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The Relationship between Body Composition Components by Gender among Teenagers

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Abstract: *Body composition (BC) is a highly significant indicator in assessing the health status of adolescents. This study aimed to measure the components of BC, analyse them, and identify the relationships between these elements based on gender among teenagers. The study included 139 subjects aged 16.5±0.5 years on average (78 girls and 61 boys). In girls, a significant positive relation was observed between SMM in kg and BM ($p < 0.001$, $r = 0.993$), between total water and SMM in kg ($p < 0.001$, $r = 0.822$), as well as a substantial negative correlation between % SMM and % body fat ($p < 0.001$, $r = -0.911$). In boys, a very strong positive relation was found between MM in kg and BM ($p < 0.001$, $r = 0.976$); between BM and SMM ($p < 0.001$, $r = 0.996$). Furthermore, a very strong negative correlation was noted between body fat mass and % water ($p < 0.001$, $r = -0.939$); between % body fat and % water ($p < 0.001$, $r = -0.910$). Positive and negative correlations of varying intensities were noted in both genders. The data obtained can serve as a basis for educational and nutritional programs aimed at reducing the risk of obesity and promoting health among adolescents. The study opens new perspectives for the long-term investigation of the impact of BC on adult health, emphasising the essential role of monitoring and early interventions based on gender particularities.*

Keywords: *relationships, body composition, gender, teenagers, study.*

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Introduction

During adolescence, the body undergoes significant physical and mental growth and development. This stage is marked by apparent differences between girls and boys in terms of both physical appearance and biology. These discrepancies can be identified by measuring and analysing body composition (BC), which is a significant indicator in assessing the health status of each individual.

Getting a better insight into the normal parameters of BC (muscle mass, fat mass, bone mineral mass, body water content, etc.) is essential because it is possible for an individual with a body mass index (BMI) consistent with their age and gender to be diagnosed as overweight when BC components are assessed (Żegleń et al., 2024). At the same time, BC evaluation is more relevant than BMI in children and teenagers concerning the degree of satisfaction with body image (Dos Santos et al., 2020). A larger fat mass negatively impacts adolescents' quality of life (Dumuid et al., 2021). To reduce the number of youths (future adults) with health issues, it is necessary to point out and eliminate the risk factors for overweight and obesity as early as possible (Mohd Saat et al., 2023).

Both the school and family environments play a crucial role in combating unhealthy lifestyles among children and teenagers, which are characterised by the consumption of fast food, sugary drinks, and insufficient exercising (Hamulka et al., 2023). Studies demonstrate correlations between adiposity and disordered and excessive eating habits among youth, as well as associations with diets unsupervised by competent individuals, factors that lead to various imbalances in the body (Stabouli et al., 2021).

Other research highlights that a risk factor for overweight among children and teenagers is the time spent in front of screens, which is much higher and more preferred by them than engaging in physical activities (Kansra et al., 2021). Maintaining BC components within normal limits can be achieved by adequately managing body weight in youths recording eating issues (Hornberger et al., 2021). BC parameters can also be affected by genetic factors, making it difficult to intervene and prevent overweight or obesity if measures are not taken in a timely manner (Lee & Yoon, 2018).

Improving overall health and, implicitly, BC among teenagers, as well as preventing the onset of chronic diseases (type 2 diabetes, hypertension, strokes, etc.), are priority objectives of the World Health Organisation (WHO) for 2018-2030. In this context, in 2022, the first global

report on progress in physical exercise among youth was published (WHO, 2022a) in collaboration with UNESCO, UNICEF, UNFPA etc. These organisations have conducted various studies to identify current trends related to overweight and obesity, and subsequently, have proposed the implementation of several remedial programmes such as Making Every School a Health Promoting School, 2022 (WHO, 2022b) and Obesity and Overweight, 2024 (WHO, 2024), among others.

This investigation aims to identify potential associations and differences in body composition (BC) between boys and girls aged 16.5±0.5 years old on average.

Hypothesis: There are relations of association between some components of BC among teenagers by gender.

