PREVALENCE OF OVERWEIGHT AND OBESITY IN 6–15-YEAR-OLD BOYS AND GIRLS BEFORE THE COVID-19 PANDEMIC: RESULTS FROM ANTHROPOLOGICAL RESEARCH 2001–2019 IN THE CZECH REPUBLIC

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SUMMARY

Objective: Childhood overweight and obesity has been a major global problem for a long time, with a steadily increasing prevalence of obesity and a growing number of cases of serious health complications associated with childhood obesity. The main objective of the study is to assess the prevalence of overweight and obesity in boys and girls before the COVID-19 pandemic in the Czech Republic.

Methods: Body height, weight, BMI, and body composition (fat free mass, skeletal muscle mass, body fat, visceral fat area) were assessed in a cohort of 4,475 subjects (2,180 boys and 2,295 girls) aged 6–15 years. Somatic status was assessed by standardized anthropometry and body composition was determined by bioelectrical impedance. The subjects were classified according to BMI in percentile bands (up to 3rd percentile, P3–10, P25–75, P75–90, P90–97, above 97th percentile). Statistical analysis was performed using the software TIBCO Statistica 14.0.015.

Results: During growth, statistical differences in the proportion of fat-free mass and fat fractions were found between boys and girls. In boys, there is an increase in muscle mass, in girls, there is an increase in the proportion of fat fraction. Sexual differentiation is pronounced during pubertal growth. By their BMI, 10.32% of the boys and 7.36% of the girls were categorized as overweight, and 8.12% of the boys and 7.71% of the girls were categorized as obese. Using bioelectrical impedance analysis and the percentage of fat fraction, 21.61% of the boys and 21.87% of the girls were categorized as obese; 5.96% of the boys and 8.19% of the girls were found to have visceral adipose tissue posing a health risk (more than 100 cm^2). From 2002 to 2019, there was a significant increase of 3.72% in the overweight category for boys and 1.36% for girls, while the obesity category showed an increase of 3.62% for boys and 4.91% for girls.

Conclusion: The results confirm the increasing negative trend of overweight and obesity in the BMI and the relative body fat categories in children aged 6–15 years. Greater attention and monitoring of the effectiveness of preventive measures is needed to slow and stop the obesity epidemic which has health, social and economic impacts on the entire society.

Key words: children, body mass index, body composition, body fat, visceral fat area

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INTRODUCTION

In the Czech Republic, the COVID-19 pandemic broke out in March 2020. The pandemic in the period 2020–2022 has significantly affected social life, the economy, political situation and a whole range of other areas, including the lifestyle and health conditions of not only our population, but the population around the world. In 2020, two pandemics, now referred to as the "covidobesity" period, became interlinked, comprising the chronic non-infectious disease of obesity on the one hand and on the other hand the coronavirus disease COVID-19, which is characterised by severe pneumonia, significant morbidity and mortality (1).

The course of the COVID-19 pandemic has also shown that obese patients are at higher risk, with a more severe and prolonged disease progression (2, 3). Paediatric patients have mild symptoms of COVID-19 (4), but if they have other comorbidities such as obesity, kidney and respiratory disease, immune disorders, heart disease, and congenital developmental defects, the likelihood of developing a severe form of COVID-19 increases (5–7).

These studies suggest that obesity and increased visceral adiposity is a significant risk factor for the prognosis of COVID-19 (8). Obesity is a multifactorial endocrine-metabolic disorder characterized by an increase in body fat (9).

Childhood overweight and obesity is a major global problem today, with a steadily increasing prevalence of obesity and a growing number of cases of serious health complications associated with childhood obesity (10). According to a WHO study, from 1975 to 2016 worldwide obesity increased from less than 1% to 8% in boys and to 6% in girls. The 2019 OBCD report states that in 2010, one in five people were obese; currently, there is one obese person for every four (11).

The OECD 2021 report (11) shows that obesity rates in the Czech Republic have increased significantly over the past 15 years and are among the highest in Europe. The rise in adolescent obesity is worrying, with 20% of overweight and obese adolescents aged 15 in 2018, compared to 17.5% in 2014. The prevalence is more noticeable in males (26%) than in females (14%).

The problem of increasing prevalence of obesity in children diagnosed on the basis of BMI is closely linked to the risk of obesity in adulthood (12, 13).

