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Professional paper

SOCIODEMOGRAPHIC FACTORS ASSOCIATED WITH UPPER AND LOWER LIMB LENGTH IN CHILDREN AND ADOLESCENTS AGED 12-17 YEARS IN THE TETOVO REGION, NORTH MACEDONIA

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Abstract

Background: Anthropometry provide important data on the biological structure of the population that serves as the basis for microevolutionary research. The length of the limbs is very important because abnormalities in their development can lead to more serious problems, as people with a considerable length of limbs often happen to have a degenerative disease.
Objective: The main objectives of this study were the use of anthropometric measurements to give a realistic picture of anthropometric parameters in the surveyed population, to identify cases of stagnation in growth and development, as well as to compare the results with other studies of this level conducted by different authors in other populations.
Methods: The character of this research is "Cross-sectional" and was conducted in primary and secondary schools in the region of Tetovo, North Macedonia, during the period April to June 2019 with 625 male and female students aged 12-17 years. The results were processed with statistical programs STATISTICA 10.0 and SPSS 20.0.
Results: The average length of the upper limb in men varies from 65.48 cm at the age of 12 to 77.19 cm at the age of 17, while in women from 65.19 cm at the age of 12 to 70.62 cm at the age of 17 years. The average length of the lower limb in men varies from 82.13 cm at the age of 12 years to 95.73 cm at the age of 17 years, while in women from 84.76 cm at the age of 12 years up to 93.54 cm at the age of 17 years.
Conclusion: This study provides a basis for quantifying the normal growth of the limbs at different ages. The average annual growth of male extremities is about 4-5 cm, while in women it is slightly smaller.

Keywords: Children, Adolescents, Growth, Limbs length, Socioeconomic status.

1. Introduction

Anthropometry and anthropometric variability provide important data on the biological structure of the population that serves as the basis for microevolutionary research. In these researches, anthropometric variability is used in reconstructing the recent history of the (biological) populations observed. The length of the limbs is very important because abnormalities in their development can lead to more serious problems, as people with a considerable length of limbs often happen to have a degenerative disease. The body is designed in such a way as to be uniform, and a prolonged imbalance can cause various problems, among other things leading to severe back or hip pain. The conclusions and results of numerous studies in different populations have shown that the anthropometric properties of today's populations show geographical variability, which confirms migration trends, the effects of epidemics, and various social and historical events, hence the need arises to have Anthropometric data for the specific population under study. Anthropometry according to Cabello [1], allows the creation of an adequate working environment by modeling, for example, individual protective equipment in the right way, so that the person carries out his work activity by performing all the movements required by the task, without being exposed to the potential dangers arising from lack of space.

Previous research has shown that a large number of anthropometric dimensions change more during adolescence (the period of rapid growth and development) [2].

Limb development

The growth and development of the lower limbs are quite well documented by Green and Anderson [3]. We know from their work that, after 5 years, the lower limbs grow 3.5 cm/year, 2 cm/year in the femur, and 1.5 cm/year in the tibia. There are many methods to predict the final inequality of leg length, the methods of some scientists [4-6] are all based on the data of Green and Anderson. They simply reflect different mathematical formulas of the same data.

Limb development and puberty

The final burst of growth and development occurs before skeletal maturity begins at the onset of puberty. This usually starts at the age of 13 for boys and 11 for girls. The growth rate is usually from 5 to 7.5 cm/year. Body height increases from 154 cm (± 1 cm) to 174 cm (± 1 cm) in boys and from 143 cm (± 1 cm) to 161 cm (± 1 cm) in girls. Thus, from the above results, it can be seen that the average growth and development at the onset of puberty, in relation to body height is 21 cm (± 1 cm) for boys and 19 cm (± 1 cm) for girls [7]. Growth and development in the lower limbs is 10 cm in boys and 9 cm in girls. The growth rate of the lower limbs increases from 3 to 5 cm/year at the peak of puberty. The maximum growth rate in the lower limbs occurs 6 months earlier than the maximum growth rate of the spine, ie at the age of 14 years in boys and 12 years in girls. The growth of the lower limbs during puberty is characterized by the gradual acceleration of growth for 1 year, followed by a phase of gradual slowing down [7,8].

