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Sex-Based Differences in Body Composition Parameters Among 16-Year-Olds Using BIA

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Abstract: *This research analyzes the differences in body composition between adolescents aged 16 from Kosovo and the relationships between major anthropometric and physiological properties between boys and girls aged 16. In total, 84 females and 64 males were selected through a simple random sampling method to be part of the sample. Body composition was analyzed by performing a bioelectrical impedance analysis (BIA) on each member of the sample, while the statistical analyses included descriptive statistics, normality testing, Pearson correlation analysis, and independent samples t-tests. Findings from this study revealed substantial differences between sexes, confirming results from studies conducted globally, with boys having greater levels of lean body mass, whereas girls had greater levels of bodily fatness. Through the correlation analysis, a distinct difference between fat-related variables (body fat percentage, BMI, visceral fat, and vitality) was established to form a single cluster of closely related variables, whereas lean body mass indicators (muscle mass, bone mass, and BMR) formed another cluster. In addition, the independent sample t-tests established that males and females differed significantly for all variables (except for vitality), indicating that the differences seen in the study support the expected differences in physical and physiological development by gender at age 16 based on studies on males and females in similar age groups conducted recently in other parts of the world.*

Keywords: *Body composition, differences, adiposity, Physiological development*

Introduction

The adolescent phase of a child's life includes several important phases of growth and personal development. During this time, there are many biological changes taking place at an accelerated pace. Starting at around 16 years of age, the maturation process, along with hormonal fluctuations, will create a more pronounced variable in terms of fat distribution, skeletal muscle development, bone mineral density (bone mineral density), as well as hydration status between females and males. The physiological growth that occurs during the adolescent years will alter the ratio of total body weight, fat mass and lean mass to water; therefore, the female and male biological difference is one of the primary factors that significantly impacts the body composition of females and males aged 12–24. Traditional body weight measures, such as the body mass index (body mass index), cannot accurately measure an individual's body composition,thus, it is possible for a 12 to 24-year-old individual with a one BMI classification to have an excessive amount of fat but still maintain an adequate amount of lean mass. As a result, the nutritional and physiologic classification of the individual's health indicators would be incorrect. Various studies have demonstrated the numerous advantages that BIA has over traditional practices, as BIA can provide accurate estimates of fat mass, fat-free mass, lean mass, skeletal muscle mass, bone mass, total body water and many other body compartments. Studies completed with data generated from population samples using the BIA method indicate that males, generally speaking, have more fat-free mas, lean mass, total body water, bone density, and skeletal muscle than their female counterparts. In contrast, females have a lower percentage of fat mass, more indicators of fat mass than males, and have lower hydration status (Kaczmarek, Durda-Masny, & Hanć; Hu et al. All cited by Pavlovic et al., 2024). Additional research has provided confirmation of these findings regarding BMI as it relates to pediatric populations when BMI is analyzed as a method of determining the body composition of children aged 0–12 years, high rates of misclassification have been documented, indicating that the majority of children classified as having a healthy or normal BMI have excess fat. The rates of misclassification with traditional BMI measurements, in conjunction with the decline in motor competence among overweight children, suggest that traditional BMI measurements alone do not accurately reflect functional physique composition (Banjac & Kuscevic).The differences between males and females reach a peak around 16 years of age, therefore using BIA as a method of assessing body composition in males and females is important and will improve our understanding of adolescent growth and development. Using BIA will assist healthcare professionals in identifying health conditions related to excessive adiposity and low muscle tone, ultimately, this evaluation will assist healthcare providers in developing targeted therapies and will strengthen the evidence base regarding the impact of weight on physical health and development.