Materials and methods

The research's objective is to assess morphological and functional characteristics of boys and girls who are 16.5 ± 0.5 years old on average and to analyse the results derived from statistical and mathematical data in relation to existing literature.

Ethics: The Research Ethics Committee from the Faculty of Physical Education and Sports at "Alexandru Ioan Cuza" University, Iaşi, has given permission for this study through Registration No. 27/30.04.2024. The paper also complies with all ethical and deontological standards of scientific research, as stated in the Declaration of Helsinki.

Morphofunctional Parameters:

Height:

The exact height of the subjects was measured using an HM 200 M metal stadiometer. The students involved in the study removed their shoes, stood upright while facing forward, and ensured their back, head, and heels were in contact with the stadiometer. The subjects were measured from the floor to the vertex, the highest point of the head, using the stadiometer's folding lever with a locking button. The height was recorded in centimetres with subdivisions of 0.5 cm.

Body Composition (BC): BC was assessed using a professional device, named TANITA MC 580, in conjunction with GMON V 3.4 (Tanita, n.d.), which is a specialized analysis software. The method used to assess BC is called Bioelectrical Impedance Analysis (BIA), and it uses a low-intensity electrical current (about 500 μA) that passes between electrodes placed in both hands and under the feet. This advanced model provides segmental analysis, utilizing six electrodes to deliver data for each upper and lower limb as well as the abdominal region. The electrical current moves rapidly through hydrated lean

tissue and more slowly through adipose tissue, with the resulting resistance, or impedance, incorporated into scientifically validated Tanita equations. These calculations yield body composition parameters, including weight (kg), body fat (kg and percentage), BMI (kg/m²), muscle mass (kg and percentage), bone mass, skeletal muscle mass (kg and percentage), total body water (percentage), and basal metabolic rate (BMR in kcal).

Measurements were conducted in September 2024 during the first half of the day, between 10 AM and 12 PM, at the gymnasium of the "Emil Racoviță" National College in Iași. The data collected from the measurements were subsequently entered and analysed using SPSS 20.0.

The results of the measurements were analysed using statistical tests. The normality of data distribution was evaluated using the Kolmogorov-Smirnov one, given the sample size exceeded 50 subjects, while Pearson's correlation determined how intense and which way of associations between quantitative variables analysed in pairs.

The study included 139 subjects (78 girls and 61 boys) who are students in the 11th grade at "Emil Racoviță" National College (CNER) in Iași (Table 1).

Table 1. Subjects' distribution by grade, profile, gender, age and academic institution

Grade	Profile	Total students	Gender		Age (mean± std.dev.)	Academic institution
			F	B		
XI A	Mathematics–computer science	29	18	11	16,4±0,5	CNER
XI B	Mathematics–computer science	28	15	13	16,2±0,6	CNER
XI C	Natural sciences	28	12	16	16,2±0,4	CNER
XI D	Sciences – English intensive course load	28	13	15	16,7±0,5	CNER
XI E	Philology	26	20	6	16,7±0,4	CNER
Total		**139**	**78**	**61**	16,5±0,5	CNER

Findings

Upon conducting the distribution normality test (Kolmogorov-Smirnov) by gender, we observe in Table 2 that regarding boys, there are significant differences from the normal distribution for percentage muscle mass, skeletal muscle mass percentage and total water. As far as the girls are concerned, there are more variables with significant differences from the

normal distribution, such as body fat in kg, muscle mass percentage, bone mineral mass, water percentage, and BMI.