Limb development and socioeconomic status

Research shows that SSE is one of the main factors affecting the quality of life, throughout the life cycle, both in children and young people. For years, studies in adults have documented a link between SSE and health [9]. Data on children are somewhat less complete and less consistent, but the evidence points to an essential correlation that begins before birth [10].

2. Purpose of the study

The purpose of this study was the anthropometric measurement of children and adolescents with a sample of subjects that are representative of this category of population in the Tetovo region and using some anthropometric indicators to give a more realistic picture of anthropometric characteristics in the surveyed population, identifying cases of stagnation in growth and development, as well as comparing the results with other studies of this level conducted by different authors in other populations.

3. Material and methods

This study is focused on Tetovo and its surroundings, which are located in the Polog region, the northwestern part of North Macedonia. There are 184 settlements on this territory, with a total population of 322,605 people [11,12]. It is worth noting that this cross-sectional is the first of its kind in this part of North Macedonia. According to the proposal of the International Biologic Program IBP, No. 9, 1969, the research was conducted in primary and secondary schools in the Tetovo region [11,13] from April to June 2019. In this study, we surveyed girls aged 12–17 years who were physically capable of performing anthropometric measurements and volunteered to answer the questionnaire.

Sample size determination

Initially, the sample reliability level was set at 95% and P = 0.05. So, from the total number of students aged 12 to 17 who have attended primary and secondary schools in the Tetovo region in the school year 2018/2019 [11], the minimum number required for inclusion in this research that level of 95% reliability is 392 students. In our research, we included 625 male and female students aged 12, 13, 14, 15, 16, and 17 years old, from the primary and secondary schools in the Tetovo region. Cluster sampling was used for sample selection because of the difficulty in researching all individuals (budgetary and time constraints). The lead author described the objective of this study to selected participants. Written consent from each selected student and permission from the school authorities were obtained. Anthropometric data of 625 students were recorded on the anthropometric card.

Data collection procedure

The intervention protocols were developed according to the Helsinki Declaration [14] and approved by the Regional Bureau for Development of Education in the municipalities where students' anthropometric measurements were taken. Additionally, written consent from each selected participant and permission from the school authorities were obtained. Anthropometric measurements were taken by trained individuals in two-person teams: one conducted the measurements, and the other recorded the measurements in a questionnaire. Based on the culture and customs of the population, in some cases in females, the measurements were performed by trained female collaborators.
Anthropometric methods that were needed to measure limb length were used according to standardized manuals [15]. The measurements were taken in the morning when the students were attending the physical education class and were wearing light clothing (T-shirts, shorts, and socks), using the techniques of Martin and Saller [16]. An anthropometric card was formed for each student, and the biological age of each student was determined by the date of birth and the date of measurement. GPM Swiss Made anthropological instruments were used for anthropometric measurements.

Anthropometric measurements

In this study, in each measured subject, we collected data on the upper and lower limbs, of one side of the body. We have not collected data for both limbs (i.e. both left and right upper limbs) to exclude the impact, due to the approximation of the lengths of the right and left upper limbs to each other. Each subject before the measurement should have a fixed position, which can represent the function of the limbs very well, without any movement while the measurement is being performed.

Upper limb length (ULL)

Is measured with an anthropometer. The measuring arm and palms should be fully extended. One arm of the anthropometer is placed on the tip of the shoulder acromion and we measure the distance to the tip of the longest finger of the hand.

Lower limb length (LLL)

Is measured with an anthropometer. The examinee stands as if measuring body height. The anterior superior iliac spine is determined by palpating with the third finger of the hand, with which the horizontal arm of the anthropometer is held, which is then pressed into the superior anterior iliac spine and the distance from the floor is read.

