

# BODY COMPOSITION IN PHYSICALLY ACTIVE MALE STUDENTS ASSESSED USING MULTI-FREQUENCY BIOELECTRICAL IMPEDANCE ANALYSIS

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Body composition is strongly influenced by physical activity and dietary habits. Male students enrolled in Physical Education and Sport programs represent a distinct population because their curricula include systematic physical activity that directly affects physiological characteristics. This study aimed to establish a representative body composition profile of physically active male Physical Education and Sport students using a multi-frequency bioelectrical impedance analyzer (BIA) and to evaluate the reliability and consistency of measurements across two assessments. A total of 108 male students aged 19–25 years participated in the study. Body composition was assessed using ten indicators: body fat percentage, visceral fat index, body mass index (BMI), muscle mass, skeletal muscle mass, sarcopenic index, total body water, body weight, height, and phase angle. Descriptive statistics, paired-samples t-tests, effect size analysis (Cohen's *d*), and Bland–Altman analyses were used to evaluate agreement, reliability, and measurement consistency between pre- and post-test assessments. No statistically significant differences were observed between assessments for any parameter ( $p > 0.05$ ). Effect sizes were trivial across all indicators, indicating negligible changes between measurements. Bland–Altman analysis revealed bias values close to zero and relatively narrow 95% limits of agreement, confirming good measurement reliability and reproducibility. Physically active male students exhibited a stable and reproducible body composition profile. The obtained values may serve as reference data for body composition assessment in similar populations. Although the BIA method demonstrated high reliability, it appears more sensitive to moderate-to-large changes than to very small individual physiological fluctuations.

Keywords: pattern, physiological profile, reliability assessment

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## INTRODUCTION

Body composition is influenced primarily by physical activity level, diet, lifestyle, and other factors. In addition to commonly used indicators such as body mass index (BMI) and body fat percentage, contemporary research also considers parameters such as the sarcopenic index and total body water (TBW), which provide deeper insight into muscle quality and hydration status (1). The sarcopenic index (2) reflects the proportion of skeletal muscle relative to body size, and it is an indicator of functional muscle status, while TBW is closely related to fat-free mass and overall physiological balance. These parameters allow for a more comprehensive evaluation of body composition in relation to physical activity and nutritional habits. Nowadays, physical activity levels among students are often low (3,4), which affects body image and contributes to weight management issues such as overweight and obesity by increasing body fat percentage and creating a risk for chronic diseases associated with physical inactivity (5). However, some studies have found no significant differences in body composition between students involved in sports and those who are not (6). Not all physical activity programs lead to significant changes in students' body composition; the regularity of activity is a critical factor (7,8), with moderate-intensity continuous training showing greater benefits for improving body composition (9). Longitudinal studies have reported an increasing trend in students' BMI over four consecutive years, alongside a decline in physical fitness, particularly in upper limb strength (10). There is a clear association between BMI and physical fitness, as well as between physical activity levels, body composition parameters, and physical performance. Specifically, the proportion of adipose tissue is negatively correlated with physical condition (11). Moderate leisure physical activity has also been linked to lower body fat percentages among students (12).

Diet is another key factor influencing body composition. While a varied and healthy diet is desirable, many students adopt lifestyles incompatible with healthy eating (13). Unhealthy diets are associated with higher obesity prevalence, emphasizing the need for nutritional recommendations targeted at students (14). Lebanese male students demonstrated better dietary habits, greater nutrition knowledge, and maintained normal BMI values; a mild to moderate correlation was observed between dietary habits and body composition, especially body mass, fat mass, and skeletal muscle mass (15). Associations have also been found between sugar consumption and visceral fat,

bone mass, and muscle mass, whereas fruit and vegetable intake correlates with lower fat percentages (16). The Mediterranean diet positively influences body composition, associating with lower levels of visceral and subcutaneous adipose tissue, BMI, and waist circumference (17). Physical activity combined with a varied diet is essential for achieving optimal body weight and preventing nutritional and health problems (18).