Literature Review

During puberty, rapid biological, hormonal and morphological changes occur to the body in addition to becoming more different in both body composition and fat distribution for Boys versus Girls. A few examples of the body's maturation process include a divergence of body fat distribution, development of skeletal muscles, development of bone mineralization and an increase of hydration status during this time frame (16 years of age). In addition, many of these components are changing so rapidly, that standard Anthropometric measurements (e.g., BMI) have limited diagnostic value for adolescents because those measurements do not account for Lean Tissue vs. Adipose Tissue. This misclassification of Nutritional and Physiological Status across different countries was reported in many studies conducted worldwide (Ferozi et al., 2024; Pavlović et al., 2025). Bioimpedance Analysis (BIA) has emerged as a superior method of assessing the morphology of adolescents because BIA estimates the total amounts of fat and fat-free mass skeletal muscle mass, bone mass, and all of the major compartments of the body's water status. The consistent results of large-scale population studies indicate that boys have significantly higher fat-free mass, skeletal muscle mass, body cell mass and total body water, while girls show significantly higher percentages of adipose tissue. (Kaczmarek, 2025; Kaczmarek, Durda-Masny & Hanć, 2024). Longitudinal cohorts have demonstrated predictable developmental trajectories in fat-free mass, water compartments, muscle mass, and phase angle, thereby indicating that adolescence is a critical period for the examination of body composition (Hu et al., 2025). Intervention-based studies support the importance of the body composition component. The results of studies that utilize high-intensity and plyometrics-based training in adolescents show that muscle mass, body fat percentage and motor performance have a significant relationship with physical activity patterns (Domaradzki et al., 2025). Additionally, initiatives designed to monitor fitness and health, such as "Athletics for All!", have shown that differences between the sexes in strength, endurance and morphology exist, and these differences are consistent with previous literature (Baj-Korpak et al., 2024). The limitations of the use of BMI are made more apparent when conducting systematic analyses. A comprehensive review of the existing literature by Banjac and Kuscevic (2020) showed that BMI scores in the higher ranges for children and adolescents have a negative association with motor skills and performance, indicating that the BMI is not a true measure of functional body composition. Environmental factors also play a role in determining body composition in adolescents. In a study by Stankovic and colleagues (2024), it was shown that morphological and motor differences exist between rural and urban girls, indicating that body composition can be influenced by other environmental factors such as environment physical activity, nutrition, school and lifestyle. Research conducted by Požar et al., (2024) found that BIA is able to reliably detect changes in body composition as a result of nutrition counselling (fat mass, abdominal fat, muscle mass, and TBW). BIA is also suitable for monitoring physiological changes from population to population. Therefore, it is a relevant method for evaluating the body composition of adolescents. Large samples of youth have been analyzed in this area and findings point to a clear relationship between sex and developmental progress for the body. In research conducted by Nikšić et al., (2025) on primary- and secondary-school children, there were significant differences in the morphological characteristics and motor performance between boys and girls. This difference increases over the course of development and shows an exact match with the patterns found in BIA studies. Overall, literature suggests that the composition of the bodies of adolescents is determined by a combination of biological sex, environment, physical activity, and nutrition. In all studies, boys are consistently found to have a larger lean mass and lower %fat as compared to girls. Patterns of % fat and lean mass peak at age 16. Thus, to properly assess girls and boys and identify hidden low muscularity or hidden fat mass, utilizing both BIA and traditional anthropometry to evaluate differences between sexes is critical for early identification, accurate assessments, and the development of evidence-based interventions supporting healthy growth in adolescents.

Methods and materials

The purpose of this study is to evaluate the variances in body composition between men and women who are 16 years old, using BIA (bioelectrical impedance analysis), a common method employed by current researchers studying pediatrics and adolescents (for example: Hu and colleagues 2025 and Kaczmarek and colleagues 2024). Variables associated with Body Composition through BIA include the following: height, weight, %BF (percent body fat), muscle mass, bone mass, BMI (Body Mass Index), BMR (Basal Metabolic Rate), vitality, TBW (Total Body Water) and visceral fat.

Hypotheses

The development of the project and the methods used for statistical analyses of the data collected dictate the hypotheses developed to direct the study design of this research project.

H – Statistically significant differences in Body Composition between males and females exist between boys and girls 16 years old

The general hypothesis was split into three specific hypotheses.

H1 – Body composition variables will be normally distributed.

H2 – There will be significant and statistically significant bivariate correlations between the body composition variables for the significance level $p < 0.01$.

H3 – There will be statistically significant differences in body composition indicators between females (girls) and males (boys) at age 16 years.

Sample of population

The sample population for the study consisted of both males and females, age 16, recruited from the general source pool of the "population of age 16" using a simple random sample approach. The total sample of Adolescents (n = 149) included 65 males and 84 females in the following groups for purposes of this analysis.

All individuals that participated provided informed consent to participate in this study, met the age requirement for participation and currently were enrolled in school at the time of the study. There were no medical diseases/disorders that could impact Body Composition by the participants of this study.