The risk of childhood overweight and obesity continuing to adulthood has been confirmed by scientific studies (14). Obesity in childhood significantly predicts the prevalence of obesity in adulthood. Earlier studies highlighted the fact that overweight and obesity in prepubertal children carries over into adulthood in 70–80% of cases, which leads to a range of serious health, psychological and social complications, longer hospital stays for treatment and higher rates of work disability (13, 14).

Finally, childhood obesity is a risk factor for shortened life expectancy and mortality in adulthood (15). Overweight and obese children and adolescents have more than 40 times higher risk of developing uncontrollable chronic inflammation and metabolic changes that subsequently manifest in the development of cardiovascular disease, energy regulatory disorders, immunodepression, and type 2 diabetes mellitus (16). It has been reported that 50% of obese children are diagnosed with metabolic syndrome (12), posing a risk of early development of atherosclerosis, hypertension, insulin resistance, hepatic steatosis, and liver cirrhosis.

From this perspective, the period of "covidobesity 2020–2022" can be described as a strong endogenous factor that has significantly influenced the impact of individual obesogenic factors on a person's health. During the pandemic, in many countries, including the Czech Republic, there were significant changes in living conditions and lifestyles, especially for children. There was a significant reduction in physical activities, changes in dietary activities, and reduced school attendance. Teaching was mostly done online, the leisure time spent watching mobile phone screens and TV increased, and more leisure time was spent on social media. Gyms, sports grounds, and after-school clubs for children were closed and movement of people was reduced while stress increased, and sleep regulation was disrupted (17, 18).

In summary, there was a significant increase in sedentary lifestyles, to the detriment of physical activity, and changes in dietary habits in the current population (19). During the pandemic, economic and social disparities also became more pronounced in disadvantaged families, where there was a higher increase in childhood obesity due to financial hardship limiting the purchase of fresh and nutritious foods (20, 21).

Currently, the impact of pandemic measures in 2020–2022 on the change in the prevalence of overweight and obesity in the Czech population of children and young people is not yet fully assessed. One of the main reasons for this is that the conditions for anthropological field research outside health care facilities were significantly tightened during and after the COVID-19 pandemic.

For this reason, the main aim of our study is to present the results of a transversal anthropological study of 6–15-year-old boys and girls, which focused on the assessment of somatic parameters and body composition using standardized anthropometry and bioelectrical impedance methods from 2001 to 2019 before the COVID-19 pandemic in the Czech Republic.

MATERIALS AND METHODS

Setting and Subjects

The transversal anthropological research included 4,475 subjects (2,180 boys and 2,295 girls) aged 6–15 years. The research was conducted in 15 primary schools (both elementary and lower-secondary schools) in the Olomouc Region in 2014–2019 and took place before the COVID-19 pandemic in the Czech Republic.

Schools with a sports focus were not included in the research. There was a total of 271 primary schools and 50,813 pupils in primary schools in the Olomouc Region (Regional Administration of the Czech Statistical Office, 2019). The presented findings are based on 5.53% of the primary schools and 0.78% of the pupils in the Olomouc Region.

The research was approved by the Ethics Committee of the Faculty of Health Sciences of Palacký University in Olomouc in accordance with the Declaration of Helsinki (UPOL-4261/1040-2014, UPOL-22862/1040-2015). A total of 4,930 legal representatives (parents) of children were contacted in the course of the research. Measurements were performed solely on the basis of the consent of the subjects and informed consent of their parents. A total of 4,475 (90.77%) parents gave their consent in writing.

Data anonymity was ensured by keeping the measurement parameters of the subjects in a coded form. For each subject, based on their date of birth and day of measurement, we calculated decimal age according to IBP principles (22, 23), where age categories were set by year according to the WHO (e.g., category of 11-year-olds – children aged 10.00–10.99 years). The numbers of subjects in the respective age categories are shown in Table 1.

Table 1. *Numbers of 6–15-year-old boys and girls in the study population*

Sex	Age categories										
	6	7	8	9	10	11	12	13	14	15	Total
Boys	240	343	328	204	167	184	179	186	164	185	2,180
Girls	276	393	275	174	174	193	218	170	178	244	2,295
Total	516	736	603	378	341	377	397	356	342	429	4,475

Measurements

The subjects were measured at the respective primary schools. Boys and girls were measured in separate classrooms that were set aside for this research. The subjects were measured in the morning in their underwear or sportswear and without shoes or socks. One week prior to the actual measurement, all subjects were given information about the measurement procedure and compliance with the measurement conditions according to the manufacturer's instructions (24). Boys were measured by a team of men; girls were measured by a team of women. The research teams were composed of academics and students. Prior to the actual research, a unified methodology was developed for measurements according to the methods of standardized anthropometry (25). Practical training was carried out in anthropometry and the use of the InBody 230 diagnostic device (24, 25). The measurement methodology was developed, and training of the implementation team members was carried out by an experienced anthropologist who was also present during the actual measurement and supervised the accuracy of the measurements (first author of the paper). An anthropometric instrument, the A-226 anthropometer (26), was used to measure body height.

