

THE GROWTH CHARTS OF ESTONIAN SCHOOLCHILDREN. COMPARATIVE ANALYSIS

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ABSTRACT

The current growth charts of Estonian children are based on the data collected in 1996. The aim of this article is to study whether children still correspond to these norms. For that purpose, an overview is given of the height, weight and body mass index of Estonian schoolchildren. These measurements have been collected mainly from 2006–2009. These data are compared with the results of 1996 by means of statistical tests.

During the interim period, the development of Estonian schoolchildren has changed. Children are significantly taller (boys by 4.84 cm and girls by 3.86 cm on average) and heavier (boys by 5.90 kg and girls by 4.20 kg on average). The mean body mass index has also increased significantly (in boys by 1.30 units and in girls by 0.99 units on average). In conclusion, it can be said that schoolchildren do not correspond well to the current norms, and the growth charts need updating.

Keywords: Estonian schoolchildren, growth charts

INTRODUCTION

To monitor children's growth, countries with developed medicine have used growth charts for more than 50 years. Body height and weight are some of the most essential indicators of physical development, and visual graphs enable to monitor the child's growth and deviations from normal development. Children's repetitive measuring at regular intervals and comparison of measuring results with the standard facilitates early noticing of growth disorders. A growth disorder can be a manifestation of several diseases, and therefore, finding of

disorders makes one think about their possible causes. Application of growth charts makes it easier for family physicians, pediatricians, geneticists and other specialists to find children with growth disorders and to monitor their development.

In Estonia, growth charts were first compiled and used in 1993. They were based on cross-sectional and longitudinal measurements of children's height and weight conducted in the 1970s. The norms currently used at schools are based on the data collected in 1996

In addition to watching the correspondence of growth to the norms, children's growth rate should also be monitored. Growth rate is the absolute increase in height during a certain period. In order to obtain more precise assessments, growth rate is measured after relatively long periods, e.g. half a year or a year. Growth rate slows down or accelerates before the child's height passes the limits of the norm, and therefore, this indicator is considered the most informative in assessment of growth disorders. [1]

MATERIAL AND METHODS

The data include the height and weight measurements of 21 764 Estonian children collected mainly from 2006 to 2009. Additionally, the body mass index (BMI) was calculated. All the measurements had been carried out by school physicians and pediatricians earlier in the course of their routine work. For each subject, the birth date and the date of measuring were also recorded. The schools and medical establishments from which the data were collected were selected by random sampling. In total 10 282 boys and 11 482 girls aged from 6–19 years were measured. In addition to descriptive statistics, the physical development was visualized by centile splines. The 3-, 10-, 25-, 50-, 75-, 90- and 97-percentiles were calculated for each age group and then connected using cubic spline interpolation.

The data were compared to the summary statistics of Estonian children published in 1996 when 17 175 children (8 408 boys and 8767 girls) aged from 6–19 years were measured. Therefore, the 19-year-olds of the newer data set have been left out of the comparison.

To determine the changes in growth curves, the means and standard deviations of body height, body weight and body mass index were compared for each

age group (from 6 to 18 years). For comparison, the F-test and the t-test using summary statistics were used. For significance level, the familywise error rate of 0.05 was chosen. Using the Bonferroni correction, the difference was statistically significant if p-value was less than 0.00385.

RESULTS

The key characteristics (sample size, mean, standard deviation, minimum, maximum) of height, weight and body mass index are presented respectively in Tables 1, 2 and 3.