Table 2. Values of the Tests of Normality Kolmogorov-Smirnov

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Gender	Statistic	df	Sig.	Statistic	df	Sig.
Weight Kg	M	.097	61	.200*	.980	61	.409
	F	.085	78	.200*	.942	78	.001
Height	M	.086	61	.200*	.976	61	.286
	F	.105	78	.034	.975	78	.119
Body Fat Kg	M	.071	61	.200*	.981	61	.474
	F	.142	78	**.001**	.860	78	.000
Fat Mass %	M	.059	61	.200*	.993	61	.974
	F	.057	78	.200*	.984	78	.455
Muscle Mass Kg	M	.072	61	.200*	.989	61	.867
	F	.081	78	.200*	.927	78	.000
Muscle Mass%	M	.167	61	**.000**	.664	61	.000
	F	.166	78	**.000**	.642	78	.000
Bone Mass	M	.105	61	.093	.974	61	.219
	F	.132	78	**.002**	.950	78	.004
Water Kg	M	.158	61	**.001**	.848	61	.000
	F	.087	78	.200*	.964	78	.026
Water %	M	.070	61	.200*	.973	61	.185
	F	.214	78	**.000**	.679	78	.000
BMI	M	.084	61	.200*	.985	61	.648
	F	.139	78	**.001**	.763	78	.000
SMM	M	.082	61	.200*	.988	61	.824
	F	.082	78	.200*	.964	78	.028
SMM %	M	.140	61	**.005**	.783	61	.000
	F	.053	78	.200*	.984	78	.412
BMR kcal	M	.086	61	.200*	.985	61	.643
	F	.095	78	.082	.958	78	.012

*. This represents the genuine significance's lower limit. a. Correction of Lilliefors Significance

The statistical analyses of the Pearson correlation coefficient values for the girls' group demonstrate that there are positive or negative

associations of varying intensities between body composition components, even for variables without a normal distribution, as this test is quite robust to violations of normality conditions (Table 3).

Table 3. Girls' group - Results of the Pearson correlation coefficient

Girls		W	BF KG	MF%	MM KG	MM %	B M	W KG	W %	BMI	SMM KG	SMM %
W	PC	1	**,826****	**,717****	**,721****	**-,402****	**,887****	**,875****	**-,513****	**,719****	**,891****	**-,680****
	Sig. (2-tld)		0	0	0	0	0	0	0	0	0	0
	N	78	78	78	78	78	78	78	78	78	78	78
BF KG	PC	**,826****	1	**,788****	**,495****	-,441**	**,622****	**,704****	-,431**	,597**	**,608****	**-,735****
	Sig. (2-tld)	0		0	0	0	0	0	0	0	0	0
	N	78	78	78	78	78	78	78	78	78	78	78
MF%	PC	**,717****	**,788****	1	,286*	-,580**	,343**	,582**	-,447**	,609**	,340**	**-,911****
	Sig. (2-tld)	0	0		0,011	0	0,002	0	0	0	0,002	0
	N	78	78	78	78	78	78	78	78	78	78	78
MM KG	PC	**,721****	,495**	,286*	1	-0,145	**,806****	**,632****	-,356**	**,466****	**,802****	-,293**
	Sig. (2-tld)	0	0	0,011		0,204	0	0	0,001	0	0	0,009
	N	78	78	78	78	78	78	78	78	78	78	78
MM%	PC	**-,402****	-,441**	**-,580****	-0,145	1	**-0,191**	-,298**	,258*	-,325**	-0,182	**,533****
	Sig. (2-tld)	0	0	0	0,204		0,095	0,008	0,022	0,004	0,11	0
	N	78	78	78	78	78	78	78	78	78	78	78
B M	PC	**,887****	**,622****	,343**	**,806****	-0,191	1	**,815****	-,430**	,600**	**,993****	-,338**
	Sig. (2-tld)	0	0	0,002	0	0,095		0	0	0	0	0,002
	N	78	78	78	78	78	78	78	78	78	78	78
W KG	PC	**,875****	**,704****	,582**	**,632****	-,298**	**,815****	1	-,419**	,658**	**,822****	**-,556****
	Sig. (2-tld)	0	0	0	0	0,008	0		0	0	0	0
	N	78	78	78	78	78	78	78	78	78	78	78
W %	PC	**-,513****	**-,431****	**-,447****	-,356**	,258*	-,430**	-,419**	1	**-,555****	-,431**	,425**