Body height was measured at the wall with an accuracy of 0.1 cm, body weight was measured on an InBody 230 diagnostic device with an accuracy of 0.1 kg. BMI – weight (kg)/height (m^2) – was then calculated using the measured parameters. The classification of subjects into the respective BMI bands was done according to the standards, empirical percentiles, for the Czech population of children and adolescents (27). To assess the nutritional status of the study population of boys and girls, the empirical percentiles and BMI charts from 1991 were used, which are used for the Czech population aged 0–18 years for arbitrary reasons (27, 28). Based on the determination of chronological age and BMI, subjects were classified into individual BMI percentile bands (27, 28): very low weight (up to 3rd percentile), low weight (3rd–10th percentile), decreased weight (10th–25th percentile), normal weight/proportional (25th–75th percentile), increased weight (75th–90th percentile), overweight (90th–97th percentile), and obese (above 97th percentile).

Body composition assessment was performed using the InBody 230, a tetrapolar, 8-touch diagnostic device based on the direct segmental multi-frequency bioelectrical impedance analysis (MF-BIA) method. The impedance method used 2 different frequencies (20 kHz, 100 kHz,) on each of the 5 segments (right arm, left arm, torso, right leg, left leg). Measurements were performed once for each subject under standardized measurement conditions recommended by the manufacturer using the MF-BIA method (InBody 230). Body weight (kg) was measured using the InBody 230 and then fat free mass (FFM) (kg, %), skeletal muscle mass (SMM) (kg, %), body fat mass (BFM) (kg, %), and visceral fat area (VFA) expressed by area in cm^2 were determined.

Based on the diagnosis of body fat percentage, we classified the subjects in the obesity category: in boys >25% fat and in girls >30% fat.

Visceral fat area (cm^2), which is measured as the transverse cross-sectional area in the abdominal region at the level of the L4–L5 lumbar vertebrae, was subsequently assessed at 3 levels: normal values < 100 cm^2, above the health risk threshold 100.01–150 cm^2, extremely above the health risk threshold 150.01 cm^2 and more. The percentage of skeletal muscle in body weight was calculated according to the formula: % SMM = (skeletal muscle mass in kg/body mass in kg) x 100.

The results of body composition analysis obtained from InBody 230 were processed by Lookin'Body 3.0 software (24).

Each subject was given the results of the measurements from the diagnostic device. The measurements were explained, and the BMI was calculated and plotted on a BMI percentile chart. In cases of overweight and obesity, the subjects were given consultation and written contact information for an obesity specialist and an obesity centre.

Statistical Analysis

Statistical characteristics (mean, SD) were calculated for each age category of boys and girls. The normality of the data was verified by the Shapiro-Wilk test.

From the measured parameters, statistical characteristics were calculated for each age category of our study population: M – arithmetic mean, SD – standard deviation, differences between the mean values of the measured parameters for boys and girls in the respective age category (diff). The year-to-year increments in somatic parameters were calculated using one-factor analysis of variance ANOVA, the assessed frequency distribution of boys and girls in the categories of BMI, and the percent of fat and visceral fat area using chi-square test. Comparisons of sexual differentiation between boys and girls at each age were made using a two-sample t-test and means from the 2002 research were compared using a one-sample t-test. Student's t-test for the difference between two relative values was used to compare the percentage of individuals in the BMI categories from 2001–2002 and 2019. Tests were performed at the significance level $^*p<0.05$ and $^{**}p<0.01$. Statistical processing of the results was performed by the software TIBCO Statistica 14.0.015.

