

Relationship between body composition changes and aerobic capacity in elite youth football players: A comparative study using Vameval and InBody 270 assessments

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Abstract

Purpose: Aerobic capacity, typically assessed by maximal oxygen uptake (VO₂ max), is an essential factor influencing endurance and overall performance in football. This study examined the relationship between changes in body composition and VO₂ max in elite youth football players over six months using Vameval field tests and bioelectrical impedance analysis (InBody 270). **Methods:** Fifteen elite male youth football players (~14–15 years old) completed two assessments: post-season (June 2023) and mid-season (January 2024). VO₂ max was indirectly estimated using the Vameval test. Body composition variables—including body mass, skeletal muscle mass (SMM), and body fat mass (BFM)—were measured using the InBody 270 analyzer. Paired samples t-tests assessed intra-individual changes between the two time points, while Pearson correlation coefficients examined the relationships between changes in VO₂ max and changes in body composition. **Results:** The analysis showed significant individual differences in VO₂ max between June and January. Players who decreased BFM generally experienced improvements or maintained their VO₂ max, whereas those who increased BFM showed declines. There were strong negative correlations between changes in BFM and VO₂ max ($r \approx -0.70$), as well as between changes in body mass and VO₂ max ($r \approx -0.60$). Additionally, changes in SMM exhibited a moderate positive correlation with VO₂ max ($r \approx 0.35$). **Conclusion:** This study suggests that improvements in body composition, especially reductions in body fat, are associated with positive changes in aerobic capacity. Regular monitoring of both VO₂ max and body composition provides valuable information for tailoring training programs and improving performance in youth football.

Keywords: VO₂ max, youth football, body composition, InBody 270, Vameval, fat mass

Introduction

Aerobic capacity is an essential component of physical performance in football, a sport characterized by intermittent high-intensity efforts combined with extended periods of submaximal activity (Bangsbo, Mohr, & Krstrup, 2006; Michalidis, 2024). Maximal oxygen uptake (VO₂ max) is recognized as the gold-standard measure of aerobic fitness and closely relates to a player's ability to recover between repeated bouts of exertion and sustain high performance during a match (Helgerud et al., 2001; Slimani, 2025). Sustaining intense activity and rapid recovery during a football match strongly depend on aerobic fitness (Radziminski et al., 2020). Additionally, previous studies highlight the importance of anthropometric and physical characteristics as key contributors to successful football performance (Svensson & Durst, 2005; Nikšić et al., 2020).

In young athletes, VO₂ max is affected by both non-trainable factors, such as biological maturation (Bok & Foster, 2021), and trainable factors, including physical conditioning and body composition (Malina, Bouchard, & Bar-Or, 2004). During adolescence, changes in fat mass and lean tissue mass play an important role in changing relative VO₂ max (ml/kg/min) because this measure depends on body weight (Silva et al., 2021; Balogh et al., 2025). Excess fat mass adds non-functional weight, potentially lowering oxygen delivery efficiency per unit of body weight (Armstrong & Welsman, 2007). In contrast, increases in skeletal muscle mass (SMM) increase oxygen extraction and utilization at the muscular level, thereby improving aerobic capacity (Legaz & Eston, 2005).

Despite growing interest in individualized conditioning and performance monitoring in youth football, there is a lack of studies examining the longitudinal relationship between body composition and aerobic fitness across competitive seasons. Gaining insight into how seasonal fluctuations in fat and muscle mass influence VO₂ max could lead to more accurate training programs and improved injury prevention strategies.

A recent study by Ivanov et al. (2022) examined the body composition of youth football players from the Levski Sofia academy using the InBody 270 device (Biospace, California, USA). The sample consisted of 57 players divided into three age groups: U13, U14, and U15. Findings revealed a consistent increase in height and body weight with age, from 159 cm and 45.9 kg in U13 to 175 cm and 62.1 kg in U15. Body mass index (BMI) also increased steadily, ranging from 17.9 to 20.3. These reference values provide an important baseline for

assessing physical development and optimizing training and selection processes in youth football. The study underscores the effectiveness of bioelectrical impedance analysis (BIA) tools such as the InBody 270 device for non-invasive and objective monitoring of somatic growth and body composition trends in academy players.

