

## Dynamic Body Composition Adaptations in Young Athletes (15–17 Years Old): A Two-Year Follow-Up Using Professional Bioelectrical Impedance Monitoring.

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### ABSTRACT

**Background:** Monitoring body composition in youth athletes is essential for understanding growth, training-related adaptations, and health trajectories during adolescence. Professional bioelectrical impedance analysis (BIA) provides a practical and reliable method to evaluate these changes longitudinally.

**Objective:** To examine two-year changes in skeletal muscle mass, fat mass, bone mass, and body mass index (BMI) in young amateur football players using repeated BIA assessments.

**Methods:** Twenty male regional-level football players (mean age: 15.9 years; height: 169 cm; weight: 52.82 kg) were followed across two competitive seasons (2023–2024 and 2024–2025). Body composition was measured at four standardized time points (start and end of each season) using a professional BIA system (Tanita PRO 780). The training regimen consisted of four sessions per week over 26-week seasons (~170 hours per season). Analyses included repeated measures comparisons, Wilcoxon tests, and effect size calculations (Cohen's d).

**Results:** Muscle mass increased significantly over the two years (+5.66 kg,  $d = 2.05$ , +9.17%). Bone mass showed a substantial increase (+0.40 kg,  $d = 2.21$ , +17.39%). Fat mass remained stable over time (–0.01 kg,  $d = 0.01$ , 0.13%). BMI increased moderately (+1.24 kg/m<sup>2</sup>,  $d = 0.97$ , +6.84%). Early seasonal fluctuations were not cumulative, while long-term improvements in lean and bone tissue were pronounced.

**Conclusion:** Two consecutive seasons of structured football training induced significant gains in muscle and bone mass, maintained stable fat mass, and moderately increased BMI in young athletes. Professional BIA is a valuable tool for monitoring growth and physiological development in adolescent sports contexts..

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**Keywords:** youth athletes; football; body composition; bioelectrical impedance analysis; muscle mass; fat mass; bone mass; longitudinal study; adolescence; sports science..

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### 1. INTRODUCTION

Adolescence is a critical developmental window characterized by rapid changes in body composition, neuro-muscular maturation, and metabolic growth (Beunen & Malina, 2020).

For young athletes, monitoring these changes is essential to better understand physiological adaptation to training, detect imbalances, and guide long-term athletic development. Among the components of body composition, skeletal muscle mass, fat mass, and bone mass are key predictors of health, performance, and injury risk (Faigenbaum et al., 2019).

Bioelectrical impedance analysis (BIA) has become a widely used method for evaluating body composition in youth sports due to its non-invasiveness, reproducibility, and practicality during regular training settings. Professional BIA systems, such as the Tanita PRO series, provide improved precision and are suitable for longitudinal monitoring (Ling et al., 2022).

Although several studies have described seasonal variations in adult athletes, longitudinal data covering multiple seasons in adolescents remain scarce. Most available studies examine short-term fluctuations or single-season changes, with limited evidence on cumulative adaptations across multiple years of training. Understanding these long-term trajectories is crucial for optimizing talent development and designing age-appropriate training loads.

The present study aims to address this gap by investigating two-year changes in muscle mass, fat mass, bone mass, and BMI in young amateur football players using repeated BIA assessments

**Objectifs**

To evaluate longitudinal changes in skeletal muscle mass, fat mass, bone mass, and BMI over two consecutive seasons.

To examine seasonal (within-season) and inter-seasonal variations.

To determine the cumulative effect of structured football training across the two-year period.

**Hypotheses**

Skeletal muscle mass and bone mass will increase progressively over two competitive seasons.

Fat mass will increase temporarily during off-season periods but return to baseline levels by the end of each season.

Overall BMI will remain stable, reflecting balanced changes in muscle, bone, and fat mass.

**Methods**

**Study Design**

This was a longitudinal observational study conducted over two consecutive football seasons (2023–2024 and 2024–2025). Body composition was assessed at four key time points to capture both seasonal and cumulative changes

**Participants :**

	Age (years)	Height (cm)	Weight (kg)	Training volume	Sessions per week	Training season duration (week)
<b>N20</b>	15.9±0.1	169±2	52.89±0.2	10248±6	4	26

**Table(1) : Characteristics of the research sample**

The sample included **20 young male football players** competing at the **regional amateur level**. All participants were regularly involved in structured football training and competition. Inclusion criteria included: (1) being registered in the same club for the full duration of the study, (2) absence of any medical contraindication to physical activity, and (3) availability for all four measurement sessions.

**Measurement Timeline**

Body composition was assessed at **four time points**:

**T1 – Beginning of pre-season (Season 1)**

**T2 – End of competitive season (Season 1)**

**T3 – Beginning of pre-season (Season 2)**

**T4 – End of competitive season (Season 2)**

This design allowed evaluation of both **intra-seasonal** (T1–T2, T3–T4) and **inter-seasonal** (T2–T3) changes.