RESULTS

Tables 2 and 3 present the statistical characteristics of boys and girls aged 6 to 15 years: body height, weight, body mass index, relative body fat, fat-free mass, skeletal muscle mass, and visceral intra-abdominal fat area. Statistically significant changes occurred in all parameters in boys and girls between 6 and 15 years of age (ANOVA). The year-to-year increments showed statistically significant differences ($p<0.01^{**}$) in body height and weight. There were no statistically significant differences in the year-to-year increments for BMI (kg/m^2), BF (%), FFM (%), SMM (%) and VFA (cm^2). Only in boys between 13 and 15 years of age there was a significant year-on-year increase in SSM (%) (Table 2), while in girls there was a significant increase in BMI (kg/m^2) and VFA (cm^2) between 14 and 15 years of age (Table 3). A comparison of the mean values between 6–15-year-old boys and girls in each category shows a regular alternation of stages of acceleration and deceleration in growth and body structure development. There is marked sexual dimorphism in this age period, with changes happening between the developmental periods of younger school age (prepubertal boys 6–7 to 12 years, girls 6–7 to 10 years), the period of second physical maturity, the period of older school age, and the pubertal growth spurt. The results showed that during the period of growth acceleration in girls, there were no statistically

Table 2. *Body characteristics of 6–15 years old boys (N = 2,180)*

Age (years)	Body height (cm) Mean (SD)	Body mass (kg) Mean (SD)	Body mass index (kg/m²) Mean (SD)	Body fat (%) Mean (SD)	Fat free mass (%) Mean (SD)	Skeletal muscle mass (%) Mean (SD)	Visceral fat area (cm²) Mean (SD)
6	123.90 (4.87)	24.55 (4.23)	15.92 (1.98)	17.43 (6.27)	82.56 (6.27)	40.47 (3.12)	39.26 (19.84)
7	128.95 (5.30)**	27.60 (5.53)**	16.51 (2.53)	18.32 (7.48)	81.67 (7.49)	40.88 (3.65)	39.62 (19.58)
8	133.35 (5.98)**	30.93 (6.93)**	17.28 (3.86)	20.50 (8.51)	79.50 (8.51)	40.32 (4.12)	45.16 (23.59)
9	138.90 (5.68)**	34.33 (7.48)**	17.67 (3.01)	21.04 (8.24)	78.97 (8.25)	40.65 (4.12)	48.75 (25.82)
10	144.70 (6.72)**	38.68 (9.57)**	18.30 (3.51)	21.90 (9.12)	78.10 (9.12)	40.72 (4.48)	55.33 (30.90)
11	150.48 (7.55)**	43.52(10.26)**	19.07 (3.56)	21.59 (9.09)	78.40 (9.09)	41.55 (4.78)	57.94 (32.13)
12	157.24 (8.02)**	48.56 (11.39)**	19.46 (3.47)	19.72 (9.01)	80.29 (9.02)	43.07 (5.14)	57.16 (36.99)
13	163.80 (8.30)**	56.06 (12.78)**	20.77 (3.89)	18.81 (9.53)	81.19 (9.53)	44.36 (5.36)	57.46 (36.38)
14	171.16 (7.35)**	62.66 (14.20)**	21.28 (3.91)	16.58 (8.26)	83.42 (8.26)	46.23(4.59)**	52.74 (36.36)
15	175.70 (4.82)**	66.02 (10.38)	21.37 (3.12)	13.14 (6.35)	86.86 (6.35)	48.74 (3.62)**	41.72 (28.31)

SD – standard deviation; **$p < 0.01$

Table 3. *Body characteristics of 6–15 years old girls (N = 2,295)*

Age (years)	Body height (cm) Mean (SD)	Body mass (kg) Mean (SD)	Body mass index (kg/m²) Mean (SD)	Body fat (%) Mean (SD)	Fat free mass (%) Mean (SD)	Skeletal muscle mass (%) Mean (SD)	Visceral fat area (cm²) Mean (SD)
6	121.43 (4.95)	23.21 (3.70)	16.68 (1.74)	20.05 (6.16)	79.96 (6.16)	38.35 (2.93)	39.71 (16.10)
7	127.39 (4.79)**	26.67 (5.05)**	16.35 (2.40)	21.12 (7.64)	78.87 (7.65)	38.36 (3.67)	39.92 (18.81)
8	133.11 (5.88)**	30.36 (7.03)**	17.00 (2.96)	22.68 (8.62)	77.32 (8.61)	38.76 (4.09)	45.52 (23.98)
9	138.37 (6.54)**	33.14 (7.39)**	17.17 (2.88)	22.42 (8.27)	77.59 (8.27)	39.44 (3.99)	46.46 (25.00)
10	144.22 (6.86)**	37.72 (9.37)**	17.96 (3.34)	23.79 (8.77)	76.21 (8.77)	39.34 (4.34)	52.56 (29.65)
11	151.20 (6.68)**	43.19 (9.70)**	18.77 (3.44)	24.22 (8.03)	75.78 (8.04)	39.81 (4.10)	55.99 (30.11)
12	157.90 (6.48)**	49.89 (11.54)**	19.90 (3.88)	24.48 (7.91)	75.52 (7.91)	40.33 (4.02)	59.24 (33.16)
13	161.70 (5.98)**	53.98 (11.87)**	20.59 (4.12)	25.67 (8.28)	74.34 (8.28)	39.95 (4.30)	65.37 (36.23)
14	164.52 (6.63)**	56.19 (9.37)**	20.72 (3.11)	25.66 (6.96)	74.34 (6.96)	40.22 (3.76)	63.34 (30.27)
15	166.03 (4.94)	61.18 (11.33)**	22.19 (3.92)**	28.61 (7.36)	71.39 (7.36)	38.83 (3.97)	76.62 (35.48)**