Therefore, this study investigated the relationship between intraseasonal changes in body composition and aerobic capacity in elite U15 football players using data from standardized field testing (Vameval) and laboratory-based assessments (InBody 270). Longitudinal data on how intra-seasonal changes in body composition affect aerobic capacity in adolescent footballers are scarce. Although VO₂ max is routinely measured in youth athletes (Villaseca-Vicuna et al., 2022), its interaction with fluctuating levels of fat mass and lean muscle mass remains insufficiently studied, especially in elite academy environments where maximizing performance is essential. The research was performed in the structured seasonal framework of elite youth football, a context where training intensity, physiological development, and body composition experience substantial changes during the annual cycle.

These changes can affect aerobic capacity positively or negatively, depending on their direction and extent. Adolescent football players undergo dynamic growth, often accompanied by fluctuating body composition influenced by training load, nutrition, or maturation. However, many training programs lack systematic monitoring of these variables. While research by Nazarudin et al. (2025) highlights the influence of defensive performance indicators on match outcomes, few longitudinal studies have explored the interaction between body composition and aerobic fitness during the competitive season. This study fills that gap by exploring the relationship between seasonal changes in body fat and muscle mass and VO₂ max, providing insights for tailoring physical preparation programs to individual needs (Barrera et al., 2022).

The study used a repeated-measures design, evaluating the same elite youth football players at two critical points in the competitive season—mid-season (January) and post-season (June). This design enabled tracking of individual physiological changes over time. Aerobic capacity was estimated through the Vameval field test, a validated field method for measuring VO₂ max.

Body composition metrics—including body mass, SMM, and body fat mass (BFM)—were assessed using the InBody 270 analyzer. Statistical analysis included paired-sample t-tests to assess intra-individual changes and Pearson correlation coefficients to explore relationships between VO₂ max and body composition changes. Using the methodology of Rodríguez Aponte et al. (2025), which correlated body composition with neuromuscular and technical performance, this study applies similar methodological rigor to analyze seasonal variations in aerobic performance in subjects.

Methods

Participants

Fifteen elite male football players from a U15 academy team participated in this study (mean age 14.9 ± 0.3 years). All participants trained regularly and competed in official matches. Written informed consent was obtained from both the players and their guardians.

Testing Procedures

Testing was performed at two time points: late June 2023 (off-season) and early January 2024 (mid-season). Vameval Test: Aerobic capacity was assessed using the field-based Vameval test (Selmi et al., 2022), which estimates VO₂ max using a progressive speed protocol on a marked field with audio pacing. The final running speed was recorded and converted into VO₂ max values using validated equations (Cazorla & Léger, 1993; Silva, 2022).

Body Composition Assessment:

Body composition was measured using the InBody 270 analyzer. Players were assessed under standardized conditions—at 8:00 AM, after an overnight fast, and wearing minimal clothing. Testing was performed during the preparatory period (June) and mid-season (January), after two introductory training sessions to ensure consistent physical readiness. Participants were instructed to avoid strenuous activity and maintain normal hydration for 24 h before testing. Recorded variables included total body mass (kg), SMM (kg), and BFM (kg).

Data Analysis:

Paired-sample t-tests were performed to compare body composition and VO₂ max between June and January. Individual changes (delta values) were calculated for each participant. Pearson's correlation coefficients were then used to assess the strength and direction of the relationships between changes in VO₂ max and changes in body mass, BFM, and SMM.

Results

This section outlines the study's findings, featuring statistical summaries and visual representations that highlight the relationship between body composition changes and aerobic capacity during the observation period.

