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Normative Values for the Growth and Development of Morphological Characteristics in Students Aged 12, 13, 14, and 15 in Kosovo

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Abstract

Monitoring adolescent growth is important for understanding public health trends, especially in the regions and countries where national reference data are still missing, such as Kosovo. The aim of this study was to establish age- and sex-specific reference values for height, weight, and body mass index (BMI) among school-aged students in the Republic of Kosovo and to compare these values with World Health Organization (WHO) growth standards. The study included 1,950 students (997 boys and 953 girls), aged 12 to 15 years, selected from a nationally representative sample. Standard anthropometric methods were used, and BMI was categorized based on WHO criteria. Descriptive statistics, t-tests, and percentile calculations (P1–P99) were performed. The results showed a linear increase in height, weight, and BMI across all age groups. No significant gender differences were found at ages 12 and 13, but from age 14, boys were significantly taller and heavier. Compared to WHO references, height values were mostly similar, except for slightly lower height in 13-year-old boys, while BMI values were consistently higher in both sexes from ages 12 to 14. A high percentage of students, especially boys, were categorized as overweight or obese. Further research is needed to determine whether the higher BMI reflects increased fat mass or lean body mass.

Keywords: *Adolescent Growth and Development; Anthropometry; Body Mass Index; Overweight; Reference Standards*

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Introduction

From an early age, children require not only regular medical care, but also strong emotional and cognitive support in order to grow and develop properly (Moisiu et al., 2005). These early influences are important because they form the base for a child's future physical and mental health. Therefore, monitoring the healthy growth and development of school-aged children is very important, especially for those who are already in the education system. It supports their physical, emotional, and mental development during a period that is full of changes. In addition, growth monitoring allows teachers, doctors, and parents to identify any delays or

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problems that may need attention. It also helps governments and institutions to design better policies and practical programs in the areas of health, education, and social services (Institute of Medicine & National Research Council, 2015). Among many available health indicators, anthropometric characteristics like height, weight, and body mass index (BMI) are considered reliable and simple to measure. These indicators are commonly used to assess physical growth and general health status in children and adolescents. They are also used in public health research to study population-level trends over time.

Adolescent growth is not only a biological process, but also strongly influenced by social and environmental conditions, including daily lifestyle habits. Teenagers do not grow in isolation; their development is shaped by many factors inside and outside the home. For example, the education level and financial situation of the parents can affect how children eat, how active they are, and whether they have regular access to medical and health services (Mollborn et al., 2014). Children from families with lower income may have fewer opportunities for sports or healthy meals, which can directly affect their physical development. On the other hand, improvements in living conditions and the fast spread of digital technology have brought both benefits and problems. While digital tools help with learning and communication, they have also increased screen time and reduced movement, especially among students who spend many hours on computers or mobile devices (Panjeti-Madan et al., 2023). Today, physical inactivity in youth has become a well-known issue and is considered a serious public health concern (Opstoel et al., 2015; WHO, 2019; Halilaj & Gallopeni, 2022). Although it is true that genetic factors play a strong role in how a child grows (Jelenkovic et al., 2011), environmental influences must also be carefully studied and included when evaluating child development (Lilic et al. 2024). Therefore, it is widely accepted that both nature and lifestyle work together to shape the growth of young people.

The World Health Organization (WHO) developed international growth standards in 2006, based on a large multicenter study that collected data from six different countries: Brazil, Ghana, India, Norway, Oman, and the United States. These countries were selected because they represented a range of ethnic and geographical backgrounds, and the children included were raised in environments that provided optimal health, nutrition, and care (Stein et al., 2009; Yang et al., 2015). The goal of the WHO was to create a set of global reference standards that could be used to monitor child growth in any country, regardless of location or income level. These growth charts became widely used in medical and educational systems around the world. By 2011, about 125 countries had already adopted the WHO growth standards, and another 25 were still in the process of evaluating them. Around 30 countries had not adopted them at that time (de Onis et al., 2012; Yang et al., 2015). Even though the WHO growth charts are widely accepted and useful for international comparison, they may not fully match the genetic and environmental conditions of every population. For this reason, some countries have started to develop their own national growth references to better reflect their local population and health realities.

It is of utmost importance for each country to develop its own national norms of growth in children. These norms help to detect any delays in development and to respond early with proper support (Shonkoff & Phillips, 2000; American Psychological Association, 2019). When growth is evaluated using data from the same country and context, the results are more realistic and useful. Such reference norms are used in schools, health centers, and even in sports. Kosovo is a young country and still faces many challenges in the public health system. It still does not have national reference values for growth in adolescents. Due to lack of resources and limited research, many professionals rely on WHO norms, which may not always match the genetic and environmental situation of Kosovo. The aim of this study was to develop local growth references for students aged 12 to 15 in Kosovo and compare them with WHO standards.