Table 1. The key characteristics of height according to sex and age group

Age	Girls					Boys				
	Sample size	Height	Sd	Min	Max	Sample size	Height	Sd	Min	Max
6	113	123.79	5.60	111.0	139.0	99	125.44	5.19	113.5	137.0
7	1041	128.24	5.60	110.5	146.5	936	129.61	5.71	111.5	150.0
8	667	132.89	5.92	115.3	148.8	705	133.73	5.94	114.0	155.5
9	1063	139.45	6.44	121.0	162.0	1052	139.85	6.23	119.0	162.0
10	450	145.13	7.47	120.5	172.0	456	144.60	6.38	126.0	165.0
11	1298	152.16	7.28	128.5	175.0	1114	151.35	7.10	129.9	175.6
12	536	157.70	6.90	134.0	173.0	569	156.23	7.98	134.0	183.5
13	1355	163.39	6.43	141.0	183.5	1227	165.51	8.73	140.0	193.0
14	637	165.20	6.54	143.5	185.0	680	169.62	8.65	142.7	195.0
15	1829	167.13	5.95	149.3	188.0	1596	176.75	7.34	151.5	200.0
16	978	167.63	6.24	149.5	189.0	831	178.55	7.10	154.5	200.0
17	588	168.62	5.88	150.0	188.0	373	180.82	6.24	162.0	202.0
18	762	168.23	5.88	149.0	184.0	523	181.28	6.53	160.0	200.1
19	165	168.25	5.94	152.5	181.5	121	182.57	6.53	166.4	198.0

Table 2. The key characteristics of weight according to sex and age group

Age	Girls					Boys				
	Sample size	Weight	Sd	Min	Max	Sample size	Weight	Sd	Min	Max
6	113	24.46	3.73	18.0	34.0	99	25.45	4.32	18.0	41.0
7	1041	27.05	4.85	15.8	44.5	936	28.30	5.16	13.3	49.0
8	667	29.73	5.65	18.0	47.4	705	30.51	5.93	19.5	55.5
9	1063	33.83	6.75	16.5	57.0	1052	34.70	7.19	19.0	63.0
10	450	37.88	8.89	20.4	69.0	456	38.76	8.63	24.9	65.0
11	1298	43.13	9.28	21.0	75.5	1114	43.24	9.74	26.0	84.0
12	536	47.77	9.76	26.0	80.7	569	46.91	10.36	25.1	84.0
13	1355	53.26	9.56	30.0	87.0	1227	55.06	11.81	28.0	95.5
14	637	55.38	10.01	33.2	87.2	680	58.59	11.56	29.7	98.5
15	1829	58.44	8.90	32.7	91.2	1596	65.84	10.94	35.8	103.0
16	978	58.87	8.35	35.5	88.5	831	67.59	10.59	40.0	104.0
17	588	60.84	8.57	43.0	91.5	373	71.50	11.10	47.0	107.0
18	762	60.76	9.15	41.0	93.0	523	74.12	11.06	47.0	110.0
19	165	61.51	9.18	44.5	88.6	121	73.86	9.10	50.0	104.0

Table 3. The key characteristics of body mass index according to sex and age group

Age	Girls					Boys				
	Sample size	BMI	Sd	Min	Max	Sample size	BMI	Sd	Min	Max
6	113	15.91	1.75	12.39	21.29	99	16.08	1.82	12.50	22.38
7	1041	16.36	2.17	10.33	23.89	936	16.75	2.20	8.79	24.82
8	667	16.75	2.39	11.42	25.13	705	16.97	2.43	12.08	26.02
9	1063	17.29	2.57	8.86	26.66	1052	17.62	2.70	10.74	27.74
10	450	17.82	3.07	12.57	27.78	456	18.42	3.23	13.13	28.15
11	1298	18.49	3.04	11.19	29.34	1114	18.74	3.25	13.04	31.18
12	536	19.08	3.00	12.96	29.36	569	19.07	3.18	12.72	30.70
13	1355	19.88	3.03	12.98	31.22	1227	19.95	3.20	12.91	31.62
14	637	20.24	3.16	14.18	31.25	680	20.25	3.10	14.19	31.12
15	1829	20.90	2.82	13.35	31.44	1596	21.01	2.85	14.28	31.67
16	978	20.93	2.61	13.61	30.09	831	21.15	2.76	15.27	30.94
17	588	21.38	2.67	15.89	30.86	373	21.82	2.89	15.27	32.43
18	762	21.43	2.79	15.37	31.14	523	22.52	2.92	16.07	33.46
19	165	21.68	2.68	16.96	30.45	121	22.15	2.45	15.87	30.30

Centile splines. The graphs of boys' and girls' centile splines of height, weight and BMI are presented in Figures 1, 2 and 3. In all the figures, the centile lines correspond to percentiles 3, 10, 25, 50, 75, 90 and 97. They give a good visual overview of the temporal development of the characteristics. As the percentiles 3 and 97 describe a very small group of subjects, they can behave in a relatively unstable way.