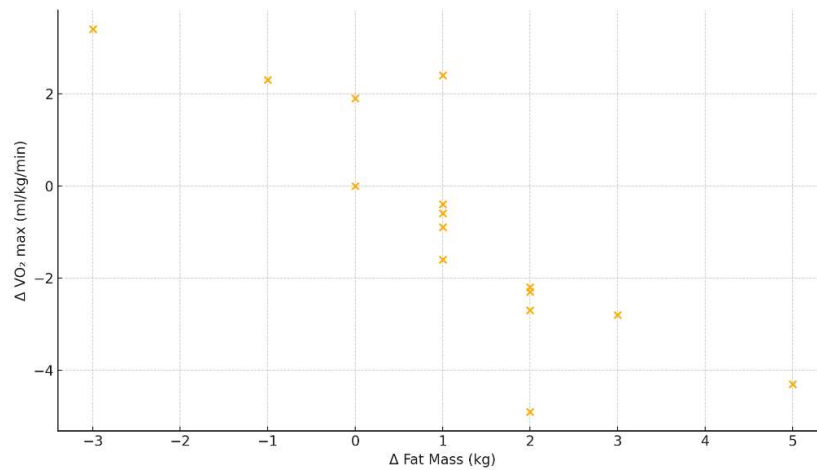


Figure 1. Change in Body Fat vs. VO2 max

Figure 1 shows the relationship between changes in body fat mass (Δ BFM) and changes in VO2 max during the study period. The scatter plot reveals a clear negative correlation, indicating that players who decreased their fat mass tended to maintain or improve their VO2 max, whereas those who gained fat mass experienced a decline in aerobic capacity. This result supports the correlational analysis presented later in this section.

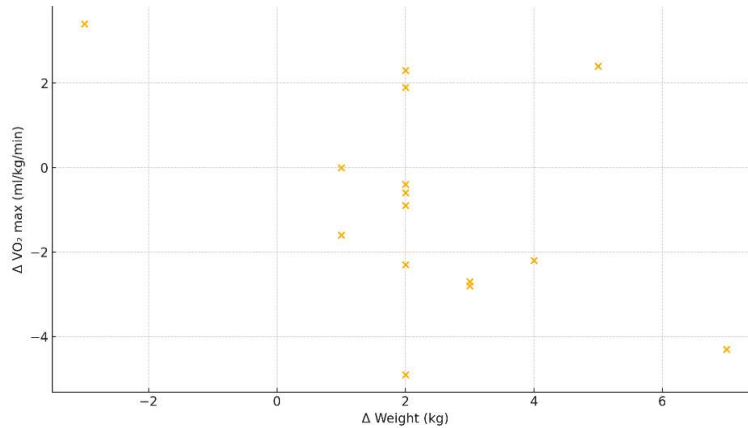


Figure 2. Change in Body Weight vs. VO2 max

Figure 2 shows the association between changes in total body mass and changes in VO2 max. Similar to Figure 1, a negative relationship is evident, showing that players who gained weight generally experienced a decline in aerobic performance.

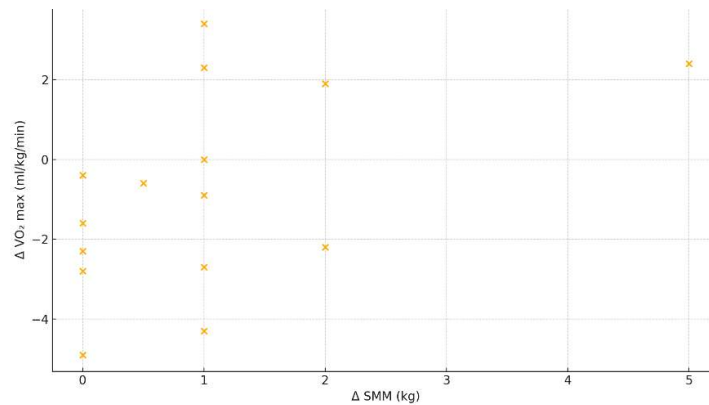


Figure 3. Change in SMM vs. VO2 max

Figure 3 shows the relationship between changes in skeletal muscle mass (Δ SMM) and VO2 max. Although the correlation is less pronounced than in Figures 1 and 2, a modest positive trend suggests that players who increase their lean mass may maintain or improve their aerobic capacity.

Table 1. Descriptive statistics of weight, fat, and SMM

Variable	Count	Mean	Std	Min	25%	50%	75%	Max
Weight_June	15.0	59.27	10.92	40.0	56.5	59.0	64.5	78.0
Weight_Jan	15.0	61.6	10.82	42.0	58.5	62.0	66.5	82.0
Fat_June	15.0	7.47	2.75	4.0	5.5	7.0	8.0	15.0
Fat_Jan	15.0	8.6	2.64	5.0	7.0	8.0	10.0	15.0
SMM_June	15.0	29.53	5.66	18.0	29.5	30.0	34.0	35.0
SMM_Jan	15.0	30.57	5.05	19.0	29.5	32.0	34.25	36.0

Descriptive statistics showed an overall increase in body weight, fat mass, and SMM between the June and January assessments. As shown in Table 1, mean body weight increased from 59.27 ± 10.92 kg to 61.60 ± 10.82 kg. Fat mass increased from 7.47 ± 2.75 kg to 8.60 ± 2.64 kg, while SMM increased from 29.53 ± 5.66 kg to 30.57 ± 5.05 kg.