The living environment appears to have little impact on body composition, as rural and urban students exhibit similar average values across most body composition indicators (19). In one study, El-Hayek Fares et al. (20) found that 40% of students were overweight or obese; 52.5% of males required dietary changes, with many showing lower fitness scores. Using bioelectrical impedance analysis, university students were found to have normal BMI but elevated body fat mass. Despite most reporting as active via the International Physical Activity Questionnaire (IPAQ), nearly half were actually less active or sedentary (21). Students tend to gain weight and body fat during their academic studies, especially in the first year, which affects BMI (22). Significant differences in fat mass, lean mass, skeletal muscle percentage, and overall body mass were identified between students with excessive weight and those with normal weight using bioimpedance methods (23).

Regarding body fat, no significant differences were observed between active and inactive male students; however, other indicators like body water and muscle mass showed significant differences (24). Among male students specializing in physical education and sport, BMI and fat percentage were within normal ranges, and the proportion of overweight and obese students was lower than that of other Ecuadorian male youth (25). Similar results were found for Lebanese students, where sports students had normal body weight and healthier body composition profiles compared to students from other fields (26). Students enrolled in sports programs also demonstrated better body composition indicators and blood pressure levels compared to their peers in other courses, particularly for waist and hip circumferences, muscle mass, and bone mineral content (27). Nonetheless, approximately 20% of students are overweight despite positive attitudes toward physical activity; without regular exercise, these attitudes are insufficient. Offering a diverse range of sports and recreational activities could encourage youth participation and improve quality of life (28).

Obesity and overweight negatively correlate with self-esteem, which tends to be lower in these groups compared to physically active students who exhibit higher self-esteem

and better health status (29). Students with larger body silhouettes often experience dissatisfaction, body image concerns, and lower self-esteem (3). More than half of the physical education students in a study by Rocha et al. (30) exhibited distortions in self-body perception, which raises concerns for future professionals in the physical activity field. Male students averaged 38% skeletal muscle mass and 24% body fat, reflecting high levels of physical activity (31).

The level and regularity of physical activity and diet primarily influence body composition in male students. Male students in physical education and sport represent a distinct group due to the higher physical activity demands in their curricula compared to students in other fields. Previous studies that have reported differences in body composition among male students, typically attributed to variations in physical activity, diet, and lifestyle. Our research focuses on determining a body composition pattern for Romanian male students in physical education and sport. There is a lack of information on this population in journals indexed by Web of Science, and our study aims to fill this gap by providing reliable data. This study aimed to establish a reference pattern of body composition in physically active young males enrolled in a Physical Education and Sport program using a multi-frequency bioelectrical impedance analyzer. Specifically, the objectives were to (a) assess ten key body composition indicators, (b) evaluate the reliability and agreement between two consecutive assessments using the Bland–Altman method, and (c) determine whether statistically significant differences exist between the two assessments. It was hypothesized that physically active male students enrolled in the Physical Education and Sport program would exhibit a consistent and reliable body composition pattern, with values aligning with those reported for healthy, active youth populations and showing no significant differences between repeated assessments.

## METHODS

The subjects involved in this research were 108 male students enrolled in the Physical Education and Sport program at Ștefan cel Mare University of Suceava. All participants provided written informed consent before participation. The study was conducted in accordance with the Declaration of Helsinki. It was approved by the Ethics Research Committee of Ștefan cel Mare University of Suceava (protocol code no. 64, approved on May 23, 2022).

## Study design

In designing the study, we established the following inclusion criteria: male sex, age between 19 and 25 years, and active student status. Exclusion criteria included: female sex, age below 19 or above 25 years, and non-student status.

During the 8-week experimental period, participants engaged in four hours of structured physical activity per week as part of their academic curriculum, as well as an additional average of six hours of voluntary physical activity weekly.