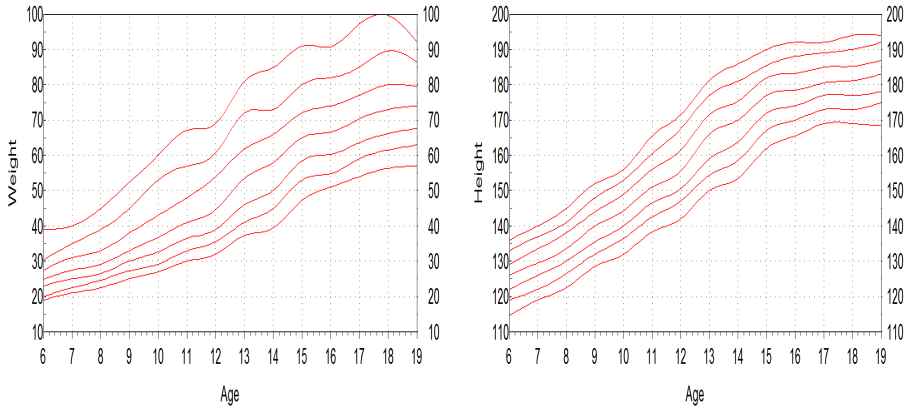


Figure 1. Graphs of centile splines of boys' height and weight

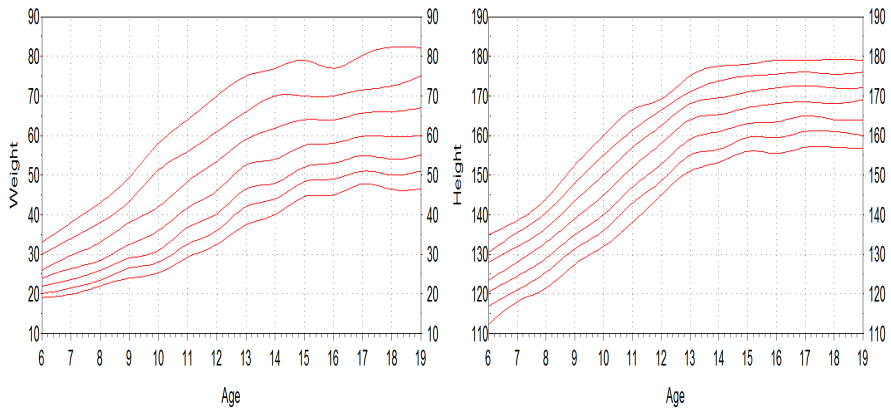


Figure 2. Graphs of centile splines of girls' height and weight

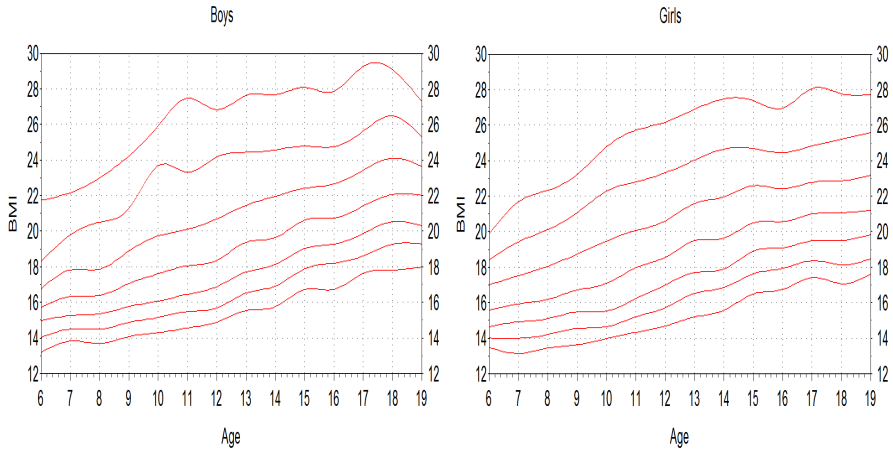


Figure 3. Graphs of centile splines of boys' and girls' body mass index

Growth rate. Figure 4 presents the smoothed graphs of average growth rates at different ages. The girls' growth rate reaches its maximum at the age of 10–11 years, that of the boys at the age of 12–13 years. Compared to the growth rate graphs of 1966, the peaks have moved to approximately a year earlier in both sexes.

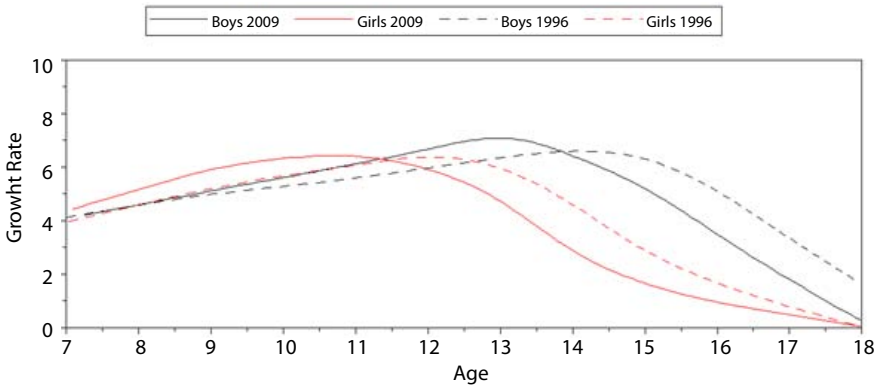


Figure 4. Boys' and girls' growth rates at different ages in 1966 and 2009

Height. Figures 5 and 6 depict changes in boys' and girls' mean height during their school age. The results of the F-test and the t-test comparing the height of both sexes are given in Tables 4 and 5. The mean difference of height is 4.84 cm in boys and 3.86 cm in girls. The greatest changes have happened in boys at age 13 and in girls at age 11–8.71 cm and 7.50 cm respectively. The changes are statistically significant in children aged 6–17 years. In comparisons of dispersion only a few differences proved significant, generally the variability has remained at the same level.

