ORIGINAL ARTICLE

Establishing cross-sectional curves for height, weight, body mass index and waist circumference for 4- to 18-year-old Greek children, using the Lambda Mu and Sigma (LMS) statistical method

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Abstract

Background: We sought to establish cross-sectional curves for body weight, height, body mass index (BMI), and waist circumference for 4- to 18-year-old Greek boys and girls, using the empirical distribution and the Lambda Mu and Sigma (LMS) statistical method.

Methods: From March 2014 to May 2014, a total of 473,837 boys and girls aged 4 to 18 years who attended school in Greece were enrolled. The studied sample was representative, in terms of age-sex distribution and geographical region. Anthropometric indices measurements (i.e., height, weight and waist circumference) were performed and BMI was calculated and used to calculate normative values, using the percentiles of the empirical distributions and the LMS method.

Results: Updated growth references for 4- to 18-year-old Greek children tabulated as critical percentiles and LMS values from 3 to 97 (P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90}, P_{97}) and smoothed curves are presented. Positive secular trends of height, weight and waist circumference were observed in children and adolescents 4 to 18 years old (all p values <0.001). At all ages, boys had higher anthropometric measurements than girls (all p values <0.01). Compared to 1998 data, mean height and weight were greater in 2014 for boys and girls at all ages.

Conclusion: Current national percentile curves for anthropometric indices could provide a more accurate estimation to assess physical growth in Greek children and adolescents. Hippokratia 2015; 19 (3): 239-248.

Keywords: Body mass index, BMI, cutoff point, children, Greece

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Background

It has been widely adopted that children's growth is determined by both genetic and environmental factors. The assessment of somatic growth by objective anthropometric indices (e.g., body weight, height and waist circumference) is essential in child's care to evaluate the nutritional status and to identify growth failure. Specifically, growth references help public health professionals to evaluate the growth status of a child and to diagnose undernutrition, overweight and obesity, and other growth-related conditions among children[1-2]. The pattern of children's growth changes with time and hence it is recommended that references should be updated regularly[3]. Moreover, various ecological, environmental and genetic factors have been associated with children's growth. Therefore, it is important for each country to use growth curves specific to the population of interest.

In Greece, the need to develop appropriate updated growth references for children and adolescents has been motivated by two contemporary events: the public health concern over the rising incidence of childhood obesity[4] and the lack of national representative epidemiologic data regarding anthropometric measurements of children for these age groups. The currently existing growth reference curves in use in Greece are based on data collected by the First Paediatric Clinic of the University of Athens in 2001[5]. To the best of our knowledge, Greece lacks current national cut-offs for a wide age-range. In addition to the aforementioned considerations, during the past decades, different methodologies have been used to develop children's growth curves, mainly based on the reference range of the distribution. However, when the measurement is strongly related to another factor, like height and age in children, the age-dependent, smoothed, centile

curves looks much more appropriate since they incorporate the dynamic of the covariate. Another issue was the lack of normality. Cole et al assumed an underlying normal distribution of the anthropometric measurements, in which case a power transformation would render to a normal distribution[6]. Thus, a three-parameter method was proposed, the Lambda Mu and Sigma (LMS) statistical method, where L reflects the Box-Cox power lambda, M the arithmetic mean of the measurement and S the coefficient of variation σ[7]. This methodology has been adopted by the International Obesity Task Force (IOTF) in order to develop global growth curves for children and adolescents[8].

Therefore, the aim of the present study was to establish updated age-sex specific normative values of anthropometric indices and to evaluate sex- and age-related differences, using both percentiles and Z-score values in a nationwide sample of 4- to 18-year-old children and adolescents.

Methods and Procedures

Participants

Population-based, representative data were derived from a nationwide school-based survey under the auspices of the Ministry of Education. Specifically, anthropometric, physical activity, nutrition, and physical fitness data along with information on age and sex were collected from March 2014 to May 2014. In total, 473,837 (51% boys and 49% girls) children aged 4 to 18 years old from public and private schools agreed to participate in the study (participation rate was 40% of the total population). The working sample was representative of the entire Greek population (chi-square p-value as compared to the current sample with the age-sex distribution of all Greek areas = 0.93). The participation rates assured the proportional enrolment of children based on the urban/rural areas student population distribution.

Measurements

Demographic information of students (e.g., school, class, gender and date of birth) was obtained from each school headmaster. Children's height, weight and waist circumference were measured in the morning, using a standardized procedure. Data collection in each school was completed in one working day. Children were instructed to wear little clothing and stand with feet close together, arms at the side so body weight was evenly distributed. The exact ages of the participants were calculated from birth and examination dates. Weight was measured in the standing upright position with electronic scales with a precision of 100 g. We determined standing height to the nearest 0.5 cm with the child's weight being equally distributed on the two feet, head back and buttock on the vertical land of the height gauge. We calculated BMI as the ratio of body weight to the square of height (kg/m^2). Waist circumference was measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest, using a flexible measure to the nearest 0.1 cm. All measurements were repeated; if the measurements were within 1 cm of one another, the average was calculated. All anthropometric measurements were performed by trained professionals (teachers of Physical Education). Specifically, measurements were performed by one teacher of Physical Education in each class. All Physical Education professionals were instructed through a detailed and extended manual of operations and followed a standardized procedure of measurements in order to minimize the potential interrate variability among schools. The Physical Education teachers were first trained by a school advisor of Physical Education for accurate anatomical landmarks, subject positioning and measurement techniques. Verbal informed consent was obtained, for each child to participate in the measurements, from physical education teachers. As the measurements were included in an obligatory school program, verbal informed consent was considered sufficient. Ethical approval for the survey was granted by the Review Board of the Ministry of Education and the Ethical Committee of Harokopio University (decision No 37/20-02-2013).