**Body Composition Assessment**

Anthropometric and body composition variables were measured using a **professional bioelectrical impedance analyzer (Tanita PRO 780)**. Measurements were conducted under standardized conditions:

Measurements were performed using a professional multi-frequency BIA system (**Tanita PRO 780**). Standardized protocols included:

morning testing,  
 fasting 2 hours before measurement,  
 no training 24 hours prior,  
 light clothing, barefoot,  
 controlled hydration.  
 The following variables were extracted:

**Skeletal muscle mass (kg)**

**Fat mass (kg and %)**

**Bone mass (kg)**

**Body mass index (BMI, kg/m<sup>2</sup>)**

**Procedures**

Relatively small sample size from a single club.  
 Only male athletes were included.  
 Dietary intake and hormonal maturation were not controlled.  
 BIA, while practical, may be sensitive to hydration variations.

**Practical Applications**

Coaches should use BIA monitoring to follow growth and adapt training load.  
 Structured training across multiple seasons is effective for improving lean and bone mass.  
 Seasonal fat fluctuations are normal and not indicative of negative development.  
 BMI alone is insufficient to assess youth athletes—body composition metrics are essential.

**Statistical analysis :**

Data normality was assessed using :  
 - Shapiro–Wilk tests. For normally distributed variables,  
 -repeated-measures  
 -t-tests were used.  
 -Non-parametric comparisons (T1–T2–T3–T4) employed Wilcoxon tests.  
 -Effect sizes were computed using Cohen’s d.  
 -Significance was set at **p < 0.05**

**Results :**

**Muscle Mass**

	Mean Difference	Margin of Error	Probability	Sig 5%	Signification
<b>T1-T2</b>	0.45	0.19	0.18	0.05	NO .SIG
<b>T1-T3</b>	1.03	0.47	0.26	0.05	NO .SIG
<b>T1-T4</b>	5.66	0.61	0.00	0.05	SIG
<b>T2-T3</b>	0.58	0.41	1.00	0.05	NO .SIG
<b>T2-T4</b>	5.21	0.58	0.00	0.05	SIG
<b>T3-T4</b>	4.63	0.37	0.00	0.05	SIG

**Table(2): Statistical significance of the differences in mean muscle mass values across two consecutive seasons**

	Mean T4	Mean T1	Mean D	ST.D	Cohiens D	effct	2 season % effect
BMI	46.54	42.63	5.66	2.76	2.05	Big	9.17%

**Table(3): The effect size of the two athletic seasons on Muscle mass**

Over the course of two consecutive athletic seasons, young athletes exhibited significant increases in muscle mass, as measured by professional bioelectrical impedance analysis. Early comparisons (T1–T2 and T1–T3) showed small, non-significant changes (0.45–1.03 kg,  $p > 0.05$ ), whereas later comparisons (T1–T4, T2–T4, T3–T4) revealed substantial and statistically significant gains (4.63–5.66 kg,  $p < 0.001$ ). The overall increase from T1 to T4 was 5.66 kg (SD = 2.76), corresponding to a very large effect size (Cohen’s  $d = 2.05$ ) and a 9.17% improvement in muscle mass. These results indicate that cumulative exposure to structured training over two seasons led to meaningful adaptations in body composition among the athletes.

**Fat Mass**

	T1-T2	T1-T3	T1-T4
Z	2.42	2.76	-0.56
Probability	0.01	0.00	0.57
Signification	No. Sig (more than 0.05)		

**Table(4):Wilcoxon test for the comparison of body fat mean values over two consecutive seasons**

	Mean T4	Mean T1	Mean D	ST.D	Cohiens D	effct	2 season % effect
BMI	7.64	7.65	0.01	1.71	0.01	Nul	0.13-%

**Table(5): The effect size of the two athletic seasons on Fat mass**

Over the two consecutive athletic seasons, changes in body fat were minimal. Wilcoxon tests showed a significant decrease between T1–T2 ( $Z = 2.42$ ,  $p = 0.01$ ) and T1–T3 ( $Z = 2.76$ ,  $p < 0.01$ ), but no significant change was observed between T1–T4 ( $Z = -0.56$ ,  $p = 0.57$ ). The overall mean fat mass remained virtually unchanged from T1 (7.65 kg) to T4 (7.64 kg), with a negligible mean difference of 0.01 kg, an effect size near zero (Cohen’s  $d = 0.01$ ), and a 0.13% change over the two seasons. These results indicate that, despite significant early fluctuations, the structured training program did not meaningfully alter body fat in this cohort of young athletes.