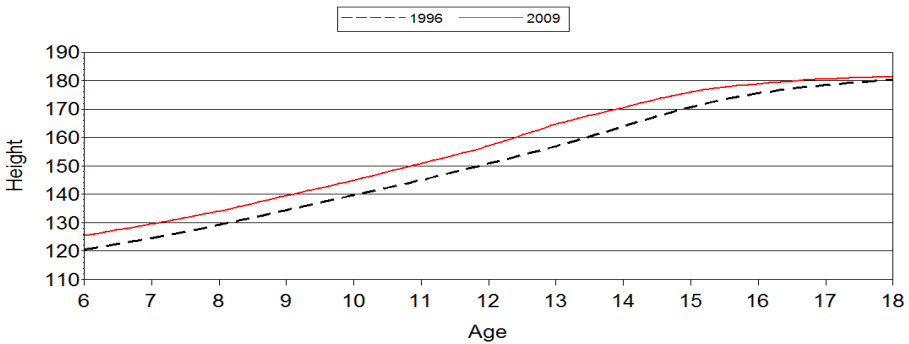


Figure 5. Comparison of boys' mean heights in 1996 and 2009

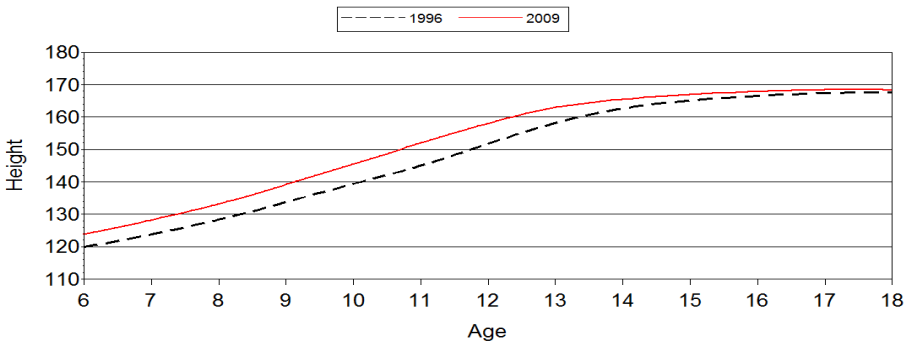


Figure 6. Comparison of girls' mean heights in 1996 and 2009

Table 4. Results of the F-test and the t-test comparing boys' mean height

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	120.58	5.01	125.44	5.19	4.86	0.5969	0.0001	0.6539
7	124.54	5.32	129.61	5.71	5.07	0.2996	0.0001	0.0659
8	129.18	5.86	133.73	5.94	4.54	0.2833	0.0001	0.6863
9	134.57	6.33	139.85	6.23	5.28	0.2779	0.0001	0.6106
10	139.69	6.39	144.60	6.38	4.91	0.3623	0.0001	0.9767
11	144.92	6.59	151.35	7.10	6.43	0.3131	0.0001	0.0212
12	150.94	7.69	156.23	7.98	5.29	0.4198	0.0001	0.3270
13	156.80	9.13	165.51	8.73	8.71	0.4038	0.0001	0.1608
14	163.79	9.14	169.62	8.65	5.83	0.4871	0.0001	0.1551
15	170.86	8.50	176.75	7.34	5.89	0.3649	0.0001	0.0001
16	175.69	7.76	178.55	7.10	2.86	0.4365	0.0001	0.0327
17	178.52	7.19	180.82	6.24	2.30	0.5617	0.0001	0.0170
18	180.27	6.25	181.28	6.53	1.01	0.5480	0.0657	0.4813

Table 5. The results of the F-test and the t-test comparing girls' mean height

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	119.89	5.59	123.79	5.60	3.90	0.6332	0.0001	0.9659
7	123.80	5.04	128.24	5.60	4.44	0.2729	0.0001	0.0036
8	128.20	5.71	132.89	5.92	4.69	0.2853	0.0001	0.2964
9	133.76	6.06	139.45	6.44	5.69	0.2781	0.0001	0.0534
10	139.61	7.11	145.13	7.47	5.52	0.4174	0.0001	0.2208
11	144.66	7.40	152.16	7.28	7.50	0.3209	0.0001	0.5945
12	151.79	7.95	157.70	6.90	5.91	0.4132	0.0001	0.0003
13	158.15	7.48	163.39	6.43	5.24	0.3082	0.0001	0.0001
14	162.94	7.00	165.20	6.54	2.26	0.3773	0.0001	0.0848
15	164.92	6.12	167.13	5.95	2.21	0.2722	0.0001	0.3732
16	166.59	6.21	167.63	6.24	1.04	0.3314	0.0017	0.9038
17	167.41	5.90	168.62	5.88	1.21	0.3964	0.0023	0.9369
18	167.62	5.54	168.23	5.88	0.61	0.3963	0.1241	0.2292

Weight. The comparison of both boys' and girls' mean weight with the results of the previous study shows an increase (Figures 7 and 8). Tables 6 and 7 show the results of the F-test and the t-test comparing the weight in both sexes. The mean difference in weight is 5.90 kg in boys and 4.20 kg in girls. In boys, all the changes are statistically significant. In girls, they are significant at the ages of 6–16 years. The comparison of dispersions of boys' weight shows that dispersion has increased in all age groups and all the differences except two are statistically significant. In girls, dispersion has increased among the 6–11-year-olds.