Data Analysis

Comparisons of the anthropometric measurement data between boys and girls were performed using the independent samples t-test, after testing for equality of variances using the Levene test. Comparisons of percentile values of anthropometric measurement data between both calculation methods were performed using the paired samples t-test. We performed the tests for sex-specific trends in the anthropometric measurements using linear regression analysis (with lag 0). We evaluated serial dependency using the partial autocorrelation function; no autocorrelation was observed for various lags tested. Age-sex specific distributions and percentiles were calculated using two methods: using the empirical distribution of the data to calculate the 3th, 10th, 25th, 50th, 75th, 90th, and 97th percentiles; also, using the LMS method proposed by Cole et al[7]. The LMS method was used in order to smooth the age-dependent skewness usually observed in anthropometric values. In this method, the data were normalized using the Box-Cox power transformation. The principle idea of the LMS method is to power-transform the measurement, i.e., height here, and to use the coefficient of variation (CV =standard deviation/mean) of the raw data. The optimal Box-Cox power λ is the one that gives the lowest CV[7]. Thus, the LMS method calculates the best power (L), the best mean (M) and CV (S) in each series of measurements at a specific age. All statistical analyses were performed using the SPSS program (version 18; SPSS Inc., Chicago, IL, USA). The LMSchartmaker[9] and the LMSgrowth[10] freeware packages were used to calculate L, M and S values at ages 4 to 18 based on Greek reference values.

Comparison with international growth references

The 3rd, 50th, and 97th percentiles of the constructed growth charts of the present study were selected to be

compared with the corresponding percentiles of the United States' Centers for Disease Control and Prevention 2000 growth charts[11], based on comparability with regard to statistical methods used and on historical usage.

Results

In Tables 1-4 are presented normative anthropometric indices (height, weight, waist circumference and BMI) for 4- to 18-year-old children in Greece, by gender and age, as tabulated critical percentiles and LMS values from 3 to 97 (P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90}, P_{97}). Also presented are the gender- and age-specific LMS values for the above anthropometric indices. Figure 1 shows the smoothened weight, height, BMI and waist circumference curves for Greek boys and girls using 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentiles. A secular trend of increasing weight, height and waist circumference was observed in all Tables and Figures (all p-values <0.001). For each of the anthropometric indices, measurements were higher in boys compared with girls, at all ages (all p-values <0.01). In girls, height and waist circumference measurements seemed to tend to peak at about the age of 17 years, although the age range was deteriorated.

In order to investigate potential differences between percentile values from the two methods, comparisons by anthropometric measurement were performed. Data analysis did not reveal any significant differences between critical percentiles and LMS percentiles in height and weight, while in waist circumference, critical and LMS percentiles differed significantly (p =0.002).

Moreover, aiming to investigate potential differences between 2014 and 1998 in weight and height in Greek boys and girls aged 8, 9 and 10 years (data not shown)[12], we compared mean values by gender. In 8-year-old boys, height and weight increased from 130.9 ± 6.1 cm and 30.0 ± 6.3 kg in 1998 to 134.2 ± 6.3 cm and 32.6 ± 7.5 kg in 2014, respectively (p-values <0.001). Correspondingly, mean values of height and weight for 8-year-old girls increased from 129.8 ± 5.9 cm and 29.3 ± 6.1 kg in 1998 to 133.2 ± 6.3 cm and 31.9 ± 7.3 kg in 2014, respectively (p-values <0.001). In 9-year-old boys, height and weight increased from 136.1 ± 6.5 cm and 33.5 ± 7.2 kg in 1998 to 139.6 ± 6.6 cm and 36.7 ± 8.5 kg in 2014, respectively while the correspondence values in girls increased from 135.0 ± 6.6 cm and 32.8 ± 7.2 kg in 1998 to 138.9 ± 6.9 cm and 35.9 ± 8.5 kg in 2014 (all p-values <0.001). In 10-year-old boys, height and weight increased from 141.1 ± 6.6 cm and 37.0 ± 8.1 kg in 1998 to 144.9 ± 7.0 cm and 41.9 ± 9.9 kg in 2014, respectively while in girls, height increased from 140.9 ± 7.0 cm to 145.5 ± 7.4 cm and weight from 36.5 ± 8.1 kg 41.0 ± 9.8 kg, over the same time period (all p-values <0.001). Furthermore, BMI increased from 17.4 ± 2.8 kg/m^2, 18.0 ± 3.1 kg/m^2 and 18.5 ± 3.2 kg/m^2 in 1998 to 18.0 ± 3.1 kg/m^2, 18.7 ± 3.4 kg/m^2 and 19.4 ± 3.7 kg/m^2 in 2014 in 8-year-old, 9-year-old and 10-year-old boys, respectively (all p-values <0.001), and from 17.3 ± 2.8 kg/m^2, 17.9 ± 3.1 kg/m^2 and 18.3 ± 3.2 kg/m^2 in 1998 to 17.9 ± 3.2 kg/m^2, 18.5 ± 3.4 kg/m^2 and 19.2 ± 3.7 kg/m^2 in 2014 in 8-year-old, 9-year-old and 10-year-old girls, respectively (all p-values <0.001).

Figure 2 shows the 3rd, 50th, and 97th percentiles for height, body mass, BMI of Greek children against U.S.[11] counterparts. Third percentile curves for weight, height and BMI of the present Greek sample were comparable with those of U.S. sample (CDC) 2000. On the other hand, as depicted in 50th and 97th percentiles, Greek boys were on average heavier, while only somewhat taller, resulting in having greater BMI than their U.S. counterparts. A similar trend was observed in Greek girls, however after puberty differences between Greek and U.S. girls are minimized.

Discussion

The aim of the present study was to develop up-to-date age- and sex-specific anthropometric indices of normative values for Greek children and adolescents aged 4-18 years and to compare specific percentile values from two widely-applied estimation methods: the frequency percentiles and the LMS smoothed percentiles. This study provides current information on normative values of somatic growth. These values could be used as approximate indicative values to compare anthropometric indices scores of children from other countries similar to Greece: i.e., a developed country with a population predominately Caucasian. These data can also be used as benchmark values for health screening and surveillance of children and adolescents 4 to 18 years old in Greece.