Table 2. Mean Difference

	Mean Difference (kg)
Weight	2.33
Fat Mass	1.13
Skeletal Muscle Mass	1.03

Table 2 shows the mean increases of 2.33 kg in body weight, 1.13 kg in fat mass, and 1.03 kg in SMM.

Paired Samples t-Test Analysis

Statistical analysis confirmed that all three changes were significant:

- Weight: $t(15) = 5.64, p < 0.001$
- Fat Mass: $t(15) = 4.69, p < 0.001$
- SMM: $t(15) = 3.21, p = 0.006$

These results indicate that the observed increases are unlikely to be due to random variation and likely represent physiological adaptations occurring over the six-month period.

Descriptive and inferential statistics showed that VO2 max decreased in players who experienced increases in BFM and total body weight, while those who reduced BFM either maintained or improved their aerobic capacity. Correlation analysis demonstrated a strong negative relationship between changes in BFM and VO2 max ($r \approx -0.70$) and a moderate negative correlation between changes in body weight and VO2 max ($r \approx -0.60$). Additionally, a weak to moderate positive correlation ($r \approx 0.35$) was observed between changes in SMM and VO2 max.

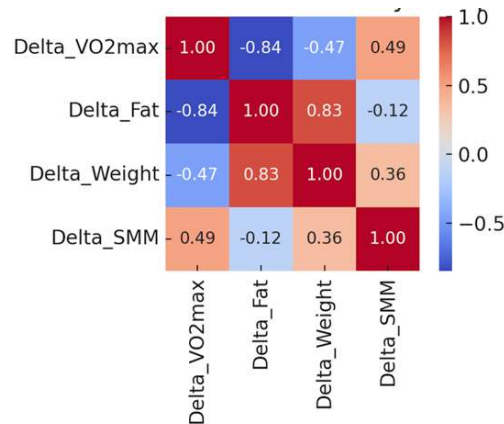


Figure 4. Correlation matrix

Pearson correlation analysis was performed to examine the relationship between changes in VO2 max and changes in body composition:

- Δ Fat Mass vs. Δ VO2 max: $r = -0.845, p < 0.001$
- Δ Body Weight vs. Δ VO2 max: $r = -0.469, p = 0.078$
- Δ SMM vs. Δ VO2 max: $r = 0.490, p = 0.064$

The results demonstrate a strong and statistically significant negative correlation between changes in fat mass and VO2 max, indicating that players who gained fat experienced a decline in aerobic capacity. In contrast, the correlations between VO2 max and both body weight and SMM were moderate but not statistically significant ($p > 0.05$), implying a trend rather than a definitive effect (Figure 4).

Discussion

Statistical analysis showed significant increases in all body composition variables—body weight, fat mass, and SMM—over the six-month period. These changes align with normal adolescent growth and training adaptations during the transitional and mid-season phases. While increases in lean mass are likely beneficial or neutral for performance, fat mass gains were related to a decrease in relative VO2 max.

Our findings demonstrated a strong, statistically significant negative correlation between changes in fat mass and aerobic capacity ($r = -0.845$, $p < 0.001$), highlighting the detrimental effect of increased adiposity on cardiovascular efficiency. Moderate trends were observed for total body weight and SMM, although these did not achieve statistical significance. However, the trend of these relationships aligns with the physiological understanding that lean mass may support aerobic function, whereas excessive mass gain—especially fat—is detrimental. These findings are consistent with previous studies on youth football players. Ivanov et al. (2022) examined body composition in academy players and emphasized age-related increases in anthropometric measures. Their study highlighted the importance of monitoring somatic growth to optimize player selection and training. Similarly, Ivanov and Gudev (2024) found that higher body fat levels in professional players were associated with reduced movement efficiency and slower reactive speed, reinforcing the considerable impact of fat accumulation on overall performance.

The findings indicate that relative aerobic capacity in elite youth footballers is affected not only by their training status but also by seasonal changes in body composition. Specifically, the negative correlations between increased fat mass and decreased VO2 max support previous studies showing that higher adiposity limits endurance performance (Silva et al., 2021; Ambroży et al., 2024; Armstrong & Welsman, 2007; Kulczyk et al., 2022). This occurs because fat mass is metabolically inactive and adds to total body weight without increasing oxygen uptake, which leads to a lower relative VO2 max when expressed in ml/kg/min.