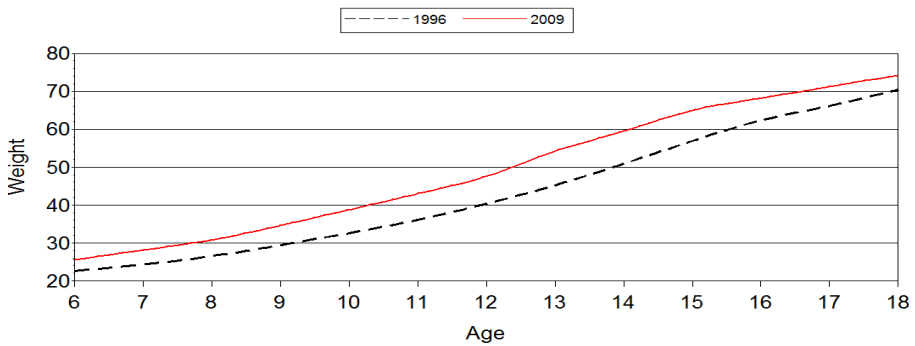


Figure 7. Comparison of boys' mean weights in 1996 and 2009

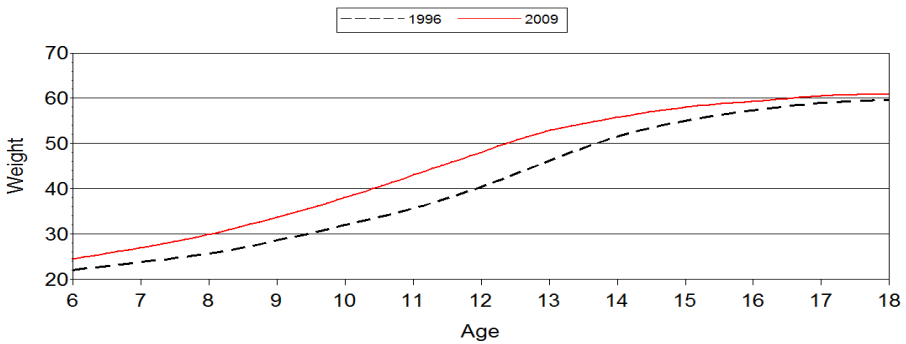


Figure 8. Comparison of girls' mean weights in 1996 and 2009

Table 6. The results of the F-test and the t-test comparing boys' mean height

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	22.66	2.93	25.45	4.32	2.79	0.3993	0.0001	0.0001
7	24.35	3.31	28.30	5.16	3.95	0.2461	0.0001	0.0001
8	26.36	3.84	30.51	5.93	4.15	0.2314	0.0001	0.0001
9	29.52	4.73	34.70	7.19	5.18	0.2734	0.0001	0.0001
10	32.60	5.45	38.76	8.63	6.16	0.3778	0.0001	0.0001
11	36.04	6.31	43.24	9.74	7.20	0.3858	0.0001	0.0001
12	40.34	8.24	46.91	10.36	6.57	0.4921	0.0001	0.0001
13	45.19	9.75	55.06	11.81	9.87	0.5029	0.0001	0.0001
14	50.84	9.91	58.59	11.56	7.75	0.5908	0.0001	0.0001
15	56.84	9.63	65.84	10.94	9.00	0.5046	0.0001	0.0002
16	62.72	10.27	67.59	10.59	4.87	0.6251	0.0001	0.4746
17	65.82	9.59	71.50	11.10	5.68	0.8982	0.0001	0.0172
18	70.57	8.69	74.12	11.06	3.55	0.8898	0.0001	0.0001