Childhood obesity is a growing public health problem worldwide. More than 20% of children are classified as overweight/obese according to the International Task Force Organisation, and percentages seem to be rising[12-13]. The prevalence of paediatric overweight among school-aged children is high across Europe, as well as in other developed countries, with a particularly worrying prevalence in Greece. Indicatively, 29.5% of 10- to 12-year-old boys and girls were classified as overweight according to a cross-sectional, population-based survey from Greece[14]. The data from our study confirm this troubling prevalence in our country, indicating a secular trend of increasing weight and waist circumference among school-aged children over the long term. The alarming magnitude of the paediatric overweight/obesity problem highlights the need for country-specific policies and interventions in order to confront this epidemic in European schoolchildren.

Interestingly, the distribution of childhood obesity differs significantly between northern and southern European countries, with the countries of the south (e.g., Greece, Italy, Cyprus, Spain) showing the highest proportions[15-16]. Despite the economic crisis of recent years, there is an inverse relationship between the prevalence of overweight and obesity in children and family income or financial status[13-14]. Moreover, the finding for each of the anthropometric indices - that the measurements were higher in boys compared with girls at all ages - is in accordance with other relative studies, where weight and height also increased with age and boys were also taller and heavier than girls

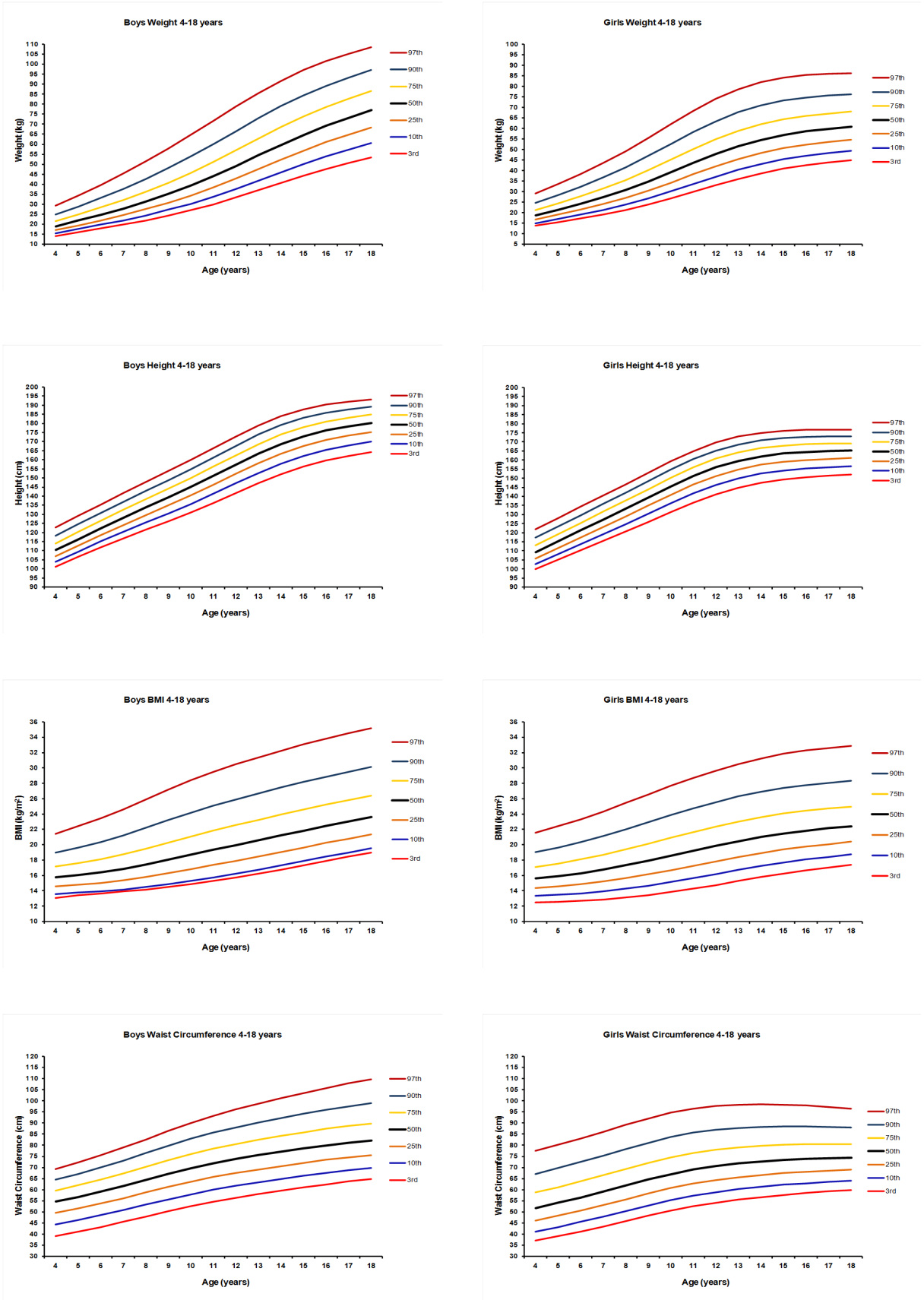

Figure 1: Growth curves for weight, height, body mass index and waist circumferences percentiles for boys (left) and girls (right) using the Lambda Mu and Sigma (LMS) method. * Age: completed age, e.g., 4 years = 4.00–4.99 years.