Conversely, changes in SMM exhibited a weak to moderate positive correlation with changes in VO2 max. While this association was less strong, it aligns with the physiological concept that muscle mass facilitates aerobic metabolism by improving oxygen extraction and utilization during sustained exercise (Legaz & Eston, 2005). However, it is important to note that absolute increases in muscle mass also increase total body weight, which may offset improvements in relative VO2 max if not accompanied by corresponding improvements in cardiovascular capacity. Figures 1–3 confirm these conclusions, showing the inverse relationship between fat or weight gain and VO2 max, alongside a tendency for positive effects from lean mass increases. This underscores the importance of personalized conditioning programs that focus on optimizing lean-to-fat ratios while avoiding excessive weight gain. Moreover, the descriptive analysis shows that, on average, players gained both fat and muscle over the six months. This likely reflects natural adolescent growth or inadequate regulation of training load during transitional phases. Coaches should be aware of these seasonal patterns and use consistent monitoring tools, such as InBody analysis and aerobic testing, to tailor nutritional and physical preparation plans effectively. Consistent with these observations, our data indicate that players who maintained lower fat mass during the study period also preserved or improved their aerobic performance (VO2 max). This highlights the importance of individualized conditioning strategies in youth football that emphasize lean mass development while managing excess adiposity, particularly during transitional periods such as the off-season and pre-competition phases.

Ayob et al. (2023) demonstrated that both prescribed and self-paced high-intensity interval exercise (HIIE) protocols produced significant improvements in aerobic capacity and body composition over five weeks in overweight and obese adults, confirming the effectiveness of structured interval training for improving cardiorespiratory fitness. Bekris et al. (2016) emphasize that aerobic and anaerobic capacities in professional football players experience considerable variations during the annual macrocycle, with VO2 max values peaking during competitive phases. Their study underlines the importance of continuous monitoring of these capacities to optimize player performance during the season.

The discussion highlights the essential role of a comprehensive athlete monitoring system that integrates physiological, anthropometric, and performance data to guide decision-making in youth football development programs.

This study has several limitations to consider. First, the small sample size ($n = 15$) may restrict the generalizability of the results and reduce the statistical power to detect subtle effects. Second, the lack of a control group limits the ability to draw causal conclusions because observed changes may be influenced by natural maturation or external variables. Future research should incorporate larger samples and controlled longitudinal designs to confirm and expand upon these preliminary findings.

Conclusion

This study showed that intra-seasonal changes in body composition—especially increases in fat mass—are significantly related to declines in aerobic capacity among elite youth football players. In contrast, increases in SMM showed a modest positive trend toward supporting VO2 max, although this did not reach statistical significance. The strong negative correlation between fat gain and VO2 max underscores adiposity as a key factor in maintaining cardiovascular fitness during adolescence.

While the strong negative correlation between fat mass and VO2 max identifies adiposity as a key performance factor, the non-significant trends observed for SMM ($r = 0.490$, $p = 0.064$) and body weight ($r = -0.469$, $p = 0.078$) suggest the presence of more complex physiological interactions. These results suggest that (1) muscle mass may have a neutral or context-dependent effect on aerobic capacity in youth players, and (2) overall weight gain is less important than its composition—specifically, the balance between fat and lean mass. To clarify these relationships and inform targeted training strategies, future research with larger sample sizes is needed. Meanwhile, these findings emphasize the importance of individualized monitoring protocols that include regular assessments of body composition and aerobic performance testing to optimize athletic development. Tools such as the InBody 270 and field-based VO2 max estimations offer practical, evidence-based methods for informing physical preparation and nutritional plans.

By carefully monitoring somatic changes during different training phases, coaches and practitioners can more effectively support the physiological development of young athletes and minimize the risk of performance declines caused by unfavorable changes in body composition.

Ultimately, integrating anthropometric, physiological, and performance data into training decisions increases the effectiveness of youth development programs and supports long-term athletic progression in football. These insights can guide coaches and sports scientists in creating evidence-based interventions that optimize body composition and maintain aerobic performance throughout youth football development.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to the publication of this article.

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