Instruments and Procedures

In this study, the Bioelectrical Impedance Analysis (BIA) technique was used to assess differences in Body Composition by sex among 16-year-old Adolescents, as this is an accepted method of evaluating pediatric and adolescent PAI in the literature in recent years (e.g., Hu, Kaczmarek, et al. 2025 and Kaczmarek, et al. 2024).

Each measurement was taken and recorded in accordance with the BIA Assessment Manuals.

Statistical Procedures

Independent-samples T-test was used to examine for sex differences in body composition of 16-year-old adolescents. Descriptive statistics were computed to determine mean values and standard deviations for all variables derived from BIA as well as their normal distribution. The assessment of normal distribution determined the appropriate tests of correlation between variables. Key indicators of body composition correlation were investigated by means of Pearson's coefficient of correlation. Statistical significance was determined as $p<0.01$.

Results

Table. 1. *Descriptive Statistics for 16 Girls*

Descriptive Statistics[a]									
	N	Range	Min	Max	Mean	Std. Devi	Variance	Skewness	Kurtosis
Body height (cm)	84	25	153	178	165.93	5.994	35.923	-.026	-.719
Body weight (kg)	84	44	42	86	59.56	10.123	102.483	.438	-.128
Body fat percentage (%)	84	28	13	41	27.95	7.019	49.267	-.171	-.503
Muscle mass (kg)	84	16	33	49	40.20	3.535	12.495	.228	-.668
Bone mass (kg)	84	1	2	3	2.16	.184	.034	.342	-.625
BMI	84	14	16	31	21.75	3.429	11.756	.527	-.297
Basal metabolic rate (kcal)	84	877	1883	2760	2226.85	197.218	38895.024	.335	-.457
Vitality score	84	23	12	35	20.73	8.779	77.069	.328	-1.634
Total body water (%)	84	20	44	64	53.53	4.823	23.263	.093	-.521
Visceral fat level	84	4	1	5	1.77	1.134	1.286	1.476	1.369

The sample of 16-year-old female participants (N=84), had an average height of 165.93cm (SD=5.99) and an average body weight of 59.56kg (SD=10.12). The average body-fat % was relatively high at 27.95% (SD=7.02); however, skeletal-muscle mass was around 40.20kg (SD=3.53). Mean BMI values were within the normal range for adolescents (M=21.75 and SD=3.43). The average total-body-water for the study population was 53.53% (SD=4.82) which is consistent with what would be expected of female adolescents. Visceral-fat levels were low (M=1.77), and the average basal metabolic-rate of participants was 2226.85kcal (SD=197.22). The results show that the female study sample has the typical pattern for body composition (i.e., relatively high adiposity and low lean mass) when compared to males. All variables for females fell within the range of a normal distribution, such as height, weight, body fat % and skeletal muscle mass, as well as calorie expenditure and total body water. Vitality levels exhibited mild left skewness, however, visceral fat levels were positively skewed.

Table 2. *Descriptive Statistics for Boys*

	N	Range	Min	Max	Mean	Std. Dev	Variance	Skewness	Kurtosis
Body height (cm)	64	27	168	195	179.00	5.721	32.730	.498	.582
Body weight (kg)	64	57	51	108	72.94	13.536	183.226	.647	-.302
Body fat percentage (%)	64	28	8	35	16.60	5.476	29.990	.844	.818
Muscle mass (kg)	64	30	44	74	56.93	6.908	47.727	.151	-.623
Bone mass (kg)	64	1	2	4	2.99	.329	.108	.206	-.745
BMI	64	19	16	36	22.81	4.264	18.182	.967	1.044
Basal metabolic rate (kcal)	64	1721	2525	4246	3223	394.843	155900.962	.340	-.599
Vitality score	64	21	12	33	18.25	8.138	66.222	.916	-.798
Total body water (%)	64	33	47	79	63.31	6.357	40.406	-.189	.144
Visceral fat level	64	12	1	13	2.63	2.826	7.984	2.496	6.668

The boys' average height (179.00 cm) and average weight (72.94 kg) were significantly greater than their counterparts in this study (N=64). They had a lower body fat % (M=16.60%), greater skeletal muscle mass (M=56.93 kg), and higher bone mass density (M=2.99 kg) compared to girls. They also had a greater total body water percentage (63.31%), and an increased basal metabolic rate (kcal/MNT) when compared to females: (M=3223.92 kcal). In addition, they had more visceral fat (M/Avg=2.63) than girls did as well. These findings represent the expected norms for male adolescents, given that they have a predominance of lean body mass compared to females at this stage of development. For boys, all variables except for visceral fat where within the normal range of acceptable limits and as such, statistical analysis on this last variable should only be considered non-parametrically due to the extreme skewness and kurtosis observed.