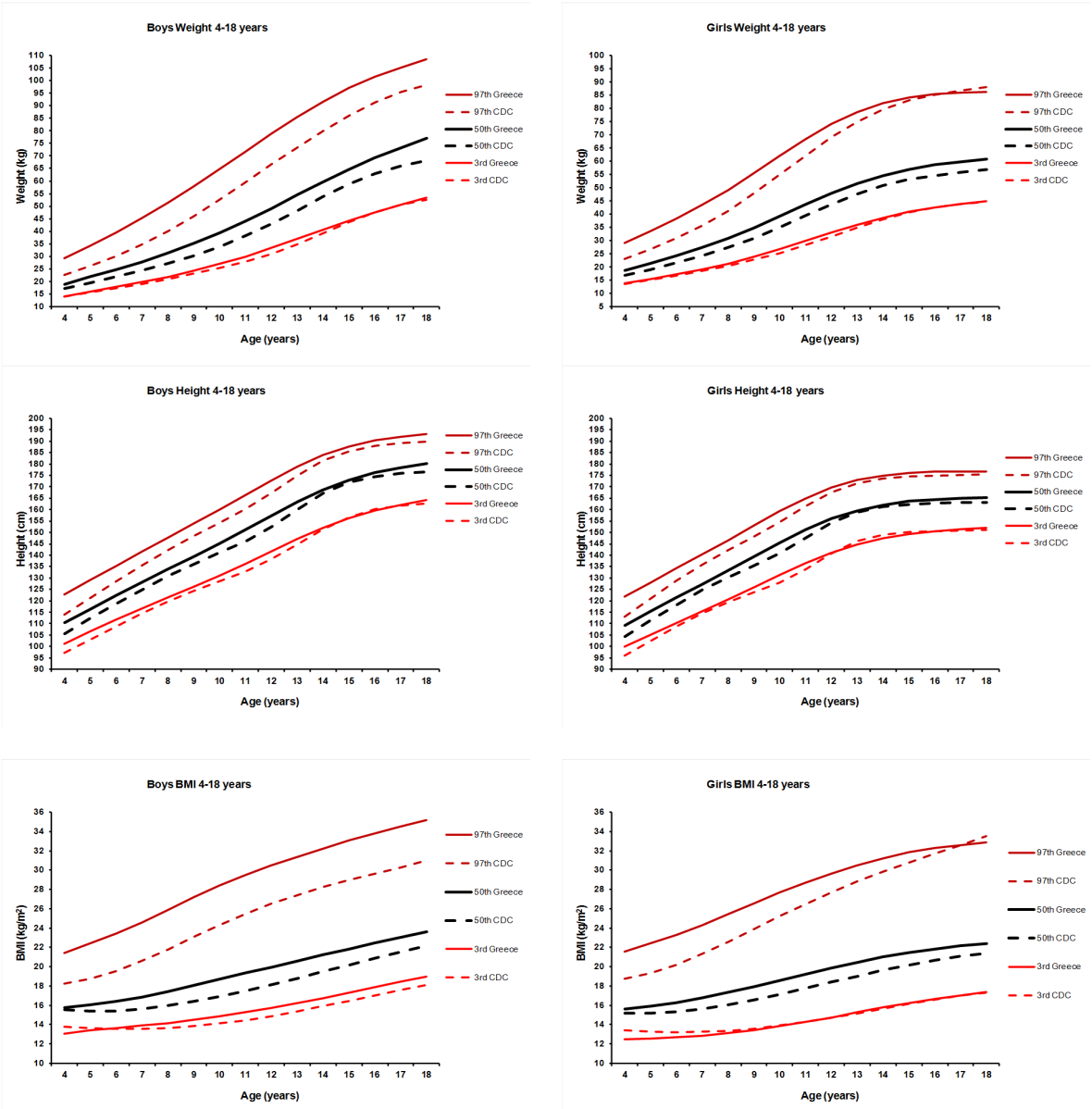

Figure 2: Comparison of the age and sex-specific 3rd, 50th, and 97th weight, height and body mass index percentile curves for the United States' Centers for Disease Control and Prevention 2000 reference (CDC) and present study (Greece) among boys (left) and girls (right) aged 4-18 years. * Age: completed age, e.g., 4 years = 4.00–4.99 years.

in all, similar, age groups[15-17]. Likewise, it is a common finding throughout the last three decades that weight and height have shown an increasing trend in developed and developing countries worldwide, beginning from early childhood. Indicatively in Greece, for 8-year-old boys and girls, height and weight increased significantly from 1998 to 2014 (e.g., 97th percentiles of height and weight for boys were 143 cm and 45 kg, respectively, in 1998, increasing to 146 cm and 50 kg in 2014, while corresponding values for girls were 141 cm and 43 kg in 1998, increasing to 145 cm and 48.2 kg in 2014), suggesting that these increases contributed to the aforementioned rise in the corresponding BMI values (23.9 vs. 25.3 kg/m^2 for boys and 23.6 vs. 24.9 kg/m^2 for girls). Interestingly, large cohort studies indicate continuous gains in both of the aforementioned anthropometric characteristics at all ages, with peak values observed in younger ages, especially in developed countries[18]. Finally, it is well accepted that a child's growth is an indicator of the health and wellbeing of a society[19]. Monitoring growth to identify health- or nutrition-related problems is an important task of health care professionals. Unfortunately, Greece has no representative national sample of children which has been regularly updated. Therefore, the results from the present study provide a very useful public health tool by which health care professionals can assess and evaluate the growth status of children nationwide. However, as previously suggested[20], using the present developed BMI curves may underestimate the

Table 1: Body height (cm) percentiles, LMS values and LMS summary statistics by sex and age in 4- to 18-year-old Greek children and adolescents.[1]