SD – standard deviation; **$p < 0.01$

significant differences between the two sexes in body height, weight, BMI, fat free mass, and visceral fat between 9–11 years of age (Table 4 and Fig. 1 and 2). The only parameter that shows a statistically significant difference between boys and girls over the entire follow-up period is the percentage of skeletal muscle mass in body composition (Table 4). Table 4 presents a statistical comparison of the differences in mean somatic parameters and body composition of 6–15-year-old boys in the respective age categories shown in Tables 2 and 3.

Differences in body composition by sex were found throughout the study period in body fat percentage and relative amount of skeletal muscle and fat free mass. It is noteworthy that boys had significantly higher relative skeletal muscle mass in all age groups and significantly lower relative body fat mass throughout the duration of the study. A lower but statistically insignificant percentage of BF was found among boys and girls between 9 and 10 years of age (Table 4). Significant differences in skeletal muscle and body fat, and thus sexual differentiation, are evident from the age of 12 with a tendency toward "gradual widening of the gap". In boys, the FFM (%) and SMM (%) increased, while in girls the percentage of BF and VFA (cm²) increased. The above changes in body composition are due, on the one hand, to the change in body morphology of boys and girls between prepubertal and pubertal periods. In the pubertal period, a second body transformation takes place, culminating in the adolescent period, when the transformation of the child organism into a truly adult organism and the accentuation of sexual dimorphism in morphological and physiological terms are completed (25).

The frequency distribution of boys and girls in the respective BMI categories is shown in Tables 5 and 6, and Figure 3. The analysis of the results of BMI of boys and girls in the individual percentile bands revealed a negative trend, where in the category of normal weight between the 25th–75th percentile there is a marked decrease in individuals from 6 to 15 years, specifically for boys at the age of 6 years from 49.58% to 40.54% and for boys at the age of 15 a decrease of about 9% (Table 5, Fig. 3). For girls, this decrease was much more pronounced. At 6 years, 50% of girls were in the normal weight category, while at 15 years only 35.25% of girls were in the normal weight category, a decrease of about 15% (Table 6, Fig. 3). The opposite trend, i.e., a gradual increase in individuals of both sexes over the period under study, was found in the categories of increased weight, overweight and obesity, with a more pronounced trend in girls compared to boys (Table 5 and 6, Fig. 3).

Table 4. *Comparison of differences in mean somatic parameters and body composition in 6–15 years old boys and girls (N = 4,475)*

Age (years)	Somatic parameters						
	Body height (cm) diff	Body mass (kg) diff	Body mass index (kg/m^2) diff	Body fat (%) diff	Fat free mass (%) diff	Skeletal muscle mass (%) diff	Visceral fat area (cm^2) diff
6	2.47**	1.34**	$0.25^{n.s.}$	−2.61**	2.60**	2.12**	$-0.45^{n.s.}$
7	1.57**	0.94*	$0.16^{n.s.}$	−2.80**	2.80**	2.02**	$-0.30^{n.s.}$
8	$0.24^{n.s.}$	$0.58^{n.s.}$	$0.29^{n.s.}$	−2.18**	2.18**	1.56**	$-0.36^{n.s.}$
9	$0.54^{n.s.}$	$1.18^{n.s.}$	$0.51^{n.s.}$	$-1.38^{n.s.}$	$1.38^{n.s.}$	1.21**	$2.29^{n.s.}$
10	$0.49^{n.s.}$	$0.96^{n.s.}$	$0.34^{n.s.}$	$-1.89^{n.s.}$	$1.89^{n.s.}$	1.38**	$2.77^{n.s.}$
11	$-0.72^{n.s.}$	$0.33^{n.s.}$	$0.30^{n.s.}$	−2.63**	2.62**	1.74**	$1.94^{n.s.}$
12	$-0.67^{n.s.}$	$-1.34^{n.s.}$	$-0.44^{n.s.}$	−4.76**	4.47**	2.74**	$-2.08^{n.s.}$
13	2.10**	$2.07^{n.s.}$	$0.18^{n.s.}$	−6.86**	6.85**	4.42**	$-7.91^{n.s.}$
14	6.64**	6.47**	$0.56^{n.s.}$	−9.08**	9.08**	6.01**	−10.59**
15	9.67**	4.84**	$-0.83^{n.s.}$	−15.47**	15.47**	9.91**	−34.90**