Questionnaire on socioeconomic status (SES)

Socioeconomic status (SES) was assessed through the Family Affluence Scale (FAS III) [17]. FAS is a measure of material family wealth, developed as an indicator of the absolute level of socioeconomic position, which is determined using the result consisting of six questions. Socioeconomic status is typically divided into three levels: Low Socioeconomic Status (LSES), Middle Socioeconomic Status (MSES), and High Socioeconomic Status (HSES).

Inclusion and exclusion criteria from the study

Included:

- students aged 12 to 17 years old,
- physically fit to perform measurements,
- who were able and willing to answer the questionnaire.

Excluded:

- students who refused to take measurements,
- were not of the age involved in the research.

Statistical analysis

Results were processed using the statistical programs STATISTICA 10.0 and SPSS 20.0. The collected data were analyzed using statistical techniques such as attributive statistical series by calculating the coefficients of relationships, proportions, norms, and the statistical significance of detected differences in the difference test. Central tendency and data distribution measures were used to analyze numerical series (mean and standard deviation).

4. Results

The results of this research are presented in the form of tables and figures. In total, 625 male and female students aged 12–17 years were considered as the sample for this study. The number of students in each age group was approximately the same.

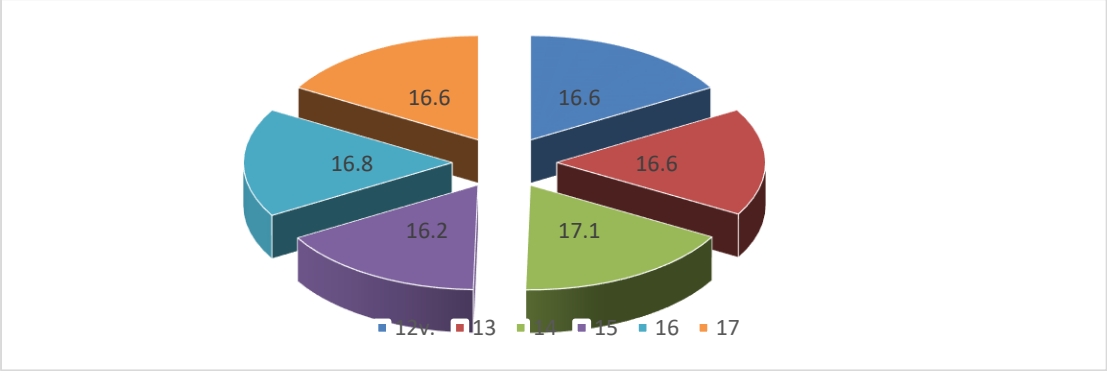

Fig 1. Percentage of students by age

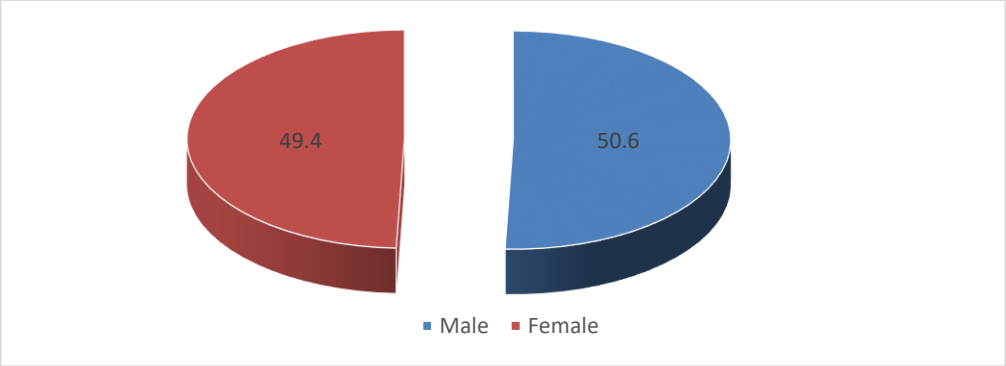

Fig 2. Percentage of students by gender

The results presented in Figure 1 show that, from the anthropometric measurements of 625 students, 104 students or 16.6% are 12 years old and attend the sixth grade in primary school, 104 or 16.6% of the students are 13 years old and attend the seventh grade in primary school, 107 students or 17.1% are aged 14 and attending the eighth grade in primary school, 101 students or 16.2% are aged 15 and attending the ninth grade in primary school, 105 students or 16.8% are aged 16 and attending the first year of high school and 104 students or 16.6% are aged 17 and attend the second year of high school. Of the total number of examinees, Figure 2 shows that 309, or 49.4% were female and 316, or 50.6% were male.