		Percentiles (SPSS)							LMS method									
Age	**N**	P3	P10	P25	P50	P75	P90	P97	3th	10th	25th	50th	75th	90th	97th	L	M	S
Boys																		
4	3157	101	104	107	110	114	117	121	101.2	104.0	107.0	110.3	114.0	118.1	122.8	-2.31	110.3	0.047
5	6550	106	109	113	116	120	123	127	106.5	109.5	112.8	116.3	120.2	124.5	129.1	-1.73	116.34	0.047
6	24240	112	116	119	123	126	130	134	111.7	115.0	118.5	122.3	126.4	130.7	135.4	-1.16	122.32	0.048
7	28848	117	121	124	128	132	136	140	116.6	120.3	124.1	128.1	132.4	136.9	141.6	-0.62	128.12	0.048
8	28637	123	126	130	134	138	142	146	121.4	125.4	129.5	133.8	138.2	142.9	147.7	-0.15	133.80	0.049
9	28254	128	131	135	139	144	148	152	126.2	130.5	134.9	139.4	144.1	148.8	153.7	0.27	139.44	0.049
10	26863	132	136	140	145	149	154	159	131.1	135.7	140.4	145.2	150.0	154.9	159.9	0.61	145.21	0.050
11	26359	137	141	145	150	156	160	166	136.2	141.2	146.2	151.2	156.2	161.3	166.3	0.89	151.21	0.050
12	17126	142	146	151	157	163	168	174	141.7	147.0	152.2	157.4	162.5	167.7	172.8	1.15	157.37	0.049
13	16142	147	152	158	164	170	175	180	147.2	152.6	158.0	163.3	168.6	173.8	178.9	1.42	163.35	0.049
14	14273	154	160	165	171	176	180	185	152.1	157.8	163.3	168.6	173.9	179.0	184.0	1.75	168.64	0.047
15	10669	160	165	170	174	179	184	188	156.3	162.1	167.6	172.9	178.0	183.0	187.8	2.12	172.89	0.045
16	8236	163	168	172	177	181	185	190	159.6	165.4	170.8	176.1	181.0	185.8	190.4	2.54	176.05	0.043
17	2958	165	169	173	177	182	185	190	162.1	167.9	173.2	178.3	183.1	187.6	192.0	3.00	178.30	0.041
18	424	165	169	173	177	182	185	191	164.3	170.0	175.3	180.2	184.8	189.1	193.2	3.48	180.19	0.039
Girls																		
4	3091	100	103	106	109	112	116	119	99.8	102.7	105.8	109.2	113.0	117.2	121.9	-2.04	109.2	0.049
5	6136	105	108	111	115	119	122	126	105.1	108.2	111.6	115.2	119.2	123.4	128.0	-1.31	115.2	0.049
6	22925	112	115	118	122	125	129	132	110.2	113.7	117.4	121.3	125.3	129.6	134.2	-0.59	121.3	0.049
7	27789	116	120	123	127	131	135	139	115.3	119.2	123.1	127.2	131.5	135.8	140.3	0.07	127.2	0.049
8	26883	122	125	129	133	137	141	145	120.5	124.7	128.9	133.3	137.6	142.1	146.5	0.65	133.3	0.049
9	26683	127	130	134	139	143	148	152	125.8	130.3	134.9	139.4	143.9	148.4	152.9	1.13	139.4	0.049
10	25943	132	136	140	145	150	155	160	131.2	136.1	140.8	145.5	150.1	154.7	159.2	1.51	145.5	0.048
11	25537	138	142	147	152	157	162	166	136.4	141.5	146.4	151.2	155.9	160.5	164.9	1.81	151.2	0.048
12	15889	143	148	153	157	162	166	170	141.0	146.2	151.2	156.0	160.7	165.2	169.6	2.06	156.0	0.047
13	14678	148	152	157	161	165	169	173	144.7	149.8	154.8	159.6	164.2	168.6	172.9	2.26	159.6	0.044
14	13284	151	155	159	163	167	171	175	147.4	152.5	157.4	162.0	166.5	170.8	175.0	2.43	162.0	0.042
15	9889	152	156	160	164	168	172	176	149.2	154.2	159.0	163.6	167.9	172.1	176.1	2.57	163.6	0.042
16	8290	153	157	160	164	168	172	176	150.5	155.4	160.0	164.4	168.7	172.7	176.6	2.70	164.4	0.039
17	2881	153	157	160	164	169	172	176	151.3	156.1	160.6	164.9	169.0	172.9	176.7	2.86	164.9	0.038
18	282	153	157	160	164	168	173	179	152.0	156.6	161.1	165.3	169.2	173.0	176.7	3.04	165.3	0.037

[1]L: skew, LMS, Lambda Mu and Sigma, M: median, P: percentile, S: coefficient of variation, SPSS: Statistical Package for the Social Sciences.

Table 2: Body weight (kg) percentiles, LMS values and LMS summary statistics by sex and age in 4- to 18-year-old Greek children and adolescents.[1]