Table 7. The results of the F-test and the t-test comparing girls' mean height

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	22.07	3.25	24.46	3.73	2.39	0.3937	0.0001	0.0847
7	23.92	3.56	27.05	4.85	3.13	0.2233	0.0001	0.0001
8	25.45	3.97	29.73	5.65	4.28	0.2331	0.0001	0.0001
9	28.62	4.92	33.83	6.75	5.21	0.2660	0.0001	0.0001
10	32.09	6.08	37.88	8.89	5.79	0.4143	0.0001	0.0001
11	35.51	7.19	43.13	9.28	7.62	0.3737	0.0001	0.0001
12	40.35	8.88	47.77	9.76	7.42	0.5027	0.0001	0.0134
13	46.12	9.43	53.26	9.56	7.14	0.4308	0.0001	0.6739
14	51.62	9.61	55.38	10.01	3.76	0.5454	0.0001	0.3000
15	55.07	9.34	58.44	8.90	3.37	0.4100	0.0001	0.1282
16	57.24	8.32	58.87	8.35	1.63	0.4437	0.0002	0.9294
17	59.12	8.46	60.84	8.57	1.72	0.5991	0.0042	0.4629
18	59.56	8.23	60.76	9.15	1.20	0.6097	0.0396	0.0328

Body mass index. Figures 9 and 10 illustrate boys' and girls' body mass indices compared to 1996. The results of the F-test and the t-test comparing the body mass indices are presented in Tables 8 and 9. In boys, the differences in

mean BMIs are statistically significant in all age groups except the 6-year-olds. The changes are considerable – the mean difference is 1.30 units. The change is the greatest in the 10-year-olds. In girls, the changes are somewhat smaller than in boys – the mean difference is 0.99 units. The changes are statistically significant at ages 6–15. The comparisons of boys’ BMI dispersion by F-tests show clear changes. Dispersion has increased in all age groups except the 16- and the 18-year-olds. In girls, the differences are statistically significant only at ages 7–11 years where dispersion has increased. In girls, the dispersion of body mass indices was quite high in the previous study already. This may be one of the reasons why the changes are not as great as in boys. Now the values of standard deviations are similar in both sexes.