Materials and Methods

Participants

This study included 1,950 students (997 boys and 953 girls) from lower secondary schools in Kosovo. All participants were aged between 12 and 15 years. According to official records of the Ministry of Education, there were 94,024 students in this age group in the 2022/2023 school year. Based on this number, the minimum sample for 95% confidence level was 1,071 participants, so the sample of this study can be considered as statistically representative.

Before starting the measurements, the research team explained the aim and procedure to the students, school directors, and parents, and consents were obtained. Students with known health conditions were not included. Only students with signed parental consent forms were measured. The study was approved by the University of Pristina's governing council (Protocol no. 2/963, dated 15.11.2023) and followed the Declaration of Helsinki (WMA, 2001).

Variables, Measurement, and Protocol

The main variables in this study were age, sex, body height, body weight, and BMI. Age and sex were taken from school records. Body weight was measured using a digital scale (accuracy: 100 g), and height was measured using a vertical anthropometer (accuracy: 0.5 cm). Students were lightly clothed, and the clothing weight was subtracted. BMI was calculated using the standard formula (kg/m^2) and compared using WHO reference values (WHO, 2006). All tools were produced by RossCraft Innovation and were calibrated before each measurement. Trained staff collected all data, which was divided by sex and age for analysis.

Statistics

The data were analyzed using basic descriptive statistics, including mean, standard deviation, and frequency. Independent t-tests were used to compare boys and girls in height, weight, and BMI. The BMI values were categorized as underweight, normal, overweight, and obese based on WHO criteria. Normality of data was checked using the Shapiro–Wilk test. If data was not normally distributed, Box–Cox transformation was applied (Oyhenart et al., 2014). Percentiles from P1 to P99 were calculated and compared with WHO reference percentiles (De Onis et al., 2007).

Results

Table 1 shows the normality test using the Shapiro–Wilk method. Only the height values of girls aged 12, 13, and 14

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years, and boys aged 12 years showed normal distribution. All other measured variables had statistically significant deviation from normality, so transformation was needed before analysis.

Table 1. Normality test according to the Shapiro Wilk test method

YEARS	GENDER	VARIABLE	SHAPIRO-WILK		
			STATISTIC	DF	P
12	GIRLS	HEIGHT	.993	209	.454
		WEIGHT	.951	209	<.001
		BMI	.929	209	<.001
	BOYS	HEIGHT	.995	240	.584
		WEIGHT	.940	240	<.001
		BMI	.929	240	<.001
13	GIRLS	HEIGHT	.995	261	.557
		WEIGHT	.931	261	<.001
		BMI	.931	261	<.001
	BOYS	HEIGHT	.986	255	.012
		WEIGHT	.951	255	<.001
		BMI	.931	255	<.001
14	GIRLS	HEIGHT	.993	210	.409
		WEIGHT	.943	210	<.001
		BMI	.875	210	<.001
	BOYS	HEIGHT	.982	246	.003
		WEIGHT	.940	246	<.001
		BMI	.904	246	<.001
15	GIRLS	HEIGHT	.983	258	.003
		WEIGHT	.972	258	<.001
		BMI	.947	258	<.001
	BOYS	HEIGHT	.984	256	.006
		WEIGHT	.936	256	<.001
		BMI	.881	256	<.001

Note. Statistic: Statistic; DF: the degrees of freedom; P: the two-tailed significance or p-value

After transformation using the Box–Cox method, data became more normally distributed. Table 2 shows the basic descriptive statistics and differences between boys and girls for height, weight, and BMI. At ages 12 and 13, there were no significant differences between sexes. Starting from age 14, boys were taller ($t = -6.90$; $p < 0.001$) and heavier ($t = -3.20$; $p = 0.01$), but BMI was not significantly different. At age 15, boys continued to be taller ($t = -13.52$; $p < 0.001$) and heavier ($t = -4.38$; $p < 0.001$), and still no difference in BMI.