		Percentiles (SPSS)							LMS method									
Age	**N**	P3	P10	P25	P50	P75	P90	P97	3th	10th	25th	50th	75th	90th	97th	L	M	S
Boys																		
4	3157	15.0	16.0	17.5	19.2	21.4	24.0	28.0	14.1	15.5	17.0	19.0	21.5	24.8	29.3	-1.08	18.99	0.17
5	6550	16.5	18.0	19.5	21.4	24.0	27.0	32.0	16.0	17.5	19.4	21.8	24.8	28.8	34.3	-1.01	21.79	0.18
6	24370	18.5	20.0	22.0	24.3	27.8	32.2	37.9	17.8	19.7	21.9	24.7	28.3	33.0	39.6	-0.94	24.71	0.19
7	28974	20.0	22.0	24.3	27.4	32.0	37.0	43.3	19.8	21.9	24.6	27.8	32.1	37.6	45.3	-0.86	27.85	0.20
8	28743	22.3	24.7	27.0	31.0	36.7	43.0	50.0	21.9	24.4	27.5	31.3	36.2	42.6	51.4	-0.78	31.31	0.21
9	23245	25.0	27.2	30.2	35.0	41.6	48.4	56.0	24.2	27.2	30.7	35.1	40.7	48.0	57.9	-0.69	35.12	0.21
10	26970	27.0	30.0	34.0	39.3	46.8	54.6	63.3	26.9	30.2	34.3	39.4	45.7	53.9	64.6	-0.60	39.36	0.21
11	26483	30.0	33.4	37.8	44.0	52.2	61.0	70.5	29.9	33.7	38.4	44.1	51.1	60.1	71.6	-0.52	44.06	0.21
12	17126	33.0	37.0	42.0	49.4	58.2	68.0	78.1	33.3	37.6	42.8	49.1	56.9	66.5	78.7	-0.44	49.14	0.21
13	16142	37.0	42.0	48.0	56.0	65.0	76.0	87.3	36.9	41.8	47.6	54.5	62.8	73.0	85.5	-0.36	54.45	0.21
14	14272	43.0	48.1	54.2	62.0	71.3	82.0	94.0	40.7	46.0	52.3	59.7	68.5	79.0	91.7	-0.28	59.71	0.20
15	10668	47.7	53.0	58.8	66.0	76.0	87.3	100	44.3	50.1	56.8	64.7	73.8	84.5	97.0	-0.18	64.66	0.20
16	8235	51.8	57.0	62.3	70.0	78.5	89.0	101	47.6	53.9	61.0	69.2	78.5	89.2	101.5	-0.07	69.17	0.19
17	2956	53.0	58.0	64.0	71.0	80.0	91.0	103	50.6	57.3	64.8	73.2	82.6	93.2	105.1	0.06	73.18	0.18
18	424	50.0	57.0	67.0	71.0	81.0	95.0	107	53.4	60.5	68.3	77.0	86.5	97.0	108.4	0.19	77.00	0.18
Girls																		
4	3091	14.5	15.7	17.0	18.9	21.0	23.6	27.0	13.7	15.0	16.7	18.7	21.2	24.6	29.2	-0.97	18.67	0.18
5	6136	16.0	17.1	19.0	21.0	23.9	27.0	31.1	15.4	17.0	19.0	21.3	24.4	28.3	33.6	-0.87	21.35	0.19
6	23045	18.0	19.4	21.0	24.0	27.1	31.2	36.3	17.2	19.1	21.4	24.2	27.7	32.3	38.4	-0.76	24.18	0.19
7	27891	19.7	21.4	23.8	27.0	31.2	36.2	42.1	19.1	21.3	24.0	27.3	31.4	36.6	43.5	-0.66	27.30	0.20
8	26884	21.4	24.0	26.6	30.7	36.0	41.9	48.2	21.3	23.9	27.0	30.8	35.5	41.5	49.2	-0.57	30.83	0.21
9	26881	24.0	26.5	30.0	34.6	40.9	47.5	55.0	23.8	26.8	30.4	34.8	40.2	46.9	55.4	-0.49	34.81	0.21
10	26057	26.5	30.0	34.0	39.7	46.8	54.0	62.3	26.7	30.1	34.2	39.2	45.2	52.6	62.0	-0.43	39.17	0.21
11	25326	30.0	33.9	38.3	45.0	52.5	60.5	70.0	29.8	33.6	38.2	43.6	50.2	58.3	68.3	-0.40	43.63	0.21
12	15900	33.5	38.0	43.0	49.0	56.8	65.0	75.0	32.9	37.1	42.0	47.8	54.9	63.4	74.0	-0.39	47.84	0.20
13	14677	38.0	42.1	47.0	53.2	60.5	69.5	80.0	35.9	40.3	45.4	51.5	58.8	67.7	78.5	-0.40	51.53	0.19
14	13284	41.4	45.4	50.0	55.8	63.0	71.5	82.0	38.6	43.1	48.3	54.6	62.0	71.0	81.9	-0.42	54.55	0.19
15	9888	44.0	47.6	52.0	58.0	65.0	74.0	85.0	40.8	45.3	50.6	56.9	64.3	73.3	84.1	-0.44	56.88	0.18
16	8290	45.0	48.7	53.0	58.0	65.5	74.0	85.0	42.4	47.0	52.3	58.6	65.9	74.7	85.4	-0.45	58.56	0.17
17	2881	44.6	48.9	53.0	58.0	65.0	74.0	86.0	43.7	48.3	53.6	59.7	67.0	75.6	85.9	-0.44	59.74	0.17
18	282	43.3	47.9	51.0	57.0	65.0	76.0	88.0	44.8	49.3	54.6	60.7	67.9	76.3	86.3	-0.42	60.74	0.16

[1]L: skew, LMS: Lambda Mu and Sigma, M: median, P: percentile, S: coefficient of variation, SPSS: Statistical Package for the Social Sciences.

Table 3: BMI (kg/m^2) percentiles, LMS values and LMS summary statistics by sex and age in 4- to 18-year-old Greek children and adolescents.[1]