To minimize measurement variability, assessments were conducted twice, at baseline (week 1) and post-intervention (week 8), at the same time of day and under similar conditions for all participants.

## Instrumentation and data collection

Body composition was assessed using a multi-frequency bioelectrical impedance analyzer (Tanita MC-780 MA) in standard mode, following the manufacturer's guidelines. Participants were instructed to avoid food, caffeine, and vigorous physical activity for at least three hours before testing to ensure consistent measurement conditions.

The device provided data on ten body composition parameters: body fat, visceral fat, BMI, muscle mass, skeletal muscle mass, sarcopenic index, total body water, weight, height, and phase angle.

## Statistics

Descriptive statistics (mean  $\pm$  standard deviation) were calculated using IBM SPSS Statistics, version 26. To evaluate agreement and reliability between pre- and post-test measurements, the Bland–Altman method was applied to examine individual differences and assess the interchangeability of results by calculating the bias and the 95% limits of agreement for each parameter. A bias value close to zero indicates the absence of systematic error and no consistent tendency to overestimate or underestimate values in the second assessment. Furthermore, narrower limits of agreement reflect higher measurement reliability and consistency. One-way analysis of variance (ANOVA) was used to assess the homogeneity of the study sample. A paired samples t-test was then conducted to identify any statistically significant differences between the two assessments. The level of significance was set at  $p < 0.05$ . Cohen's  $d$  was used to quantify the actual magnitude of the improvement in strength and velocity, where a value of 0.8 or higher meant a large effect, and the difference was substantial.

In addition, the smallest worthwhile change (SWC) was calculated for each parameter as  $0.2 \times \text{SD}$  (baseline), representing the minimal meaningful change. The comparison between SWC and the Bland–Altman limits of agreement (LoA) was used to further interpret measurement sensitivity, where SWC values smaller than LoA indicate limited ability to detect small but meaningful changes.

## RESULTS

The ANOVA method confirmed that participants were relatively uniform in terms of age, height, and weight, with no statistically significant differences observed ( $p > 0.05$ ). More specifically, one-way ANOVA revealed no statistically significant between-subject variability for baseline characteristics, with low within-group dispersion relative to total variance, indicating a high degree of sample homogeneity. The absence of significant F-ratios ( $p > 0.05$ ) suggests that individual differences in age, height, and body mass did not contribute meaningfully to variability in the dataset. Additionally, the relatively small standard deviations observed for height ( $\pm 7.02$  cm) and BMI ( $\pm 3.82$  kg/m<sup>2</sup>), alongside moderate dispersion in body mass ( $\pm 14.33$  kg), further support the conclusion that the sample was sufficiently homogeneous for subsequent parametric analyses.

Furthermore, one-way ANOVA results ( $p > 0.05$  across all baseline characteristics) confirmed sample homogeneity, indicating that variability within the group was random and not influenced by subgroup stratification, thereby justifying the use of parametric analyses.

Importantly, the homogeneity of variance assumption was considered satisfied, as reflected by the consistent spread of values across participants, which reduces the likelihood of bias in inferential comparisons and strengthens the internal validity of the study design.

The descriptive statistics and comparative results for the pre-test and post-test assessments are presented in Table 1. For each indicator, the pre- and post-test mean values were highly comparable, and no statistically significant differences were found, as confirmed by the paired samples t-test ( $p > 0.05$ ). The parameters closest to the significance threshold were skeletal muscle mass ( $p = 0.099$ ) and total body water ( $p = 0.109$ ), suggesting a tendency toward minor physiological variation rather than systematic change.

Effect size analysis revealed trivial Cohen's d values across all body composition indicators (approximately  $-0.16$  to  $0.11$ ), indicating negligible differences between the two assessments. The combination of non-significant paired-samples t-test results and very small effect sizes confirms that the observed variations were minimal and unlikely to reflect meaningful physiological changes. Instead, these findings suggest a high degree of measurement consistency and temporal stability over the study period.