diff – difference in the average values between boys and girls in specific age categories; t-test – level of significance, $^{*}p < 0.05$, $^{**}p < 0.01$, n.s. – not significant

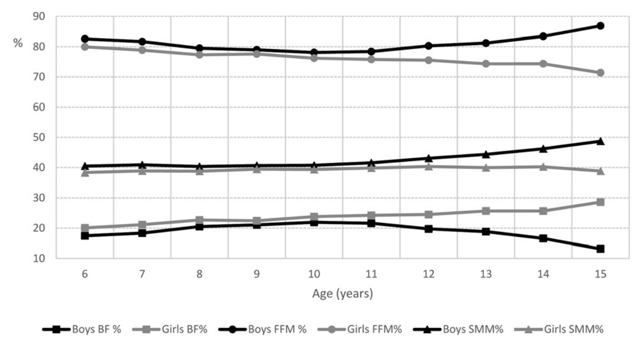

Fig. 1. *Development of fat free mass (%), body fat (%) and skeletal muscle mass (%) in 6–15 years old boys and girls.*

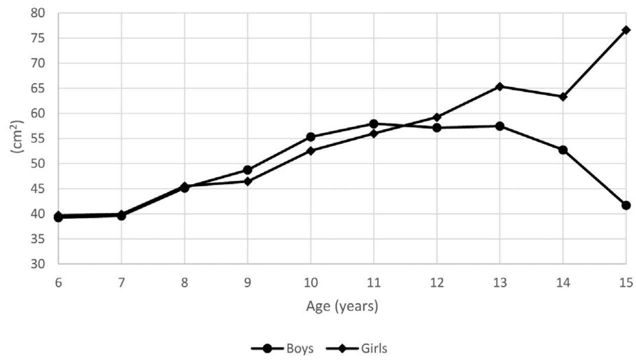

Fig. 2. *Development of visceral fat in 6–15 years old boys and girls expressed in area of visceral fat (cm^2) in the abdomen.*

Table 5. *Categorization by BMI (kg/m^2) of 6–15 years old boys (N = 2,180)*

Age (years)	n	Evaluation of BMI percentiles of boys						
		Very low weight n (%)	Low weight n (%)	Reduced weight n (%)	Normal weight n (%)	Increased weight n (%)	Overweight n (%)	Obesity n (%)
6	240	3 (1.25)	21 (8.75)	39 (16.25)	119 (49.58)	34 (14.17)	14 (5.83)	10 (4.17)
7	343	10 (2.92)	14 (4.08)	53 (15.45)	164 (47.81)	51 (14.87)	29 (8.45)	22 (6.41)
8	328	16 (4.88)	19 (5.79)	40 (12.20)	125 (38.11)	57 (17.38)	35 (10.67)	36 (10.98)
9	204	4 (1.96)	11 (5.39)	27 (13.24)	90 (44.12)	36 (17.65)	19 (9.31)	17 (8.33)
10	167	6 (3.59)	14 (8.38)	23 (13.77)	61 (36.53)	34 (20.36)	18 (10.78)	11 (6.59)
11	184	6 (3.26)	11 (5.98)	25 (13.59)	68 (36.96)	40 (21.74)	19 (10.33)	15 (8.15)
12	179	9 (5.03)	8 (4.47)	20 (11.17)	72 (40.22)	32 (17.88)	20 (11.17)	18 (10.06)
13	186	5 (2.69)	7 (3.76)	25 (13.44)	72 (38.71)	27 (14.52)	30 (16.13)	20 (10.75)
14	164	3 (1.83)	9 (5.49)	20 (12.20)	66 (40.24)	31 (18.90)	17 (10.37)	18 (10.98)
15	185	6 (3.24)	14 (7.57)	23 (12.43)	75 (40.54)	33 (17.84)	24 (12.97)	10 (5.41)
Total	2,180	68 (3.12)	128 (5.87)	295 (13.53)	912 (41.83)	375 (17.20)	225 (10.32)	177 (8.12)