Table 1. Students by place of residence

Residence	N	%	Male N	%	Female N	%
Rural	455	72,8	245	77,5	210	68.0%
Urban	170	27,2	71	22,5	99	32,0
Total	625	100,0	316	100,0	309	100,0

The results presented in Table 1 show that, from anthropometric measurements of 625 students, 455 or 72.8% of them are living in rural areas, of which 245 men and 210 women while 170 or 27.2% are living in urban areas, of which 71 males and 99 females.

Table 2. Normal range of ULL and LLL and the difference between the genders

Age	Upper limb length						Lower limb length				
	Gender	Mean (cm)	SD	Skew	t-value	p-value	Mean (cm)	SD	Skew	t-value	p-value
12 y	M	65.48	4.23	−.25	0.36	0.71	82.13	5.88	−.22	2.37	0.01
	F	65.19	3.74	.66			84.76	5.41	−.46		
13 y	M	69.24	4.90	−.18	0.00	0.99	89.54	6.31	.46	2.07	0.04
	F	69.24	3.40	.13			91.87	5.09	.14		
14 y	M	71.87	5.52	.04	−2.10	0.03	92.24	5.10	.17	2.13	0.03
	F	69.94	4.14	.44			94.22	4.36	.08		
15 y	M	75.66	3.77	.17	−6.00	0.00	95.54	3.40	.10	−0.91	0.36
	F	71.58	3.00	−.01			94.92	3.41	−.15		
16 y	M	76.76	3.70	.37	−9.49	0.00	95.18	3.39	−.15	−2.38	0.01
	F	70.62	2.81	.54			93.54	3.67	.45		
17 y	M	77.19	3.25	−.10	−11.03	0.00	95.73	4.70	.56	−2.69	0.00
	F	70.15	3.25	−.34			92.88	5.97	−.48		

According to the Student t test, in the age groups 12 and 13 years, the difference is statistically significant in the average LLL of the male versus the female with p <0.05, respectively 12 years (t = 2.375797, p = 0, 019379), and 13 year olds (t = 2.07857, p = 0.040166). While in the age group of 14 years, the difference is seen in both extremities, in the average ULL and the LLL in males versus females, in ULL (t = -2.108.8, p = 0.037404), respectively for LLL (t = 2.13550, p = 0.035045). A difference is also seen in the age group of 15 years, but in this case between the average ULL in males versus females with p <0.05 (t = -600924, p = 0.00000). In the age group of 16 years, the difference is seen in both measured parameters, respectively the development is greater in males versus females in the average ULL and LLL, which are statistically significant with p <0.05 for ULL (t = -9.49364, p = 0.000000) and LLL (t = -2.38106, p = 0.019101). The same is found in the age group of 17 years, where the difference is statistically significant with p <0.05 for ULL (t = -11.03532, p = 0.000000), and LLL (t = -2.69787, p = 0.008168).