	Sig. (2-tld)	0	0	0	0,001	0,022	0	0		0	0	0
	N	78	78	78	78	78	78	78	78	78	78	78
BMI	PC	**,719****	**,597****	**,609****	,466**	**-,325****	**,600****	**,658****	-,555**	1	**,590****	**-,580****
	Sig. (2-tld)	0	0	0	0	0,004	0	0	0		0	0
	N	78	78	78	78	78	78	78	78	78	78	78
SMM kg	PC	**,891****	**,608****	,340**	**,802****	-0,182	**,993****	**,822****	**-,431****	**,590****	1	**-,343****
	Sig. (2-tld)	0	0	0,002	0	0,11	0	0	0	0		0,002
	N	78	78	78	78	78	78	78	78	78	78	78
SMM %	PC	**-,680****	**-,735****	**-,911****	-,293**	**,533****	-,338**	**-,556****	**,425****	**-,580****	**-,343****	1
	Sig. (2-tld)	0	0	0	0,009	0	0,002	0	0	0	0,002	
	N	78	78	78	78	78	78	78	78	78	78	78

** Significant correlation exists at the 0.01 level (2-tailed),

* Significant correlation exists at the 0.05 level (2-tailed). PC-Pearson Correlation; FM %-Fat Mass %; BF-Body Fat; W-Weight; MM%-Muscle Mass%; MM kg-Muscle Mass kg; BM-Bone Mass; W kg-Water kg; W %-Water %; SMM-Skeletal Muscle Mass; SMM %-Skeletal Muscle Mass; BMI- Body Mass Index.

We note that body weight has a very strong positive correlation with most BC components, as follows: a very strong positive correlation, r = 0.891 between body weight and SMM, r = 0.887 between body weight and bone mass, r = 0.875 between body weight and total water, r = 0.826 between body weight and adipose tissue, r = 0.721 between body weight and muscle mass in kg, r = 0.719 between body weight and BMI, r = 0.717 between body weight and % adipose tissue, and a significant negative correlation, r = -0.680 with % SMM and r = -0.513 with % water.

Body fat in kg shows a strong positive correlation with % fat, r = 0.788, with total water, r = 0.704, and a significant negative relation with % SMM, r = -0.735.

Percentage body fat has a significant positive relation with body weight, r = 0.717, a very strong negative relation with % SMM, r = -0.911, (Figure 2) and a weak positive correlation with muscle mass in kg, r = 0.286.

Muscle mass in kg shows a very strong positive relation, r = 0.806, with bone mass and with % SMM, r = 0.802, and a substantial positive relation with total water, r = 0.632.

Percentage muscle mass has a robust positive relation with % SMM, r = 0.533, and a significant negative relation with % body fat, r = -0.580.

Bone mass has a highly significant positive relation with % SMM (Figure 1), r = 0.993, with body weight, r = 0.887, with total water, r = 0.815, with muscle mass in kg, r = 0.806, and a lower negative relation with % SMM, r = -0.338.

Total water shows a substantial negative relation with % SMM, r = -0.556. BMI has a highly considerable positive relation with total water, r = 0.658, with % body fat, r = 0.609, with bone mass, r = 0.600, with body fat in kg, r = 0.597, and a significant negative relation with % SMM, r = -0.580.

The test demonstrates that the results are of statistical importance, as the significance threshold is less than 0.001 for all variables.