These findings support the reliability and stability of the bioelectrical impedance analyzer used in this study, as the group and individual values remained nearly constant over the two-month testing interval, with only minor natural fluctuations observed.

To further examine measurement consistency, Bland–Altman analysis was applied to all ten indicators. The analysis provided bias estimates, 95% limits of agreement (LoA), and smallest worthwhile change (SWC) values, allowing a comprehensive evaluation of measurement reliability and sensitivity (Table 2).

The calculated bias values for all variables were very close to zero (ranging from  $-0.17$  to  $0.23$ ), indicating the absence of systematic measurement error and demonstrating that the device did not consistently overestimate or underestimate values during the second assessment. The narrow bias estimates across all indicators confirm excellent agreement between repeated measurements.

**Table 1.** Statistical analysis for body composition

| Indicator                | Pre-test ( $\bar{X} \pm \text{SD}$ ) | Post-test ( $\bar{X} \pm \text{SD}$ ) | Bias  | Lower LoA | Upper LoA | t      | p     | Cohen's d |
|--------------------------|--------------------------------------|---------------------------------------|-------|-----------|-----------|--------|-------|-----------|
| Body fat (%)             | 17.30 $\pm$ 6.85                     | 17.36 $\pm$ 6.80                      | 0.06  | -2.74     | 2.87      | 0.457  | 0.648 | 0.044     |
| Visceral fat index       | 3.27 $\pm$ 2.72                      | 3.30 $\pm$ 2.77                       | 0.03  | -0.92     | 0.97      | 0.598  | 0.551 | 0.058     |
| Body mass index          | 23.71 $\pm$ 3.86                     | 23.77 $\pm$ 3.76                      | 0.07  | -1.27     | 1.4       | 1.013  | 0.313 | 0.097     |
| Muscle mass (%)          | 78.57 $\pm$ 6.49                     | 78.52 $\pm$ 6.45                      | -0.04 | -2.64     | 2.55      | -0.334 | 0.739 | -0.032    |
| Skeletal muscle mass (%) | 45.62 $\pm$ 3.97                     | 45.49 $\pm$ 3.93                      | -0.13 | -1.72     | 1.46      | -1.665 | 0.099 | -0.16     |
| Sarcopenic index         | 8.47 $\pm$ 0.97                      | 8.46 $\pm$ 0.94                       | -0.01 | -0.45     | 0.43      | -0.574 | 0.567 | -0.055    |
| Total body water (%)     | 58.11 $\pm$ 4.72                     | 57.95 $\pm$ 4.70                      | -0.16 | -2.24     | 1.91      | -1.617 | 0.109 | -0.156    |
| Weight (kg)              | 76.18 $\pm$ 14.33                    | 76.41 $\pm$ 14.17                     | 0.23  | -3.92     | 4.37      | 1.11   | 0.269 | 0.107     |
| Height (cm)              | 179.02 $\pm$ 7.05                    | 179.03 $\pm$ 7.09                     | 0.01  | -0.32     | 0.34      | 0.576  | 0.566 | 0.055     |
| Phase angle (°)          | 6.85 $\pm$ 0.62                      | 6.83 $\pm$ 0.71                       | -0.02 | -0.79     | 0.76      | -0.487 | 0.628 | -0.047    |

Legend:  $\bar{X}$  – average; SD - standard deviation;