Table 3. Sociodemographic data for students of the age group 12-17 years old

Age	Gender	N	(%)	Rural		Urban		LSES		MSES		HSES	
				N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
12 y	M	52	(8.30)	31	(4.90)	21	(3.40)	2	(0.32)	28	(4.48)	22	(3.52)
	F	52	(8.30)	30	(4.80)	22	(3.50)	3	(0.48)	37	(5.92)	12	(1.92)
13 y	M	50	(8.0)	28	(4.50)	22	(3.50)	6	(0.96)	35	(5.6)	9	(1.44)
	F	54	(8.60)	31	(4.90)	23	(3.70)	3	(0.48)	38	(6.08)	13	(2.08)
14 y	M	57	(9.10)	34	(5.40)	23	(3.70)	3	(0.48)	34	(5.44)	20	(3.20)
	F	50	(8.0)	30	(4.80)	20	(3.20)	7	(1.12)	28	(4.48)	15	(2.40)
15 y	M	50	(8.0)	31	(4.90)	19	(2.90)	4	(0.64)	40	(6.4)	6	(0.96)
	F	51	(8.20)	31	(4.90)	20	(3.20)	5	(0.8)	33	(5.28)	13	(2.08)
16 y	M	55	(8.90)	32	(5.10)	23	(3.70)	4	(0.64)	36	(5.76)	15	(2.40)
	F	50	(8.0)	27	(4.30)	23	(3.70)	7	(1.12)	34	(5.44)	9	(1.44)
17 y	M	52	(8.30)	31	(4.90)	21	(3.40)	2	(0.32)	37	(5.92)	13	(2.08)
	F	52	(8.30)	29	(4.60)	23	(3.70)	1	(0.16)	34	(5.44)	17	(2.72)
Total	M	316	(50.60)	187	(29.90)	129	(20.60)	21	(3.36)	210	(33.6)	85	(13.60)
	F	309	(49.40)	178	(28.50)	131	(21.0)	26	(4.16)	204	(32.64)	79	(12.64)
Subtotal		625	(100.0)	365	(58.40)	260	(41.60)	47	(7.52)	414	(66.24)	164	(26.24)

Table 4. The differences in the ULL and LLL based on place of residence

Upper limb length								
Age	Rural			Urban				
	n	Mean (cm)	SD	n	Mean (cm)	SD	t value	p-value
12 y	61	65.1	3.89	43	66.8	4.39	−1.47	0.14
13 y	59	69.0	4.07	45	69.6	4.35	−0.72	0.47
14 y	64	70.4	8.50	43	70.0	3.00	0.20	0.84
15 y	62	73.6	4.16	39	73.6	3.18	0.01	0.98
16 y	59	73.8	4.48	46	73.9	4.61	−0.04	0.96
17 y	60	73.5	4.88	44	73.9	4.69	−0.32	0.74
Lower limb length								
12 y	61	83.2	5.83	43	85.5	5.14	−1.39	0.16
13 y	59	91.4	6.05	45	89.6	5.21	1.53	0.12
14 y	64	93.3	5.08	43	92.5	3.06	0.54	0.58
15 y	62	95.3	3.33	39	94.8	3.71	0.63	0.52
16 y	59	94.3	3.43	46	94.5	3.88	−0.20	0.83
17 y	60	94.2	4.86	44	94.6	6.58	−0.36	0.71

Table 4 shows the difference recorded between the average ULL and LLL in relation to age and place of residence (urban and rural) according to the Student's test is statistically insignificant with $p > 0.05$.

Table 5. Average ULL and LLL in relation to age and SES and Analysis of Variance

Upper limb length										
Age	LSES			MSES			HSES			Analysis of Variance
	Mean	N	SD	Mean	N	SD	Mean	N	SD	
12 y	63.6	5	2.30	65.2	65	4.18	65.8	34	3.76	F=0.757 p=0.471
13 y	69.7	9	4.57	68.4	73	4.05	70.8	22	3.64	F=4.888 p=0.009
14 y	63.6	10	4.93	70.7	62	4.87	71.8	35	4.78	F=4.515 p=0.013
15 y	73.2	9	3.03	73.9	73	4.23	72.6	19	3.11	F=0.907 p=0.407
16 y	72.4	11	4.88	73.7	70	4.47	74.9	24	4.40	F=1.252 p=0.290
17 y	75.0	3	4.35	73.8	71	4.81	73.3	30	4.89	F=0.218 p=0.804
Lower limb length										
12 y	80.93	5	1.64	82.21	65	2.52	81.52	34	2.98	F=0.233 p=0.792
13 y	84.16	9	2.01	83.56	73	2.25	84.47	22	2.95	F=0.288 p=0.750
14 y	90.14	10	2.83	89.03	62	2.37	88.74	35	2.61	F=0.630