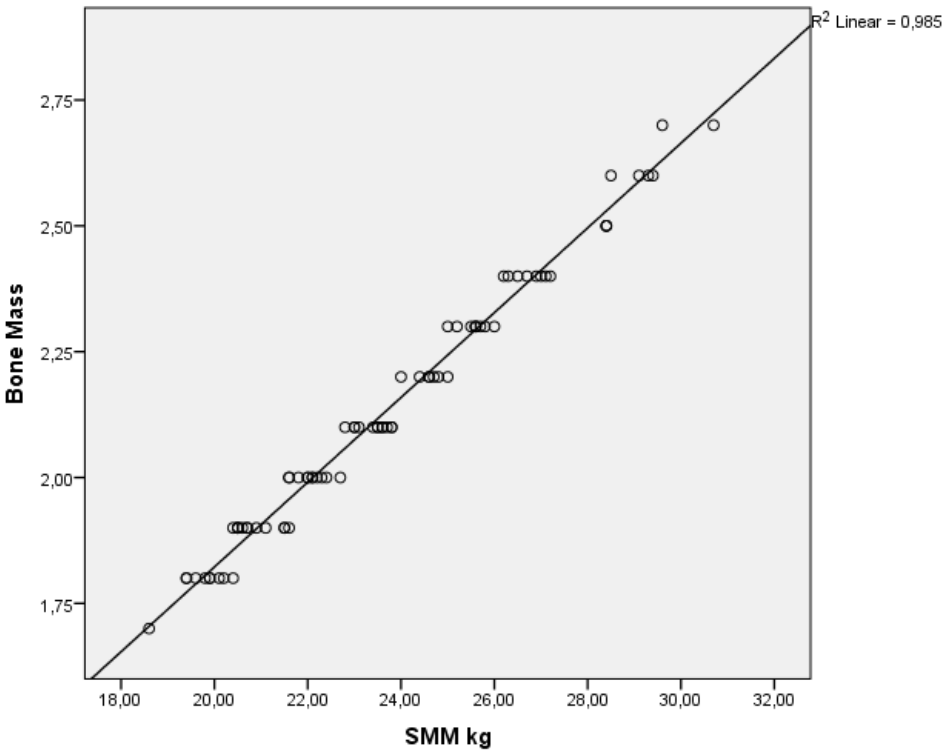


Figure 1. Correlation between skeletal muscle mass in kg and bone mass

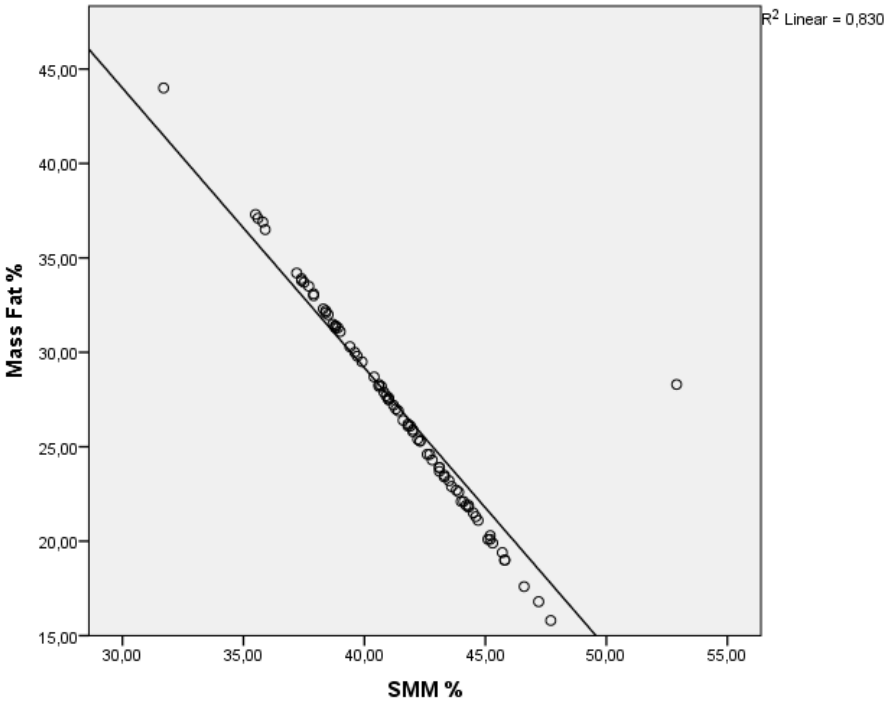


Figure 2. Correlation between skeletal muscle mass % and % of fat

Following the statistical analyses conducted to identify the Pearson correlation coefficient values in the boys' group, it is worth noting positive and negative relationships of varying intensities between the body composition components studied in this paper (Table 4).