**Table 2.** Bland–Altman agreement statistics and smallest worthwhile change (SWC) for body composition indicators in males ( $n = 108$ )

| Body composition indicator           | Bias  | Lower LoA (95%) | Upper LoA (95%) | SWC  |
|--------------------------------------|-------|-----------------|-----------------|------|
| Body fat (%)                         | 0.06  | -2.75           | 2.87            | 1.37 |
| Visceral fat index                   | 0.03  | -0.92           | 0.97            | 0.54 |
| Body mass index (kg/m <sup>2</sup> ) | 0.07  | -1.27           | 1.4             | 0.77 |
| Muscle mass (%)                      | -0.04 | -2.64           | 2.55            | 1.3  |
| Skeletal muscle mass (%)             | -0.13 | -1.72           | 1.46            | 0.79 |
| Sarcopenic index                     | -0.01 | -0.45           | 0.43            | 0.19 |
| Total body water (%)                 | -0.17 | -2.24           | 1.91            | 0.94 |
| Weight (kg)                          | 0.23  | -3.92           | 4.37            | 2.87 |
| Height (cm)                          | 0.01  | -0.32           | 0.34            | 1.41 |
| Phase angle (°)                      | -0.02 | -0.79           | 0.76            | 0.12 |

The 95% limits of agreement were relatively narrow for most parameters, confirming good absolute reliability. Specifically, variables such as height (−0.32 to 0.34 cm), sarcopenic index (−0.45 to 0.43), phase angle (−0.79 to 0.76°), and visceral fat index (−0.92 to 0.97) demonstrated particularly tight agreement, indicating high measurement precision. Conversely, wider limits were observed for body weight (−3.92 to 4.37 kg), body fat percentage (−2.75 to 2.87%), muscle mass percentage (−2.64 to 2.55%), and total body water (−2.24 to 1.91%), reflecting greater biological and measurement variability at the individual level.

Importantly, comparison of the LoA with SWC values revealed that for all variables, the LoA exceeded the corresponding SWC, indicating that the magnitude of measurement error was greater than the smallest practically meaningful change. Consequently, the device appears to be more suitable for detecting moderate-to-large physiological changes than for identifying very small individual changes over time.

Overall, the Bland–Altman analysis confirmed a high level of concordance between the two testing sessions and provided strong evidence for the reproducibility and reliability of the multi-frequency bioelectrical impedance analyzer in assessing body composition among physically active young adult males.

The graphical representation (Figure 1) illustrates the Bland–Altman plots for all body composition indicators, showing the relationship between the mean of paired measurements and their differences. The bias line was located close to zero in all panels, while the majority of observations were distributed within the 95% limits of agreement, indicating satisfactory agreement between repeated measurements.

No evidence of proportional bias was observed, as the differences remained randomly distributed across the measurement range for all variables. Although slightly greater dispersion was evident for body weight, body fat percentage, muscle mass percentage, and total body water, the overall pattern remained consistent with acceptable measurement agreement.