**Bone Mass :**

	Mean Difference	Margin of Error	Probability	Sig 5%	Signification
<b>T1-T2</b>	0.02	0.01	0.97	0.05	NO .SIG
<b>T1-T3</b>	0.12	0.02	0.00	0.05	SIG
<b>T1-T4</b>	0.40	0.04	0.00	0.05	SIG
<b>T2-T3</b>	0.10	0.01	0.00	0.05	SIG
<b>T2-T4</b>	0.38	0.03	0.00	0.05	SIG
<b>T3-T4</b>	0.28	0.02	0.00	0.05	SIG

**Table(6): Statistical significance of the differences in mean Bone mass values across two consecutive seasons**

	Mean T4	Mean T1	Mean D	ST.D	Cohiens D	effct	2 season % effect
BMI	2.70	2.30	0.40	0.18	2.21	Big	17.39%

**Table(7): The effect size of the two athletic seasons on Bone mass**

Over the course of two consecutive athletic seasons, young athletes showed significant increases in bone mass. Early

comparison between T1–T2 revealed no significant change (0.02 kg,  $p = 0.97$ ), whereas subsequent comparisons (T1–T3, T1–T4, T2–T3, T2–T4, T3–T4) demonstrated statistically significant gains (0.10–0.40 kg,  $p < 0.001$ ). The overall mean bone mass increased from 2.30 kg at T1 to 2.70 kg at T4, corresponding to a mean difference of 0.40 kg, a large effect size (Cohen’s  $d = 2.21$ ), and a 17.39% increase over the two seasons. These findings indicate that structured training had a substantial impact on bone mass development in these young athletes.

**Body Mass Index (BMI) :**

	Mean Difference	Margin of Error	Probability	Sig 5%	Signification
<b>T1-T2</b>	0.37	0.06	0.00	0.05	SIG
<b>T1-T3</b>	0.43	0.11	0.00	0.05	SIG
<b>T1-T4</b>	1.24	0.28	0.00	0.05	SIG
<b>T2-T3</b>	0.05	0.11	1.00	0.05	NO .SIG
<b>T2-T4</b>	0.87	0.28	0.03	0.05	SIG
<b>T3-T4</b>	0.81	0.23	0.01	0.05	SIG

**Table(8): Statistical significance of the differences in mean BMI values across two consecutive seasons**

	Mean T4	Mean T1	Mean D	ST.D	Cohiens D	effct	2 season % effect
BMI	19.52	18.27	1.24	1.27	0.97	Big	6.84%

**Table(9): The effect size of the two athletic seasons on body mass index**

Over the two consecutive athletic seasons, young athletes exhibited significant increases in body mass index (BMI). Early comparisons (T1–T2 and T1–T3) showed significant gains of 0.37 kg/m<sup>2</sup> and 0.43 kg/m<sup>2</sup>, respectively ( $p < 0.001$ ), with further significant increases observed at T1–T4, T2–T4, and T3–T4 (1.24, 0.87, and 0.81 kg/m<sup>2</sup>,  $p \leq 0.03$ ). No significant change was detected between T2–T3 (0.05 kg/m<sup>2</sup>,  $p = 1.00$ ). The overall mean BMI increased from 18.27 at T1 to 19.52 at T4, representing a mean difference of 1.24, a large effect size (Cohen’s  $d = 0.97$ ), and a 6.84% increase over the two seasons. These results indicate that the structured training contributed to meaningful improvements in overall body mass relative to height in these young athletes

**2. DISCUSSION :**

This two-year investigation reveals substantial and meaningful body composition adaptations in young football players undergoing structured training. Muscle mass increased significantly, particularly during the second season, highlighting cumulative neuromuscular development and improved training tolerance typical of mid-adolescence.

Fat mass remained stable over the long term, despite temporary seasonal fluctuations. This stability aligns with prior research indicating that trained youth tend to maintain low fat levels when training loads are consistent (Moran et al., 2022).

Bone mass demonstrated the strongest relative improvement (+17.39%), emphasizing the osteogenic benefits of weight-bearing sports during adolescence—a period crucial for maximizing peak bone mass (Tenforde & Fredericson, 2018).

BMI also increased moderately, driven primarily by lean tissue growth rather than fat accumulation, reinforcing the importance of interpreting BMI alongside body composition metrics in youth athletes.

Overall, these findings support the role of structured football training in promoting healthy physical development while avoiding unwanted increases in fat mass.

**3. CONCLUSION :**

Two consecutive seasons of structured football training produced significant gains in muscle and bone mass, stable fat mass, and moderate increases in BMI among young athletes aged 15–17 years. Professional BIA monitoring proved effective for tracking these physiological changes. These results highlight the importance of consistent, long-term training programs in supporting healthy adolescent development and optimizing athletic performance..

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