		Percentiles (SPSS)							LMS method									
Age	**N**	P3	P10	P25	P50	P75	P90	P97	3th	10th	25th	50th	75th	90th	97th	L	M	S
Boys																		
4	3142	13.0	14.0	14.9	15.9	17.1	18.7	21.2	12.84	13.64	14.60	15.74	17.17	18.99	21.44	-1.64	15.74	0.12
5	6340	13.2	14.0	14.9	15.9	17.2	19.0	21.5	12.90	13.76	14.79	16.05	17.61	19.64	22.39	-1.55	16.05	0.13
6	24240	13.3	14.1	15.0	16.2	17.8	20.1	23.0	12.98	13.92	15.04	16.40	18.12	20.36	23.42	-1.45	16.40	0.14
7	28848	13.4	14.3	15.3	16.6	18.7	21.2	24.0	13.15	14.16	15.37	16.86	18.75	21.21	24.60	-1.35	16.86	0.15
8	28637	13.7	14.6	15.7	17.3	19.7	22.4	25.3	13.39	14.49	15.81	17.43	19.48	22.18	25.88	-1.25	17.43	0.16
9	28254	14.0	15.0	16.2	18.0	20.7	23.4	26.4	13.70	14.88	16.31	18.06	20.29	23.20	27.18	-1.16	18.06	0.16
10	26863	14.4	15.4	16.7	18.7	21.6	24.5	27.6	14.05	15.32	16.84	18.71	21.09	24.18	28.41	-1.08	18.71	0.17
11	26359	14.7	15.8	17.1	19.4	22.3	25.3	28.5	14.43	15.76	17.37	19.34	21.83	25.08	29.49	-1.03	19.34	0.17
12	17029	15.1	16.2	17.6	19.8	22.9	26.0	29.4	14.85	16.23	17.90	19.95	22.54	25.90	30.46	-1.01	19.95	0.17
13	15994	15.8	16.9	18.4	20.5	23.6	26.8	30.5	15.33	16.75	18.46	20.57	23.23	26.69	31.38	-1.02	20.57	0.17
14	14123	16.4	17.6	19.0	21.1	24.0	27.4	31.2	15.86	17.31	19.06	21.21	23.92	27.45	32.25	-1.05	21.21	0.17
15	10535	17.0	18.2	19.6	21.6	24.5	28.0	31.8	16.42	17.88	19.65	21.83	24.58	28.17	33.06	-1.09	21.83	0.17
16	8111	17.6	18.8	20.3	22.2	24.8	27.8	31.9	16.97	18.45	20.23	22.43	25.21	28.84	33.80	-1.13	22.43	0.16
17	2928	17.6	19.0	20.6	22.4	25.0	28.3	32.3	17.51	19.00	20.80	23.02	25.82	29.48	34.50	-1.17	23.02	0.16
18	418	17.5	19.0	20.6	22.9	25.5	28.7	32.6	18.05	19.55	21.36	23.59	26.41	30.10	35.16	-1.21	23.59	0.16
Girls																		
4	3080	12.8	13.8	14.7	15.8	17.1	18.8	21.3	12.45	13.32	14.35	15.59	17.11	19.03	21.56	-1.36	15.59	0.13
5	5974	13.0	13.9	14.8	15.9	17.4	19.2	21.6	12.55	13.48	14.58	15.91	17.56	19.65	22.40	-1.27	15.91	0.14
6	22925	13.0	13.9	14.8	16.1	17.8	20.1	22.5	12.67	13.67	14.86	16.29	18.07	20.33	23.30	-1.17	16.29	0.15
7	27787	13.2	14.1	15.1	16.6	18.7	21.1	23.8	12.86	13.94	15.22	16.77	18.68	21.12	24.33	-1.08	16.77	0.15
8	26799	13.4	14.4	16.0	17.3	19.7	22.2	24.9	13.12	14.28	15.66	17.33	19.39	22.01	25.44	-0.98	17.33	0.16
9	26607	13.7	14.7	16.0	17.9	20.5	23.1	25.9	13.44	14.68	16.15	17.94	20.15	22.93	26.56	-0.91	17.94	0.17
10	25943	14.0	15.1	16.5	18.6	21.4	24.1	27.0	13.82	15.13	16.69	18.58	20.91	23.85	27.66	-0.86	18.58	0.17
11	25185	14.5	15.6	17.1	19.2	22.0	25.0	28.1	14.25	15.62	17.25	19.22	21.65	24.72	28.68	-0.84	19.22	0.17
12	15781	15.0	16.2	17.7	19.8	22.4	25.4	28.9	14.74	16.15	17.83	19.86	22.37	25.53	29.63	-0.85	19.86	0.17
13	14520	15.8	17.0	18.5	20.5	23.1	26.3	30.0	15.27	16.70	18.40	20.47	23.03	26.28	30.50	-0.89	20.47	0.17
14	13159	16.4	17.7	19.1	21.0	23.5	26.5	30.4	15.78	17.22	18.93	21.02	23.61	26.91	31.24	-0.96	21.02	0.16
15	9772	17.0	18.2	19.6	21.5	23.9	27.2	31.2	16.25	17.68	19.39	21.47	24.07	27.40	31.83	-1.03	21.47	0.16
16	8189	17.2	18.4	19.7	21.5	24.0	27.1	30.9	16.65	18.07	19.76	21.83	24.43	27.77	32.26	-1.12	21.83	0.16
17	2853	17.1	18.4	19.8	21.5	23.9	27.1	31.2	17.01	18.41	20.08	22.14	24.72	28.06	32.60	-1.20	22.14	0.15
18	277	16.5	18.0	19.5	21.0	24.1	27.2	32.5	17.35	18.73	20.39	22.42	24.98	28.33	32.90	-1.28	22.42	0.15

[1]BMI: body mass index, L: skew, LMS: Lambda Mu and Sigma, M: median, P: percentile, S: coefficient of variation, SPSS: Statistical Package for the Social Sciences.

Table 4: Waist circumference (cm) percentiles, LMS values and LMS summary statistics by sex and age in 4- to 18-year-old Greek children and adolescents[1]