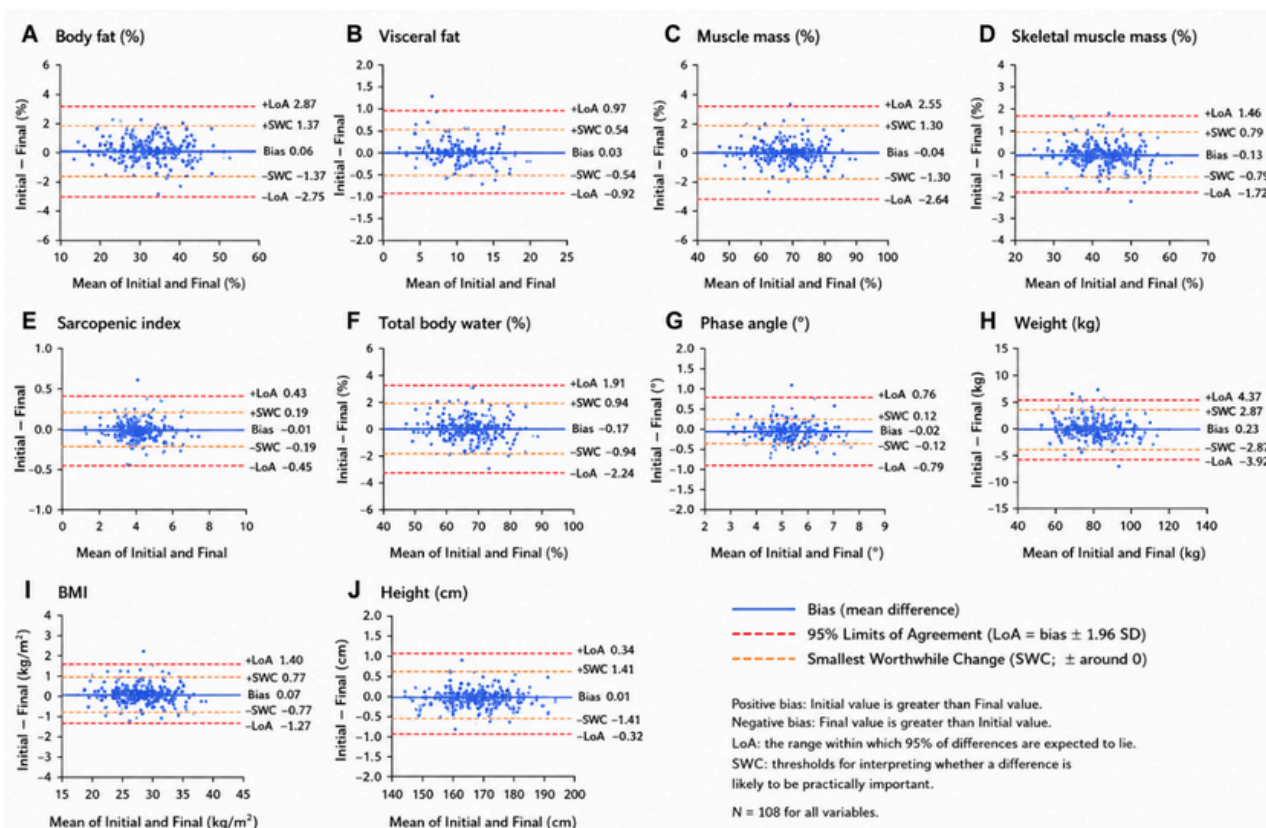
The combined interpretation of Bland–Altman analysis, SWC comparison, ANOVA homogeneity testing, and effect size magnitude indicates that the instrument demonstrates high reliability for group-level assessments. However, because the LoA were consistently wider than the SWC thresholds, caution is warranted when interpreting very small individual-level changes, which may fall within the expected measurement error of the device.

## DISCUSSION

This study aimed to establish a representative body composition pattern among male students of Physical Education and Sport using a multi-frequency BIA across key indicators. This objective was addressed through a comprehensive analytical approach that integrated multiple body composition parameters in order to provide a detailed and reliable profile of physically active young males.

Although BIA is widely recognized as a valid and practical method for assessing body composition, it is less precise compared to dual-energy X-ray absorptiometry (DXA) or magnetic resonance imaging (MRI). Its reliability can be influenced by several factors, including device calibration, operator proficiency, participant characteristics, and environmental conditions (32). Despite these limitations, BIA remains an advantageous method due to its simplicity, safety, mobility, affordability, and non-invasive nature (33). In contrast to DXA or MRI, BIA allows quick field assessments, making it particularly useful in educational and athletic environments. Moreover, BIA devices provide adjustable modes (standard or athletic) and incorporate gender, age, and height, while differences among devices are typically related to calibration, frequency spectrum, and electrode configuration (34).

By integrating results from multiple statistical analyses, this study provides a clearer understanding of the body composition profile of male students engaged in structured physical activity. The novelty lies in defining this pattern across ten distinct indicators: body fat, visceral fat, BMI, muscle mass, skeletal muscle mass, sarcopenic index, total body water, body weight, height, and phase angle. Although the sample was relatively homogeneous in terms



**Figure 1.** Data distribution for each body composition indicator (A-J) at Bland-Altman analysis

of age, height, and weight, inter-individual differences in body type, energy demands, and metabolic characteristics highlight the necessity of defining specific body composition reference patterns according to gender and activity level. Such data are particularly relevant in the context of modern lifestyle and technological changes that affect overall health, physical fitness, and well-being.