Table 2. Descriptive Statistics and discriminative T-test of anthropometric, height, weight and BMI parameters (girls & boys)

		HEIGHT					WEIGHT				BMI			
YEARS	GENDER	N	MEAN	SD	T	P	MEAN	SD	T	P	MEAN	SD	T	P
12	GIRLS	209	152.80	8.00	1.31	0.19	46.57	15.19	-0.04	0.97	19.84	5.06	-0.66	0.51
	BOYS	240	151.83	7.66			46.62	14.49			20.14	4.65		
13	GIRLS	261	157.82	6.42	0.14	0.885	51.98	12.10	0.30	0.75	20.76	4.14	0.71	0.47
	BOYS	255	157.73	8.07			51.63	14.14			20.48	4.69		
14	GIRLS	210	160.64	6.36	-6.90	<0.001	54.24	11.09	-3.20	0.01	20.91	3.85	-0.20	0.84
	BOYS	246	165.73	9.28			58.13	14.31			20.99	4.30		
15	GIRLS	258	162.55	5.53	-13.52	<0.00	58.18	9.53	-4.38	<0.001	22.02	3.40	1.86	0.06
	BOYS	256	170.55	7.68			62.44	12.35			21.42	3.97		

Note. N: number of participants; SD: standard deviation; T: T-test; P: P-value or significance

Table 3 shows the frequency and percentage of students according to BMI categories. For 12-year-old girls, 7.7% were underweight, 62.7% normal, 18.7% overweight, and 11% obese. For boys, 2.9% were underweight, 60% normal, 18.8% overweight, and 18.3% obese. Similar trends continue in other ages, with boys showing higher percentages in overweight and obesity.

Table 3. Categorization in percentage and frequencies according to body mass index data (girls & boys)

AGE	GENDER	F&%	UNDERWEIGHT	NORMAL WEIGHT	OVERWEIGHT	OBESE	N
12	GIRLS	F	16	131	39	23	209
		%	7.7	62.7	18.7	11.0	100
	BOYS	F	7	144	45	44	240
		%	2.9	60.0	18.8	18.3	100
13	GIRLS	F	5	191	40	25	261
		%	1.9	73.2	15.3	9.6	100
	BOYS	F	17	153	47	38	255
		%	6.7	60.0	18.4	14.9	100
14	GIRLS	F	6	164	26	14	210
		%	2.9	78.1	12.4	6.7	100
	BOYS	F	14	170	33	29	246
		%	5.7	69.1	13.4	11.8	100
15	GIRLS	F	4	197	44	13	258
		%	1.6	76.4	17.1	5.0	100
	BOYS	F	18	181	29	28	256
		%	7.0	70.7	11.3	10.9	100

Note. F: Frequencies; %: percentage; N: number of participants

Table 4 compares the results from Kosovo with WHO norms for height and BMI. No significant difference was found in height, except for 13-year-old boys, where WHO students were taller ($p < 0.001$). But in BMI, Kosovar students had higher values in both sexes from age 12 to 14 ($p < 0.001$).

Table 4. Differences between Kosovo and WHO student according to height and BMI (girls & boys)

		HEIGHT				BMI			
YEARS	GENDER	KOSOVO	WHO	MEAN DIFF	P	KOSOVO	WHO	MEAN DIFF	P
12	GIRLS	152.80	153.7	-0.90	-0.10	19.84	18.36	1.47	<0.001
	BOYS	151.83	152.18	-0.35	0.47	20.14	17.84	2.29	<0.001
13	GIRLS	157.82	158.08	-0.25	0.51	20.76	19.16	1.60	<0.001
	BOYS	157.73	159.35	-1.62	<0.001	20.48	18.58	1.90	<0.001
14	GIRLS	160.64	160.7	-0.05	0.90	20.91	19.83	1.08	<0.001
	BOYS	165.73	165.97	-0.23	0.69	20.99	19.35	1.64	<0.001
15	GIRLS	162.55	162.13	0.42	0.22	22.02	20.45	1.57	<0.001
	BOYS	170.55	170.91	-0.35	0.45	21.42	20.10	1.32	<0.001

Note. P: P-value or significance

Table 5. Normative values for girls - height, body weight, body mass index

AGE	VARIABLE	N	Percentiles										
		VALID	1	3	5	15	25	50	75	85	95	97	99
12	HEIGHT	209	133.18	136.77	138.92	144.23	147.63	153.18	157.61	160.64	166.01	169.02	171.09
	WEIGHT	209	12.4	18.35	21.39	31.06	36.68	46.27	56.22	63.14	72.36	76.73	83.39
	BMI	209	8.51	9.99	10.97	14.81	16.82	19.85	23.37	24.70	28.39	29.54	31.25
13	HEIGHT	261	140.25	145.56	147.03	151.63	153.96	157.88	162.19	164.35	167.81	169.48	173.34
	WEIGHT	261	23.48	30.44	33.47	40.75	44.28	51.08	59.01	64.32	75.44	77.54	81.39
	BMI	261	11.88	13.48	14.41	16.29	17.57	20.80	23.54	25.05	27.76	28.49	30.69
14	HEIGHT	210	143.91	147.11	149.40	153.81	156.75	161.41	165.12	166.94	170.24	171.08	174.37
	WEIGHT	210	28.94	34.29	35.77	43.48	46.62	53.87	60.29	65.66	72.59	76.84	85.14
	BMI	210	11.36	14.12	15.32	17.42	18.57	20.62	23.20	24.82	27.59	28.97	32.08
15	HEIGHT	257	148.92	151.06	152.52	156.75	159.28	162.70	166.25	167.99	171.43	172.39	176.08
	WEIGHT	258	39.14	40.97	43.14	47.84	51.39	57.51	65.05	68.34	74.03	76.53	79.11
	BMI	258	14.71	16.09	16.52	18.37	19.64	22.15	24.40	25.49	27.70	28.27	30.02