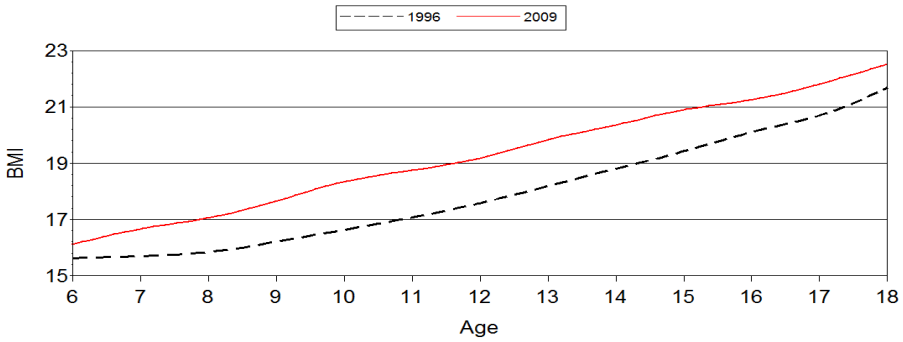


Figure 9. Comparison of boys’ mean BMI in 1996 and 2009

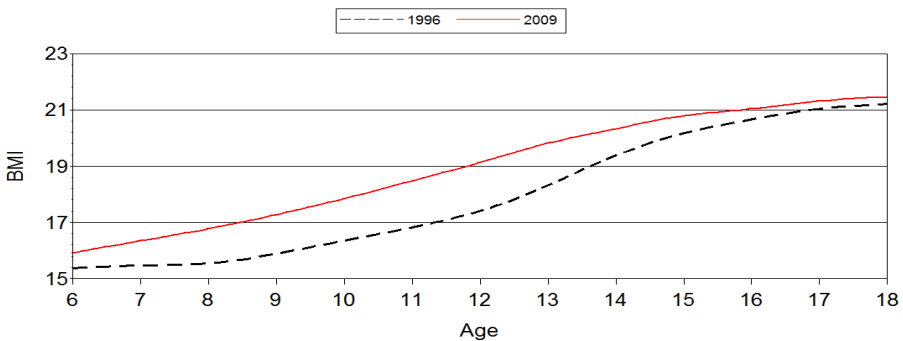


Figure 10. Comparison of girls’ mean BMI in 1996 and 2009

Table 8. The results of the F-test and the t-test comparing boys' mean BMI

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	15.63	1.43	16.08	1.82	0.45	0.1847	0.0292	0.0031
7	15.72	1.44	16.75	2.20	1.03	0.1054	0.0001	0.0001
8	15.77	1.56	16.97	2.43	1.20	0.0947	0.0001	0.0001
9	16.24	1.77	17.62	2.70	1.38	0.1026	0.0001	0.0001
10	16.63	1.91	18.42	3.23	1.79	0.1374	0.0001	0.0001
11	17.06	2.06	18.74	3.25	1.68	0.1282	0.0001	0.0001
12	17.56	2.36	19.07	3.18	1.51	0.1463	0.0001	0.0001
13	18.20	2.55	19.95	3.20	1.75	0.1350	0.0001	0.0001
14	18.81	2.51	20.25	3.10	1.44	0.1562	0.0001	0.0001
15	19.37	2.33	21.01	2.85	1.64	0.1294	0.0001	0.0001
16	20.20	2.65	21.15	2.76	0.95	0.1624	0.0001	0.3423
17	20.59	2.28	21.82	2.89	1.23	0.2278	0.0001	0.0001
18	21.72	2.51	22.52	2.92	0.80	0.2391	0.0004	0.0150

Table 9. The results of the F-test and the t-test comparing girls' mean BMI

Age	Mean (1996)	Std	Mean (2009)	Std	Difference	Std Err	Pr > t	Pr > F
6	15.35	1.50	15.91	1.75	0.56	0.1836	0.0025	0.0545
7	15.55	1.68	16.36	2.17	0.81	0.1015	0.0001	0.0001
8	15.44	1.66	16.75	2.39	1.31	0.0981	0.0001	0.0001
9	15.92	1.90	17.29	2.57	1.37	0.1018	0.0001	0.0001
10	16.37	2.08	17.82	3.07	1.45	0.1424	0.0001	0.0001
11	16.83	2.27	18.49	3.04	1.66	0.1213	0.0001	0.0001
12	17.36	2.70	19.08	3.00	1.72	0.1541	0.0001	0.0060
13	18.32	2.85	19.88	3.03	1.56	0.1344	0.0001	0.0584
14	19.38	3.00	20.24	3.16	0.86	0.1715	0.0001	0.1872
15	20.21	2.97	20.90	2.82	0.69	0.1302	0.0001	0.1026
16	20.60	2.63	20.93	2.61	0.33	0.1393	0.0179	0.8338
17	21.10	2.63	21.38	2.67	0.28	0.1788	0.1176	0.7580
18	21.18	2.60	21.43	2.79	0.25	0.1875	0.1828	0.1545

CONCLUSIONS