To establish structural framing for these parameters, the BIA device used in this study classifies results into three colour-coded categories—normal (green), below normal (orange), and above normal (red)—based on gender, age, and physical activity level (35), which simplifies clinical evaluation. For instance, for body fat percentage, values between 8% and 20% were considered normal. Approximately 60% of participants were within this range, while smaller proportions fell below 8% or above 20%. These results correspond closely to findings by Alarcón et al. (25), who reported similar body fat distributions among male university students. The mean body fat percentage in the present study (17.3%) was slightly higher than the 12% reported elsewhere (15), potentially due to differences in training volume or dietary habits.

Most participants exhibited visceral fat index values below the normal range (4–12.5), indicating favorable fat distribution. In terms of BMI, the majority of students fell within normal limits, with only a small proportion being underweight and roughly one-third classified as overweight. These trends align with previous studies conducted among male university students (20,25,28,36). The average BMI in our study corresponded closely to data reported in other populations of physically active young men.

Regarding muscle-related parameters, the majority of participants displayed normal or above-normal muscle mass and skeletal muscle mass, confirming the positive influence of regular physical activity. The sarcopenic index values were predominantly within normal limits, with only a few cases suggesting lower bone density and a potential risk for osteopenia. Total body water values were also within normal physiological limits, while phase angle results indicated a generally healthy cellular condition, although a few individuals presented values that may warrant further health monitoring.

Our findings correspond well with earlier studies conducted on similar populations. Petřeková et al. (18) reported body composition results for weight, skeletal muscle mass, body fat, total body water, and BMI comparable to those obtained in the present study. Cárdenas Quintana et al. (31), however, observed lower values for weight, height, and skeletal muscle mass but higher BMI, body fat, and visceral fat percentages. Similarly, Valenzuela Contreras et al. (11) reported comparable height and weight but higher fat percentages.

In addition, the Bland–Altman analysis performed in the present study demonstrated bias values close to zero and relatively narrow limits of agreement across all body composition indicators, supporting the stability and repeatability of the measurements over the eight-week interval. The absence of statistically significant differences between assessments, together with trivial effect sizes, further supports the temporal stability of the measured variables. Although the limits of agreement exceeded the corresponding SWC values for all variables, indicating limited sensitivity for detecting very small individual changes, the overall agreement between repeated measurements remained high, confirming the suitability of the device for monitoring body composition at the group level.

Interestingly, a previous study conducted at the same university by Leuciuc et al. (37), involving a smaller sample size and a more limited set of body composition variables, reported greater variability in participant characteristics. The larger sample and broader range of indicators included in the present investigation provide a more comprehensive characterization of body composition among male students of Physical Education and Sport.

In interpreting this collective dataset, it should also be noted that our sample included students participating in wrestling, combat sports, and rugby, disciplines that demand distinct anthropometric profiles, which may partly explain the observed variations across individual indicators and highlight the baseline diversity inherent to complex sporting cohorts.

#### Strengths, limitations, and implications

The main strength of this study lies in its inclusion of over 70% of all male students enrolled in Physical Education and Sport at Ștefan cel Mare University of Suceava, as well as in its comprehensive assessment of ten major body composition indicators. However, several limitations must be acknowledged: the study's single-institution context, a relatively small sample size, the narrow age range (19–25

years), and the exclusive focus on male participants. Moreover, differences in BIA device settings, calibration, and proprietary software algorithms may have influenced results.

In addition, the study did not include systematic monitoring of participants' voluntary physical activity outside structured academic requirements, which may have introduced uncontrolled variability in energy expenditure and body composition outcomes. Likewise, dietary intake during the intervention period was not controlled or monitored, limiting the ability to account for nutritional influences on body composition parameters. Furthermore, the potential influence of prior sporting background and accumulated sport experience was not explicitly controlled, which may have contributed to inter-individual differences, particularly given the heterogeneous engagement in sports such as wrestling, combat sports, and rugby among participants.