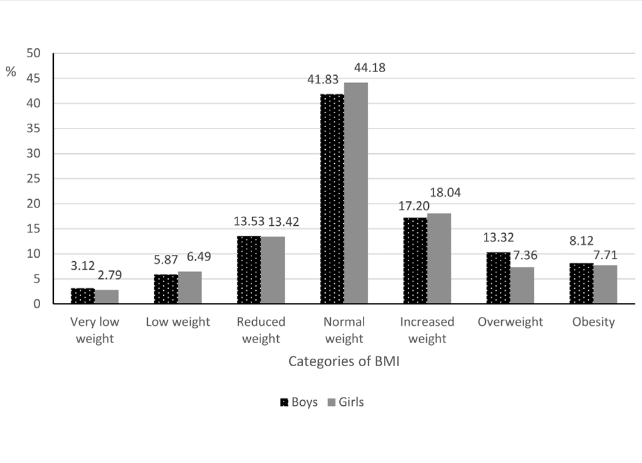

Fig. 3. *Frequency for boys and girls in the percentile bands of BMI categories.*

DISCUSSION

Anthropometric measurements are used as a basis for morphological characterization of the body and they are also used to determine body composition. The most commonly measured anthropometric parameters are body height and weight. These parameters are mainly indicative of physical growth and development (29). However, body weight is also the most important indicator of nutritional status, and in particular the determination of the ratio of fat free mass to the fat component, to which the parameter of body height always belongs. In clinical and paediatric practice, quantification of body fat is difficult. For this reason, the BMI, which is used to assess nutritional status and is a criterion for assessing deviations from the norm, is most commonly used in epidemiological studies to assess the relationship between body height and weight. Assessing BMI relative to age and sex using percentile charts is a practical way to assess the adiposity of the individual being examined. Percentile bands of overweight and obesity are important indicators of adiposity and thus health risks with adverse prognoses (9, 13, 14).

According to Bláha et al. (30), this index in both childhood and adulthood correlates well with both total body fat and body fat as a percentage of total weight. In this context, the authors also state that the values of this index vary according to age in children and adolescents. The authors state that high BMI values do not necessarily imply a high proportion of fat component because it includes all components of body composition. This index does not reflect the ratio of the development of fat free mass to the fat component in a given individual.

Table 7 presents changes in the prevalence in BMI categories in the population of boys in the Olomouc Region from 2001 to 2019. The assignment of subjects to each BMI category in both the 2002 research and the 2019 research was made using the same empirical percentiles as described above.

BMI estimates for boys and girls from 2001–2002 were obtained in the context of transversal anthropological research in the Olomouc Region (31). The population set included a total of 1,198 subjects (621 boys, 577 girls) aged 7 to 15 years. The comparison shows a clear, cautionary upward trend (Table 7), with the proportion of children in the normal weight category (25th–75th percentile) remaining about the same, although with a slight decline. The number of individuals in the category below the 25th percentile is decreasing, but there is a significant increase in individuals in the category above the 75th percentile.

The research in the Olomouc Region in 2001–2002 produced similar results to those of the 6th National Anthropological Research of Children and Youth in 2001 (31). In the Olomouc Region, the proportion of overweight children in boys was 6.60% and in girls 6.00%, and the prevalence of obesity was 4.50% in boys and 2.80% in girls. Results of the 6th 2001 CAV showed a prevalence of 7.50% in children in the overweight category and 6.40% in girls. In the obese category (27, 33), the prevalence was 4.70% in boys and 3.70% in girls.