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Table 5 gives the normative values for girls. There is a clear increase in height, weight, and BMI from age 12 to 15, which shows regular growth.

Table 6 shows the same data for boys. Linear growth is seen here too. The biggest increase in height happened between ages 13 and 14.

Table 6. Normative values for boys - height, body weight, body mass index

AGE	VARIABLE	N	Percentiles										
		VALID	1	3	5	15	25	50	75	85	95	97	99
12	HEIGHT	240	133.26	136.84	138.75	144.13	146.46	152.23	157.13	159.68	164.76	166.44	168.47
	WEIGHT	240	16.03	22.09	25.47	31.98	36.14	44.90	57.68	61.97	73.62	76.63	81.42
	BMI	240	10.60	12.49	13.05	15.30	16.30	19.92	23.69	25.33	27.90	29.02	29.78
13	HEIGHT	255	140.75	143.56	144.77	148.72	151.90	157.82	162.63	166.47	172.40	174.02	175.05
	WEIGHT	255	26.59	28.05	30.62	36.21	39.10	51.06	62.02	67.00	75.39	78.50	82.22
	BMI	255	11.57	12.11	12.76	15.20	16.98	20.47	24.37	25.62	27.73	28.13	30.31
14	HEIGHT	246	142.90	147.46	149.25	155.16	159.87	166.71	172.48	175.02	179.07	181.89	184.78
	WEIGHT	246	23.59	28.62	34.22	43.76	48.54	58.35	67.10	70.89	83.23	85.75	93.37
	BMI	246	8.97	12.80	14.19	16.94	18.55	21.07	23.44	25.10	28.62	29.42	31.97
15	HEIGHT	255	150.04	153.28	155.51	163.71	166.76	170.77	175.48	178.05	182.26	184.24	188.41
	WEIGHT	255	33.12	39.11	43.33	50.24	54.24	61.87	70.73	75.28	84.02	86.29	92.34
	BMI	255	12.93	13.93	14.66	17.65	18.54	21.20	23.90	25.79	28.37	29.23	31.64

Discussion

This study was carried out to create national reference values for height, body weight, and BMI in school-aged students in Kosovo. It included students aged 12 to 15 years and used a representative sample from different regions. The results were also compared with WHO international growth standards to observe how Kosovar children grow compared to global patterns. There are several most important results. First, students' height increased steadily across ages in both sexes, while BMI values appeared higher than the WHO standards. However, many students, especially boys, were found in the overweight and obese categories. These observations offer information about how adolescents in Kosovo are growing in recent years.

Results showed that students' body height increased every year in both boys and girls. Girls had the highest increase in height between ages 12 and 13, while boys experienced this change between 13 and 14 years. After that, the growth slowed down. This kind of development difference between sexes is commonly reported in the literature, where girls enter puberty earlier. Body weight and BMI also increased each year as expected during adolescence. The general trend of the variables followed similar results from previous studies (Sweeting & West, 2002; Madhu, 2022). These results describe the basic physical growth in adolescents from Kosovo.

At ages 12 and 13, there were no significant differences in anthropometric measures between boys and girls. At age 14 and especially 15, boys were significantly taller and heavier than girls, while BMI did not show a clear difference between sexes. This can be explained by the fact that weight and height increased at similar rates in boys, keeping BMI relatively stable. On the other hand, it is also possible that muscle mass increased more than fat mass, especially in boys, which may not be reflected in BMI. Previous studies have also shown that BMI is not always accurate to describe body composition, especially during puberty, while other measurements like body fat percentage, and/or analyses of lean body mass might provide better understanding of BMI trends, and should be definitively considered in future studies.