										p=0.534
15 y	90.88	9	2.48	92.17	73	2.41	91.47	19	1.85	F=2.966 p=0.056
16 y	90.79	11	2.29	90.84	70	2.32	92.22	24	2.80	F=1.331 p=0.268
17 y	94.85	3	2.00	94.72	71	2.25	95.21	30	2.06	F=0.890 p=0.413

According to the Analysis of Variance test, the difference between the mean of the ULL in relation to age and SES is statistically insignificant for the 12, 15, 16 and 17 year old age groups with $p > 0.05$. A statistically significant difference was recorded between students aged 13 and 14 years between the average ULL in relation to the three categories of SES with $p < 0.05$ ($p = 0.009406$, $p = 0.013166$).

Table 6. Tukey HSD of the average ULL in relation to age and SES, for students of the age group 13 years old

	{1} - M=69.768	{2} - M=68.452	{3} - M=70.818
LSES{1}		0.054797	0.818798
MSES{2}	0.054797		0.045344
HSES {3}	0.818798	0.045344	

Table 7. Tukey HSD of the average ULL in relation to age and SES for students of the age group 14 years old

	{1} - M=63.600	{2} - M=70.677	{3} - M=71.800
LSES{1}		0.022195	0.010374
MSES{2}	0.022195		0.770285
HSES {3}	0.010374	0.770285	

According to the post-hoc-Tukey HSD test for 13 years old, the difference is statistically significant with $p < 0.05$ ($p = 0.045344$) between the average ULL of students with MSES compared to students with HSES. While in the age group of 14 years the difference is statistically significant with $p < 0.05$ ($p = 0.022195$, $p = 0.010374$) between the average ULL of students with LSES compared to students with MSES, and those with LSES compared to those with HSES.

5. Discussion

This study provides a basis for quantifying the normal growth of the limbs at different ages. It is difficult to get a very clear picture of growth patterns for the limbs outside the basic literature, due to the different techniques used in estimating growth and limb development. In our results, the average ULL in men varies from 65.48 cm at the age of 12 to 77.19 cm at the age of 17, while in women from 65.19 cm at the age of 12 to 70.62 cm at the age of 17 years. Statistically significant differences of $p < 0.05$ between the sexes were found in students aged 14, 16, and 17 years. The average LLL in men varies from 82.13 cm at the age of 12 years to 95.73 cm at the age of 17 years, while in women from 84.76 cm at the age of 12 years up to 93.54 cm at the age of 17 years. Statistically significant differences with $p < 0.05$ between genders were found in students aged 12, 13, 14, 16, and 17 years.

As for the correlation with socioeconomic status, differences were found in students aged 13 and 14 years, respectively between the averages ULL in relation to socioeconomic status. In our comparisons with the research conducted in the primary schools in the city of Skopje in North Macedonia [18] in the age groups 9 to 14 years old, we notice that men aged 12, 13 and 14 years old and women aged 12 years old in our research have an average ULL for 3 cm lower than their peers in the city of Skopje, while in the age groups of women aged 13 and 14 the same average was recorded. Regarding LLL, we notice that men and women aged 12 years

in our research have a lower average of LLL with a relatively large difference of ± 10 cm in contrast to their peers in the city of Skopje, while in the age groups of males and females aged 13 and 14 years of our study recorded a lower average than their peers but with a smaller difference of ± 5 cm. Also, in comparing our results with the study conducted on their peers in Zagreb, Croatia [19] we will notice that all male and female age groups in our research have lower mean ULL values than their peers in Zagreb ± 4 cm. As for LLL, we will notice that all male age groups in our research have lower average LLL values than their peers in Zagreb by ± 6 cm, except the 12 year old age group which has a difference of ± 9 cm, while in the female age groups in our research we will notice that all age groups have the same average value of LLL as their peers in Zagreb, except the 12 year old age group which has a lower average difference of ± 6 cm.