		Percentiles (SPSS)							LMS method									
Age	**N**	P3	P10	P25	P50	P75	P90	P97	3th	10th	25th	50th	75th	90th	97th	L	M	S
Boys																		
4	3142	48.0	50.0	53.0	55.0	58.0	62.0	68.0	39.2	44.4	49.6	54.6	59.6	64.5	69.3	1.18	54.62	0.14
5	6340	49.0	52.0	54.0	57.0	60.0	65.0	71.0	41.2	46.4	51.6	56.8	62.0	67.1	72.3	1.04	56.81	0.14
6	24240	49.0	52.0	55.0	58.0	62.0	68.0	76.0	43.2	48.5	53.8	59.1	64.5	69.9	75.4	0.91	59.11	0.14
7	28848	50.3	53.0	56.0	60.0	65.2	72.0	80.0	45.5	50.7	56.1	61.7	67.3	73.0	78.9	0.77	61.65	0.14
8	28637	52.0	55.0	58.0	63.0	69.5	77.0	84.0	47.9	53.2	58.7	64.4	70.3	76.4	82.6	0.63	64.37	0.14
9	28254	54.0	57.0	60.0	66.0	73.0	81.0	88.0	50.3	55.6	61.2	67.1	73.3	79.7	86.4	0.49	67.10	0.13
10	26863	55.2	59.0	63.0	68.4	77.0	85.0	92.0	52.6	57.9	63.6	69.7	76.1	82.9	90.0	0.35	69.67	0.13
11	26359	57.0	61.0	65.0	71.0	80.0	88.0	96.0	54.6	60.0	65.7	71.9	78.6	85.7	93.3	0.22	71.92	0.13
12	17029	58.0	62.0	67.0	73.0	81.0	90.0	98.0	56.4	61.7	67.5	73.8	80.6	88.0	96.1	0.08	73.81	0.13
13	15994	60.0	65.0	69.0	75.0	83.0	92.0	101	58.0	63.3	69.1	75.5	82.5	90.2	98.6	-0.06	75.50	0.13
14	14123	63.0	67.0	71.0	77.0	85.0	94.0	103	59.6	64.8	70.6	77.1	84.2	92.2	101.1	-0.20	77.06	0.13
15	10535	64.8	69.0	73.0	78.0	86.0	96.0	106	61.0	66.2	72.0	78.5	85.8	94.1	103.4	-0.34	78.53	0.13
16	8111	66.3	70.0	74.0	80.0	86.0	95.0	106	62.4	67.6	73.4	79.9	87.4	95.9	105.7	-0.48	79.93	0.13
17	2928	66.0	70.0	75.0	80.0	87.0	96.3	107	63.7	68.7	74.5	81.1	88.7	97.5	107.8	-0.61	81.08	0.13
18	418	67.3	71.0	75.0	81.0	88.0	97.0	110	64.8	69.8	75.5	82.1	89.8	98.9	109.7	-0.75	82.15	0.13
Girls																		
4	3080	47.0	50.0	52.0	54.0	58.0	62.0	66.0	37.0	41.1	46.0	51.8	58.7	67.1	77.6	-0.51	51.75	0.18
5	5974	48.0	51.0	53.0	56.0	60.0	65.0	71.0	39.0	43.2	48.2	54.1	61.1	69.7	80.3	-0.53	54.09	0.18
6	22925	48.0	51.0	54.0	57.0	62.0	68.0	74.0	41.1	45.5	50.5	56.5	63.7	72.4	83.1	-0.55	56.52	0.17
7	27787	49.7	52.0	55.0	59.8	65.0	71.8	78.0	43.4	47.8	53.0	59.1	66.4	75.2	86.0	-0.57	59.13	0.17
8	26799	50.7	54.0	57.0	62.0	69.0	75.0	82.0	45.8	50.3	55.6	61.8	69.3	78.2	89.1	-0.59	61.85	0.16
9	26607	52.0	55.0	59.0	65.0	72.0	79.0	86.0	48.2	52.8	58.2	64.6	72.1	81.1	92.0	-0.61	64.55	0.16
10	25943	54.0	57.0	61.5	68.0	75.0	82.2	90.0	50.5	55.2	60.7	67.0	74.6	83.7	94.6	-0.63	67.05	0.15
11	25185	55.0	59.0	64.0	70.0	77.8	85.0	92.0	52.5	57.2	62.7	69.1	76.6	85.7	96.5	-0.65	69.11	0.15
12	15781	57.0	60.8	65.0	71.0	78.0	86.0	94.0	54.1	58.9	64.3	70.6	78.1	87.0	97.7	-0.67	70.65	0.15
13	14520	58.0	62.0	66.0	72.0	79.0	87.0	95.5	55.5	60.2	65.5	71.8	79.1	87.8	98.2	-0.69	71.80	0.14
14	13159	59.0	63.0	67.0	72.2	79.7	87.5	96.0	56.6	61.2	66.5	72.7	79.8	88.3	98.4	-0.71	72.68	0.14
15	9772	60.0	64.0	68.0	73.9	80.0	89.0	98.0	57.6	62.2	67.4	73.3	80.3	88.5	98.3	-0.73	73.35	0.13
16	8189	60.8	64.0	68.0	74.0	80.0	88.0	97.5	58.5	62.9	68.0	73.8	80.6	88.5	97.9	-0.75	73.84	0.13
17	2853	60.0	64.0	68.0	74.0	80.0	88.0	98.0	59.2	63.5	68.5	74.1	80.6	88.3	97.2	-0.77	74.12	0.12
18	277	60.0	64.0	68.0	74.0	81.0	90.0	97.0	59.9	64.1	68.9	74.4	80.6	87.9	96.5	-0.78	74.35	0.12

[1]L: skew, LMS: Lambda Mu and Sigma, M: median, P: percentile; S: coefficient of variation, SPSS: Statistical Package for the Social Sciences

true prevalence of overweight and obesity in Greece from now on, as the reference population used is not the "ideal" population due to the increasing obesity and overweight trends in Greece. This is a common problem in developing growth curves; however, our data are unique in Greece, regarding age, national gender and geographical distribution and methodology used. "Freezing" our curves from now on, as suggested for UK charts, may minimize these limitations in the future[21].

The present study has several strengths. The sample is representative of the national gender and geographical distribution, as we studied almost 40% of the total population of 4- to 18-year-old children and adolescents in Greece. The study was performed in children 4-18 years. This age range is an advantageous period in the life of children and adolescents at which to apply effective strategies to prevent and improve obesity levels. The use of the widely-adopted LMS method for growth curves and the huge, nationwide representative sample of about 475,000 participants aged 4 to 18 years old used here guarantee the generalization of the results. Finally, the presented data were derived using the same standardized procedures in all schools. There are also limitations in our study design. Although a common, validated protocol was used to evaluate anthropometric indices measurements in all schools, a large number of experienced, professional physical educators participated as evaluators in the study and different brands of electronic scales and stadiometers were used. In order to minimize the variability among the different experimenters, all educators were instructed through a detailed and extended manual of operations and followed a standardized procedure of measurement. Even so, some variability in measurement may still exist. Finally, the cross-sectional design of our study cannot provide causal relationships, but only hypotheses for further research.

Conclusions

In conclusion, we established sex- and age-specific normative anthropometric indices values for children and adolescents aged 4 to 18 years old living in Greece. These findings may help policy makers to evaluate somatic growth and obesity levels and to design appropriate health-related educational programs for the young.

Conflict of interest

Authors declare that they have no conflicts of interest.

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