When the data from Kosovo were compared with WHO standards, height values were mostly similar. An exception was seen in boys aged 13, where WHO values were higher. For BMI, differences were more visible, with Kosovar students showing higher values across most age groups, especially from 12 to 14 years. This was the case for both boys and girls, and almost certainly is at least partially associated with previously specified difference in body height between Kosovar students and WHO-reported data. Many factors could explain this, such as diet, lifestyle, or physical activity. The difference may also be related to environmental or social changes in the country, which are different from the populations used to develop WHO standards (Lopes et al., 2012). Irrespective of the background, these comparisons give a perspective about where Kosovo stands in terms of growth indicators.

The BMI category analysis showed that many Kosovar students, were classified as overweight or obese. This is particularly evident for boys. Most specifically, at age 12, this was 37.1% for boys and 29.7% for girls being classified as overweight/obese. The numbers were still high at older ages, although evidently lower. However, in all age groups, the percentage of overweight and obese students remained above one-fifth of the population. These numbers were higher than authors of the study expected, but in general followed a similar direction as global studies showing increasing weight problems in young people (Hedayetullah et al., 2023).

It is interesting to note that global results show that body weight issues are present already in early adolescence and affect both sexes, but a a deeper look into recent literature suggests that body weight concerns may, in fact, are more prevalent or more intense among females during early adolescence. For instance, a review by Martini et al. (2022) found that the prevalence of weight dissatisfaction ranged widely (from 10.8% to 82.5% among boys and from 19.2% to 83.8% among girls), indicating a consistently higher concern among females, while Mäkinen et al. (2012) confirmed that body dissatisfaction often begins in early adolescence, with girls reporting lower satisfaction with their bodies compared to boys. Other

studies also supported these findings, showing that 78.1% of adolescent females and 60.1% of males experienced weight-related concerns (Neumark-Sztainer et al. 2018). These studies suggest that while both sexes are affected by weight issues during adolescence, the psychological burden and body image dissatisfaction tend to be more pronounced in females.

Higher BMI in students may be the result of various lifestyle changes in recent years. Children and teenagers are now spending more time sitting indoors, using technology, and eating foods that are rich in calories but poor in nutritional value. These habits can contribute to excessive weight gain. (Barnett, et al., 2018). In countries that are still developing their health education systems, these problems may appear faster. The situation in schools may also affect growth, especially if physical activity is not promoted or if access to healthy food is limited. Some of these issues may be more common in urban areas than rural ones, but this was not analyzed in the present study. Including such variables in future research could help to understand the influence of daily habits and environment.

At the same time, we can specifically determine if the higher BMI values found in this study are caused mainly by fat accumulation or by increases in lean body mass, especially if we take into account differences between sexes (please see previously for discussion). Specifically, during puberty, boys in particular may gain more muscle, which also increases body weight and BMI (McCabe, et al., 2002). Without using direct methods to measure fat and muscle, such as skinfold tests or bioimpedance, it is difficult to interpret the health meaning of higher BMI. Future studies should include such tools to give a more complete picture of adolescent growth.

Strengths and limitations

One strength of this study is the use of a large and nationally representative sample, which included students from different regions of Kosovo. This makes the data more reliable for describing the growth patterns of adolescents in the country. Another strength is the use of standard anthropometric protocols and trained staff for measurements, which helped to reduce possible errors. The comparison with WHO growth standards also made it possible to see how students in Kosovo are developing compared to international data.

However, there were some limitations. The study only included basic anthropometric variables and did not measure physical activity, food intake, or detailed body composition. These factors may have an effect on BMI and could help explain the results more clearly. Also, information about socioeconomic status or rural and urban differences was not collected. These variables might influence the growth of children and should be considered in future research. The study was cross-sectional, so it shows a snapshot in time, and does not follow students over many years.

Conclusion

This study created the first reference values for height, weight, and BMI among students aged 12 to 15 years in Kosovo. The findings showed that growth in height was similar to WHO standards in most age groups, while BMI values were often higher. The results also showed that many students, especially boys, were in the overweight and obese categories.

At the moment, it is not known whether the high BMI values are a result of increased fat mass or increased lean body mass. BMI alone cannot make this difference, especially during adolescence, when boys often gain more muscle. Because of this, the results should be interpreted carefully. Future studies should include more detailed indicators of body composition to better understand if the increased BMI represents a health risk or a normal part of physical development.

The use of national reference data makes it easier for teachers, doctors, and researchers to evaluate physical development of students in Kosovo. These findings may help in the future when planning health education programs or improving physical activity in schools. More research is needed to explore lifestyle factors, family background, and other influences on adolescent growth.

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Conflict of interest

The authors declare no conflict of interest.

All authors read and approved the final version of the manuscript.

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