The maximum rate of increase in total body height in women in Europe most often occurs between the ages of 12 and 13 years, while in men between the ages of 14 and 15 years [20]. In this period, the average annual increase in height of males is about 10 cm, while in females it is slightly smaller. The head, body, and extremities do not contribute equally to the increase of this body mass (height), most of the "jump" in the increase of body height is realized with the increase of the speed in the longitudinal growth of the body. The maximum rate of growth of body mass, in relation to the maximum rate of "longitudinal" growth, is delayed by about half a year, while that of muscle mass by about three months. Due to the rapid growth of long bones, the muscle fibers and muscles in general also lengthen. This affects the weakening of the musculature (especially in women), the irregular posture of the body, and the characteristic uncoordinated movements of the adolescents. The difference in height between adult males and females for the most part stems from adolescence. Before adolescence, males are on average 2% higher than females, and after this period by about 8% [21].

Children from families with low SSE are more likely to experience growth retardation in their prenatal development, which is later characterized by social disorders [22,23]. Data from NHANES II show that adolescents from families with low SSE or poor families are more likely to experience stunted physical and mental development [24]. However, according to some research, SSE was not associated with asthma but was consistently associated with suicide attempts [25]. Biological influences during childhood create danger which will end up with unfavorable outcomes for his health in adulthood. In his study, Power [26] found that SSE measured during middle-aged childhood and adolescence was correlated with health status at age 23 years.

Various studies report that relatively shorter legs and shorter stature may increase the risk of overweight (obesity), coronary heart disease, and diabetes [27-30]. In a systematic review of the literature for the period before 2001, Gunnell et al [31] found that certain types of cancer, such as prostate and testicular cancer, premenopausal breast cancer, endometrial cancer, and colorectal cancer, are statistically more likely to appear in adults with a larger stature and relatively longer legs. These authors report that the positive relationship between leg length and risk for these cancers may be due to the effects of the Insulin-like growth factor 1 (IGF-1) receptor. Because of these findings, this issue has been researched since 2001 and several other reports of a relationship between IGF-1, IGF-1 receptors, and cancer risk have been published [32,33] as well as links between IGF-2 receptors and IGF-2 and cancer risk [34].

6. Conclusion

Based on the data from our research we can conclude that:

- The average annual growth of male extremities is about 4-5 cm, while in women it is slightly smaller.
- Using anthropometric measurements we have shown that the length of the limbs in the measured students increases continuously throughout researched age, from 12 to 17 years, while the period of most intense increase in anthropometric parameters was observed between the ages of 13-14 years in females and between the ages of 14-15 in males.
- It is also observed that women slow down the growth and development of their limbs before men,

but they continue to develop their stature.

- Children and adolescents who come from families with low SES are more likely to experience retardation or stunted growth and physical development, as noted in other research as well.
- The place of residence doesn't play any significant role in the growth and development of the lower and upper limbs

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Abbreviations

ULL - Upper Limb Length, LLL - Lower Limb Length, SES - Socioeconomic Status, LSES - Low Socioeconomic Status, MSES - Middle Socioeconomic Status, HSES - High Socioeconomic Status, SD - Standard Deviation.

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Ethics approval and consent to participate

The authors complied with all laws and rules of the ethical committee. The intervention protocols were used following the guidelines of the Helsinki Declaration and were approved by the Regional Bureau for Development of Education in the respective municipalities of the Tetovo region. Written consent was obtained from each participant in this study.