Table 3. Boys' group - Results of the Pearson correlation coefficient

Boys		W	BF KG	MF&	MM KG	MM %	B M	W kg	W %	BMI	SMM KG	SMM %
W	PC	1	**.859****	**.731****	**.909****	**-.437****	**.902****	**.617****	**-.904****	**.858****	**.900****	**-.401****
	Sig.(2-tld)		0	0	0	0	0	0	0	0	0	0.001
	N	61	61	61	61	61	61	61	61	61	61	61
BF KG	PC	**.859****	1	**.965****	**.590****	-.581**	.559**	.451**	**-.939****	**.865****	.551**	**-.569****
	Sig.(2-tld)	0		0	0	0	0	0	0	0	0	0
	N	61	61	61	61	61	61	61	61	61	61	61
MF%	PC	**.731****	**.965***	1	.416**	**-**	.383*	.357*	**-**	**.792***	.372**	**-**

			*****			**.614****	*	*	**.910****	*****		**.604****
	Sig.(2-tld)	0	0		0.001	0	0.002	0.005	0	0	0.003	0
	N	61	61	61	61	61	61	61	61	61	61	61
MM KG	PC	**.909****	**.590****	.416**	1	-0.242	**.976****	**.610****	9	**.673****	**.981****	-0.199
	Sig.(2-tld)	0	0	0.001		0.06	0	0	0	0	0	0.124
	N	61	61	61	61	61	61	61	61	61	61	61
MM%	PC	-.437**	**-.581****	**-.614****	-0.242	1	**-0.217**	-0.181	.594**	**-.458****	-0.218	.361**
	Sig.(2-tld)	0	0	0	0.06		0.093	0.164	0	0	0.092	0.004
	N	61	61	61	61	61	61	61	61	61	61	61
B M	PC	**.902****	.559**	.383**	**.976****	-0.217	1	.618**	**-.678****	**.683****	**.996****	-0.194
	Sig.(2-tld)	0	0	0.002	0	0.093		0	0	0	0	0.135
	N	61	61	61	61	61	61	61	61	61	61	61
W Kg	PC	**.617****	.451**	.357**	**.610****	-0.181	**.618****	1	-.466**	.515**	**.622****	-0.159
	Sig.(2-tld)	0	0	0.005	0	0.164	0		0	0	0	0.221
	N	61	61	61	61	61	61	61	61	61	61	61
W %	PC	**-.904****	**-.939****	**-.910****	**-.709****	.594**	-.678**	-.466**	1	**-.807****	**-.675****	.544**
	Sig.(2-tld)	0	0	0	0	0	0	0		0	0	0
	N	61	61	61	61	61	61	61	61	61	61	61
BMI	PC	**.858****	**.865****	**.792****	**.673****	-.458**	.683**	.515**	**-.807****	1	.662**	**-.469****
	Sig.(2-tld)	0	0	0	0	0	0	0	0		0	0
	N	61	61	61	61	61	61	61	61	61	61	61
SMM kg	PC	**.900****	.551**	.372**	**.981****	-0.218	**.996****	.622**	**-.675****	.662**	1	-0.168
	Sig.(2-tld)	0	0	0.003	0	0.092	0	0	0	0		0.197
	N	61	61	61	61	61	61	61	61	61	61	61
SMM %	PC	-.401**	**-.569****	**-.604****	-0.199	.361**	-0.194	-0.159	**.544****	-.469**	-0.168	1
	Sig.(2-tld)	0.001	0	0	0.124	0.004	0.135	0.221	0	0	0.197	
	N	61	61	61	61	61	61	61	61	61	61	61

** Significant correlation exists at the 0.01 level (2-tailed)
* Significant correlation exists at the 0.05 level (2-tailed). PC-Pearson Correlation.

In the boys' group, a highly significant positive correlation was pinpointed, similar to the girls, between several BC components, as follows: body weight has a highly significant positive correlation with muscle mass in kg, r = 0.909, with bone mass, r = 0.902, with SMM in kg, r = 0.900, with body fat in kg, r = 0.859, with BMI, r = 0.858, and with % body fat, r = 0.731. However, it has a very strong negative relation with % water, r = -0.904, and a moderate negative correlation with % muscle mass, r = -0.437, and with % SMM, r = -0.401.

A highly significant positive relation is also noted between body fat mass, r = 0.965, and % body fat, with r = 0.865, a very relevant positive relation with BMI, and a notable positive relation with muscle mass in kg, r = 0.590, as well as a high negative relation with % water, r = -0.939 (Figure 4).