Estonian children's mean height has increased in both boys and girls in the age groups of 6–17-year-olds. Present-day children aged 18 years, however, are not taller than children in 1996. Thus, children have started to grow more quickly

and reach their final height earlier. Dispersion has not changed, and there is reason to believe that the increase in height has been even in children with both quicker and slower growth rates.

In boys, mean height has increased in all age groups and in girls at the ages of 6–16 years. The range of changes is also noteworthy. As a comparison, it can be said that between the studies conducted in 1956 and 1996, the changes in mean body mass were 0.5–2 kg. Thus, Estonian schoolchildren have become considerably heavier. In boys, the dispersion of weights has increased in nearly all age groups and in girls at ages 7–11.

The mean body mass index has increased in boys aged 7–18 years and in girls aged 6–16 years. The changes are considerable. Consequently, the schoolchildren have become stronger and more corpulent in their body build. The increase of dispersion in nearly all age groups of boys suggests that the proportion of children with big BMI has grown.

The results of the study lead to the conclusion that children's physical development is quicker nowadays. Therefore, the mean height and weight have increased in all age groups. In relation to height, the increase in weight has been quicker, and this is reflected in the increase of the body mass index. Nearly all the changes are statistically significant; thus, the Estonian children do not correspond well to the standards of 1996. The need for updating the growth charts is statistically substantiated. The results confirm the results of earlier analysis based on a similar dataset [2].

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