Future research should include larger, multi-institutional, and gender-diverse samples to enhance generalizability. Establishing normative reference values across different populations, levels of physical activity, and body weight categories could contribute significantly to public health and sports science. Future studies should also incorporate objective monitoring of physical activity levels (e.g., accelerometry or training logs), standardized dietary assessment protocols, and stratification according to prior sport experience in order to better isolate training effects from background-related adaptations.

#### Practical and public health relevance

Considering that over 80% of young adults globally do not meet recommended physical activity levels—which negatively impacts their body composition, health, and quality of life (38)—the results of this study emphasize the importance of continuous promotion of physical activity and healthy lifestyle habits among university students. The established reference values can serve as a practical tool for educators, coaches, and health professionals in monitoring and improving the physical status of young adults engaged in sports and physical education.

This study aimed to establish a representative pattern of body composition among physically active male university students enrolled in the Physical Education and Sport program, using a multi-frequency BIA. The results confirmed a high degree of consistency and reliability across ten key body composition indicators—body fat percentage, visceral fat index, BMI, muscle mass, skeletal muscle mass, sarcopenic index, total body water, weight, height, and phase angle.

The absence of statistically significant differences between pre- and post-test assessments, together with the bias values close to zero and the relatively narrow 95% limits of agreement identified through Bland–Altman analysis, supports the stability and reproducibility of the applied measurement method. These findings validate the main hypothesis that active male students maintain a consistent body composition profile, comparable to previously established healthy ranges reported in the literature.

The identified body composition values and agreement characteristics may serve as useful reference data for evaluating body composition in young, physically active males, particularly in sports and academic environments. Individuals whose body composition indicators fall within the observed ranges may be considered representative of this population, whereas substantial deviations may warrant additional medical, nutritional, or training-related evaluation. Furthermore, although the Bland–Altman analysis demonstrated high measurement reliability, the comparison between the limits of agreement and the smallest worthwhile change indicated that the device is better suited for detecting moderate-to-large changes than very small individual physiological fluctuations.

To build substantively upon these baseline patterns, future research should extend these findings by including larger and more heterogeneous samples, incorporating both sexes, different age categories, and various physical activity levels, to establish more comprehensive normative data for youth and adult populations in physical education and sport sciences. Longitudinal studies employing multiple assessment methods, including criterion techniques such as DXA, would further contribute to the validation and refinement of body composition reference values.

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## Author Contributions

Conceptualization, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.; Data curation, D.P. and S.B.; Formal Analysis, D.P. and S.B.; Funding acquisition, V.L.F., E.V.L., D.P.F., V.T.G., and T.D.; Investigation, V.L.F., E.V.L., D.P.F., V.T.G., and T.D.; Methodology, V.L.F., E.V.L., D.P.F., V.T.G., and T.D.; Project administration, V.L.F., E.V.L., D.P.F., V.T.G., and T.D.; Resources, V.L.F., E.V.L., D.P.F., V.T.G., and T.D.; Software, D.P., and S.B.; Supervision, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.; Validation, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.; Visualization, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.; Writing – original draft, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.; Writing – review & editing, V.L.F., E.V.L., D.P.F., V.T.G., T.D., D.P., and S.B.

## Statement of Ethics

The study was approved by the Ethics Research Committee of Ștefan cel Mare University of Suceava (protocol code no. 64, issued on May 23, 2022). and conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent before participation.

## Statement of Competing Interest

The authors declare no relevant conflicts of interest.

## Statement of Data Availability

The data analyzed during this study are included in the published article. Additional data are available from the corresponding author upon reasonable request.

## Statement of Generative AI Technologies Use

No generative AI was used.

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