Table 3. *Correlation matrix for Girls*

	BH	BW	BFP	MM	BM	BMI	BMR	VS	TBW	VFL
Body height (cm)	1									
Body weight (kg)	.406**	1								
Body fat percentage (%)	.291**	.907**	1							
Muscle mass (kg)	.502**	.883**	.639**	1						
Bone mass (kg)	.466**	.846**	.608**	.966**	1					
BMI	.035	.897**	.845**	.760**	.747**	1				
Basal metabolic rate (kcal)	.483**	.917**	.705**	.983**	.952**	.796**	1			
Vitality score	.217*	.855**	.886**	.623**	.575**	.809**	.693**	1		
Total body water (%)	-.257*	-.854**	-.979**	-.556**	-.527**	-.777**	-.630**	-.854**	1	
Visceral fat level	.104	.812**	.763**	.613**	.594**	.803**	.690**	.836**	-.750**	1

The correlation matrix demonstrated that there are biologically sensible and strongly associated relationships between body composition variables. Weight, %BF, muscle mass, bone mass, BMI, BMR and visceral fat were positively correlated with each other due to the common influences of total body size and fatness on all these variables. %TBW was also strongly negatively correlated with the fat-related variables, showing that a person with a greater relative amount of fat has a lower amount of relative TBW. Muscle mass, bone mass and BMR were all very strongly positively correlated to each other, further indicating that lean mass is the strongest predictor of BMR. These patterns also conform to the physiological processes of adolescents and substantiate the accuracy of the BIA derived variables.

Table 4. *Correlation matrix for Boys*

	BH	BW	BFP	MM	BM	BMI	BMR	VS	TBW	VFL
Body height (cm)	1									
Body weight (kg)	.217	1								
Body fat percentage (%)	-.071	.847**	1							
Muscle mass (kg)	.385**	.868**	.603**	1						
Bone mass (kg)	.412**	.891**	.626**	.958**	1					
BMI	-.112	.933**	.898**	.750**	.764**	1				
Basal metabolic rate (kcal)	.379**	.932**	.690**	.962**	.988**	.819**	1			
Vitality score	-.011	.826**	.919**	.588**	.622**	.854**	.684**	1		
Total body water (%)	-.091	-.706**	-.866**	-.535**	-.563**	-.694**	-.610**	-.778**	1	
Visceral fat level	-.137	.812**	.843**	.495**	.517**	.887**	.588**	.839**	-.606**	1

In summary, the above correlation patterns reveal that adolescents with high body masses typically have a broader profile of increased fat, muscle mass, bone density, metabolic rate, and visceral fat levels. All of the adiposity variables (i.e., % body fat, BMI, visceral fat, vitality) are grouped together in one cluster, while all the lean-tissue variables (muscle mass, bone mass, and BMR) are included in another coherent cluster. The percentage of total body water exhibited an inverse mirror relationship with each of the adiposity variables, definitively demonstrating a physiological distinction between fat-dominant bodies and lean-dominant bodies in adolescents. This study demonstrates that the individual components of body composition in adolescents are highly interconnected and that they also reflect very distinct physiological patterns that are produced by the way in which fat is distributed and formed in the body as well as by the way lean tissues are formed and distributed in the body.

Sex Differences and Comparative Analysis

Independent Samples t-Test Comparing Girls and Boys (Age 16)

Table 5. *T-test*

Variable	Girls (M)	Boys (M)	t	p
Body Height (cm)	165.93	179.00	-13.49	< .001
Body Weight (kg)	59.56	71.69	-5.40	< .001
Body Fat %	27.95	16.96	9.94	< .001
Muscle Mass (kg)	39.76	57.42	-17.78	< .001
Bone Mass (kg)	2.41	3.00	-18.20	< .001
BMI	21.75	22.91	-2.43	.016
Basal Metabolic Rate	2226.85	3219.00	-18.55	< .001
Vitality Score	20.73	18.25	1.77	.079
Total Vitality Score	53.83	63.31	-9.45	< .001
Visceral Fat Level	1.77	2.63	-2.27	.026

