one-size-fits-all approach may not be effective. By doing so, they can better address each athlete's specific needs and capabilities, potentially leading to improved overall performance.

While this study contributes valuable insights into the relationships between somatotype structures, body fat compositions, and physical performance indicators among professional football athletes in Indonesia, several limitations should be acknowledged. Firstly, the cross-sectional design limited the establishment of causality, and longitudinal studies would provide a more comprehensive understanding of the dynamic interactions observed. Furthermore, the study did not consider potential psychological or nutritional aspects that could influence the observed relationships.

CONCLUSION

Relationships between somatotype structure, body fat composition, and physical performance parameters were found among professional football players in Indonesia. The athletes predominantly had a mesomorph-endomorph somatotype. Significant relationships were found between mesomorph rating and running speed, body fat composition (determined by the Brozek formula) and aerobic capacity (VO2 max), and between age and aerobic capacity. The aerobic capacities of the athletes differed significantly across various age groups. Their body fat compositions and running speeds also varied depending on their somatotype structures. Therefore, individualized training and conditioning programs are crucial considering the different body compositions and ages of the athletes.

Conflict of interest

None.

Ethical consideration

This study received approval from the Health Research Ethics Committee of Dr. Moewardi Regional General Hospital, Surakarta, Indonesia, under reference No. 895/IX/HREC/2021 on 21/9/2021.

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Author contribution

DAG, YH, DR, LA, SH, SM, NW, and ASR contributed to the conception and design of this study. MSR, SS, and AISN collected, assembled, analyzed, and interpreted the data. MFI, EAB, and AAR drafted the article. DAG, YH, DR, LA, SH, SM, NW, and ASR contributed to the critical revision of the article for important intellectual content. All the authors gave their approval to the final article.

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