Percentage body fat has a considerable positive relation with BMI, r = 0.792, and a very strong negative relation with % water, r = -0.910.

There is also an evident highly significant positive relation between muscle mass in kg and SMM, r = 0.981, with bone mass r = 0.976, with BMI r = 0.673, but a very significant negative relation with % water, r = -0.709, and a weak negative correlation with % muscle mass, r = -0.242.

Another high positive relation can be noted for the percentage muscle mass with % water, r = 0.594, but a significant negative relation with body fat mass, r = -0.581, and a weak negative correlation with bone mass, r = -0.217.

It is also observed that bone mass has a highly notable positive relation with SMM, r = 0.996 (Figure 3), and a significant negative relation with % water, r = -0.681.

We found a high positive relation between total water and SMM, r = 0.622, and similarly with bone mass, r = 0.610.

BMI recorded a significant negative relation with % water, r = -0.807, as well as a substantial positive relation with SMM, r = 0.662.

Just like in the case of girls, the results for boys are also considerable, since the significance threshold has the same value ($p < 0.001$).

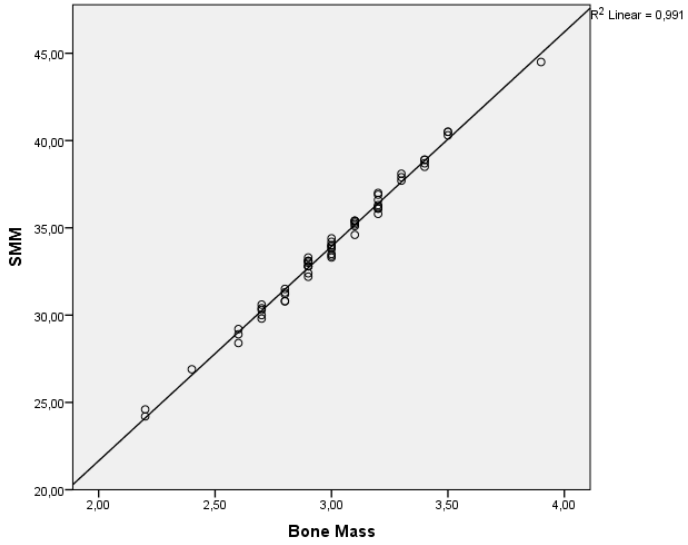


Figure 3. Correlation of bone mass with skeletal muscle mass

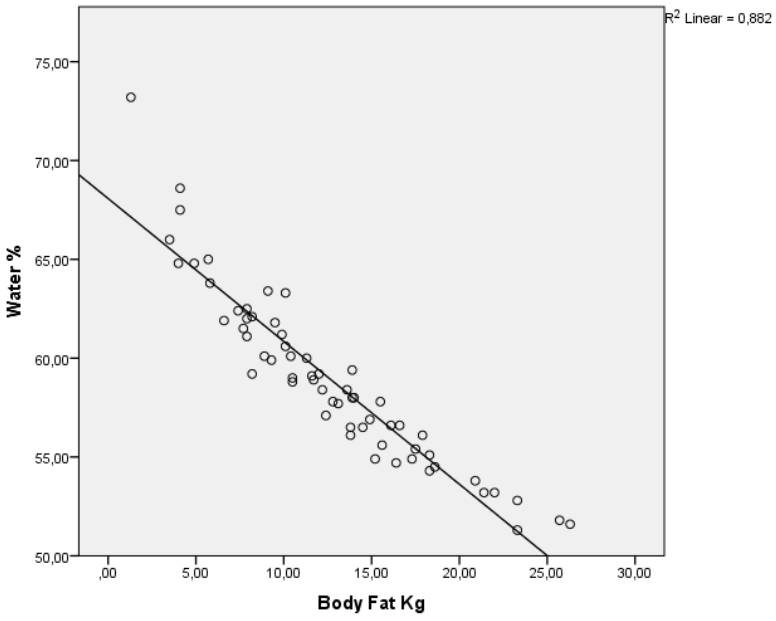


Figure 4. Correlation of body fat mass with % water

Discussion

Evaluating body composition during adolescence has proven relevant, as the resu4lts obtained confirmed the biological transformations recorded in young people's bodies and the ways in which body composition components influence each other, whether positively or negatively.