The sex-based differences in body composition of 16-year-old adolescents were examined using independent samples t-tests. About 90% of the sex-based difference analysis results indicated large, statistically significant differences across all body composition variables measured. Therefore, it can be concluded that in the adolescent developmental stage, sex is responsible for a large portion of the physiological development. For example, in 16-year-old adolescents, boys were taller than girls ($t(df\approx139) = -13.49$, $p < .001$), and boys are heavier than girls ($t(df\approx113) = -5.40$, $p < .001$). The body fat percentage is significantly higher in girl adolescents (M = 27.95%) than in boy adolescents (M = 16.96%), $t(df\approx146) = 9.94$, $p < .001$ demonstrates one of the largest sex-based differences found in this study. Whereas boys have a much higher concentration of lean muscle mass than girls, boys have a significantly higher weight of skeletal muscle mass (M = 57.42 kg) than girls (M = 39.76 kg), t(df≈88) = –17.78, $p < .001$; as well as bone weight, t(df≈93) = –18.20, $p < .001$. In addition, boys have a significantly higher average resting energy expenditure (i.e., basal metabolic rate (BMR)) than girls (M = 3219 kcal for boys and M = 2226 kcal for girls), t(df≈87) = –18.55, $p < .001$. Higher BMR in boys can be attributed to the higher concentrations of lean body mass than in girls. Body mass index (BMI) was only slightly higher for boys than girls (22.91 for boys vs. 21.75 for girls; t = –2.43, p = .016), which represents a small effect. Energy vitality scores were not significantly different between the sexes (p = .079). However, total vitality scores were significantly higher for boys than for girls, t = –9.45, $p < .001$. Visceral fat was modestly, but significantly, higher in boys than in girls (M = 2.63 for boys and M = 1.77 for girls), t(df≈79) = –2.27, p = .026. Although this is statistically significant, the difference between boys and girls in regard to visceral fat represent much smaller differences than the difference found in skeletal muscle and bone mass.

Discussion

Results of this research show that physical changes during adolescence in the sample population of 16-year-old boys and girls in Kosovo were closely aligned with the findings of other recent international studies. The female sample population had a significantly higher percentage of body fat and lower amounts of lean mass than the male sample population, which had higher levels of muscle, total mineral, total body water, and basal metabolic rates. Body fat distribution in females peaks earlier, while males see a rapid increase in fat- free mass starting at 16 years of age (Kaczmarek, Durda-Masny & Hanć, 2024). Our correlation analyses indicate that the relationships between the adiposity and the lean-mass variables form two separate clusters, which supports the findings of Hu et al., 2025, who state that there is a high degree of interdependence between fat (fat free mass), TBW and skeletal muscle indices. The variance in the relationship between BMI and the actual amount of adiposity in some study participants reinforces the findings of the Ferozi et al., 2024 study that the utilitarian value of BMI for diagnosing excessive body fat is limited. With regard to sex-related performance differences shown in the form of lean-mass advantages identified among our male participants and the indication of a physiological correspondence between lean tissue and other physiological variables listed in Keirns et al., 2025, it could be said that males and females between 14 and 20 years of age will have a marked difference in their rates of physical development as well as their relative amounts of adiposity and lean-body mass. As confirmed by the results of this & studies, it is apparent that adolescents in Kosovo are developing in much the same manner as adolescents worldwide.

Conclusion

Our study shows that sex is a strong determinant of body composition among male and female adolescents at age 16 years, and that there is a consistent sex difference between males and females in body composition during adolescent development. Males demonstrate a greater amount of lean body mass (muscle, mineral, total body water & basal metabolic rate) and females demonstrate a greater overall percentage of body fat due to the differences in hormonal and physiological characteristics between males and females in mid-adolescence. The correlations between fat (fat free mass) and lean body mass variables support the concept of the integrated nature of adolescent body composition and highlight the importance of using bioimpedance analysis over conventional anthropometric measures (BMI) to assess adolescent body composition. Our results are also consistent with the body composition patterns observed in adolescents in recent studies outside Kosovo. Accordingly, when evaluating the growth and potential health risks of adolescent males and females, use of measures that assess body composition should supplement measures of partial growth determined using BMI.

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