The conducted study allowed us to uncover several aspects of great significance for adolescents' health. The fact that body weight strongly correlates positively with many BC components (e.g., a highly significant positive correlation of $r = 0.891$ between body weight and SMM; $r = 0.887$ between body weight and bone mass; $r = 0.875$, between body weight and total water; $r = 0.826$ between body weight and body fat; $r = 0.721$ between body weight and muscle mass in kg; $r = 0.719$ between body weight and BMI, etc.) demonstrates that an imbalance among these elements could negatively impact health, as also noted by Deng et al. (2021) in a study analysing BC, particularly the complex relationship between muscle mass and bone mineral mass in children and teenagers.

Similarly, Ofenheimer et al. (2021), in evaluating BC to identify correlations to certain chronic diseases, highlighted the impact of changes in normal BC parameters on general health among teenagers and recommended developing effective prevention strategies.

Another recent study (Clayton et al., 2023) mentions relationships between certain BC components, such as the statistically significant correlation between total water and skeletal muscle mass, which was also identified in the present study in the girls' group ($r = 0.822$, $p < 0.001$). These associations are considered normal during adolescence, as they are largely determined by growth and maturation processes and by hormone secretion levels (França et al., 2023). Another study using the same technology as this one, highlighted the importance of this method for obtaining accurate results (Galan-Lopez et al., 2022). The need for precise measurement of body composition stems from it being the primary way to diagnose overweight or obesity accurately (Li et al., 2022).

Appropriate dietary intake and regular exercise can influence body composition parameters during adolescence and beyond (Grams et al., 2022). Body composition was also evaluated and assessed in a study by Farheen et al. (2024), where a statistically significant positive relation was observed between muscle mass and bone mass, $r = 0.64$, while in the present study, a strong statistically significant correlation is apparent for $r = 0.806$ for girls, and a really important positive relation of $r = 0.986$, was

identified in boys between these components. The same study indicated a statistically considerable negative relation, r = -0.68, between bone mass and % body fat, compared to the present study, which shows a moderate positive statistical correlation of r = 0.383 in boys.

Early detection of signs indicating a propensity to obesity, such as a high body fat percentage identified at a young age through BIA measurement, represents an effective method for preventing obesity-related diseases (Thajer et al., 2021). Students should maximise physical education classes since they spend much time sitting in school, a factor that negatively impacts their health and can lead to significant deviations from normal body composition parameters, as Bogataj et al. (2021) emphasised. Young people from developing countries tend to be more physically active than those in developed countries, thus less prone to diseases associated with excess weight (Gualdi-Russo et al., 2021). Regular physical activity is a highly effective strategy for reducing body fat, which is well-correlated with low cardiorespiratory fitness levels (Manzano-Carrasco et al., 2020). These actors found in their research that the lack of systematic physical exercise influences BMI.

This study also has some limitations. One limitation is the sample size. Another is the lack of Romanian literature on this topic, which makes it impossible to compare this study with other national research results.

On the other hand, this study's strength lies in being among the few to evaluate and analyse body composition components among teenagers from an educational institution using professional equipment.

Conclusions

The conclusions of this study point out not only the differences in body composition between genders but also the statistically significant relationships among body composition elements – such as muscle mass, bone mass, and body fat – within each gender category. These results emphasize the significance of gender-differentiated evaluation of body composition parameters among teenagers, a period marked by complex changes in body structure influenced by specific hormonal and biological factors.

Moreover, physical development differences between boys and girls at this age are amplified by behavioral factors, such as levels of participation in physical activities and variations in dietary habits, which play a significant role in shaping body composition. Better insight into these differences and correlations is essential to design tailored interventions that address the specific needs of each gender and for guiding public health policies and educational programs that promote healthy development among teenagers.

Therefore, this study makes a valuable contribution to a nuanced, differentiated approach to health and physical education. It thus enables more accurate monitoring and early interventions that support well-balanced and healthy growth among young people, with potential long-term benefits for the health of adults.

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