The results show that over the past 17 years (if we consider the completion of the research in 2002 and in 2019) the number of obese children increased significantly: 3.62% for boys and 4.91% for girls (Table 7). Of note, however, is the category between the 75th–90th percentiles, the increased weight category,

Table 6. *Categorization by BMI (kg/m^2) of 6–15 years old girls (N = 2,295)*

Age (years)	n	Evaluation of BMI percentiles of girls						
		Very low weight n (%)	Low weight n (%)	Reduced weight n (%)	Normal weight n (%)	Increased weight n (%)	Overweight n (%)	Obesity n (%)
6	276	9 (3.26)	20 (7.25)	38 (13.77)	138 (50.00)	55 (19.93)	7 (2.54)	9 (3.26)
7	393	9 (2.29)	29 (7.38)	56 (14.25)	175 (44.53)	75 (19.08)	27 (6.87)	22 (5.60)
8	275	9 (3.27)	14 (5.09)	37 (13.45)	126 (45.82)	44 (16.00)	27 (9.82)	18 (6.55)
9	174	6 (3.45)	13 (7.47)	20 (11.49)	86 (49.43)	22 (12.64)	16 (9.20)	11 (6.32)
10	174	7 (4.02)	10 (5.75)	19 (10.92)	85 (48.85)	29 (16.67)	10 (5.75)	14 (8.05)
11	193	5 (2.59)	11 (5.70)	25 (12.95)	83 (43.01)	39 (20.21)	14 (7.25)	16 (8.29)
12	218	5 (2.29)	12 (5.50)	30 (13.76)	88 (40.37)	45 (20.64)	15 (6.88)	23 (10.55)
13	170	5 (2.94)	10 (5.88)	28 (16.47)	68 (40.00)	29 (17.06)	12 (7.06)	18 (10.59)
14	178	3 (1.69)	11 (6.18)	30 (16.85)	79 (44.38)	24 (13.48)	15 (8.43)	16 (8.99)
15	244	6 (2.46)	19 (7.79)	25 (10.25)	86 (35.25)	52 (21.31)	26 (10.66)	30 (12.30)
Total	2,295	64 (2.79)	149 (6.49)	308 (13.42)	1,014 (44.18)	414 (18.04)	169 (7.36)	177 (7.71)

Table 7. Changes in the percentage of 7–15-year-old boys and girls in the BMI categories in the Olomouc Region between 2001 and 2019

Evaluation of BMI perecentiles	Boys			Girls		
	2001 n (%)	2019 n (%)	diff (%)	2001 n (%)	2019 n (%)	diff (%)
Very low weight	31 (5.00)	65 (3.35)	−1.65**	35 (6.00)	55 (2.72)	−3.28**
Low weight	59 (9.50)	107 (5.52)	−3.98**	56 (9.70)	129 (6.39)	−3.31**
Reduced weight	107 (17.20)	256(13.20)	−4.00**	105 (18.10)	270 (13.37)	−4.73**
Normal weight	274 (44.10)	793 (40.88)	−3.22n.s.	265 (45.70)	876 (43.39)	−2.31n.s.
Increased weight	80 (12.90)	341 (17.58)	+4.68**	68 (11.70)	359 (17.78)	+6.08**
Overweight	41 (6.60)	211 (10.88)	+4.28**	35 (6.00)	162 (8.02)	+2.02**
Obesity	28 (4.50)	167 (8.61)	+4.11**	16 (2.80)	168 (8.32)	+5.52**

diff – difference in percentages between groups of boys and girls in BMI categories between 2001 and 2019, level of significance – **$p < 0.01$, n.s. – not significant

with a 4.30% increase in prevalence in boys (12.90% in 2002 to 17.20% in 2019) and a 6.34% increase in girls (11.70% in 2002 to 18.40% in 2019). We can denote this trend as "hidden, latent, population obesity", which may fully develop in the coming years, especially after the COVID-19 pandemic. In the overweight category (90th–97th percentile), there was an increase of 3.72% in boys and 1.36% in girls (Table 7).

Our results indicate a further negative trend in BMI in children aged 6–15 years compared to the findings of the 6th CAV 2001 (27). The authors state that according to the standards of 1991, when the 5th National Anthropological Research (32, 33) was conducted, the proportion of obese boys 2.26% and girls 1.16% increased, while the proportion of increased weight and overweight children remained unchanged in 2001. Based on the results of the 6th CAV research from 2001, 8.03% of boys and 7.43% of girls in the Czech Republic were overweight, and 5.26% of boys and 4.16% of girls in the 6–15 age group were obese (27).

These results are not supported by our research, as shown in Table 7. The percentage of boys and girls in the increased weight and overweight categories increased significantly. Conversely, in the BMI categories of very low weight, low weight and decreased weight, the opposite shift occurred, i.e., a significant decrease in the percentage of children in these categories between 2001–2019. Similarly, in the BMI category normal weight 25th–75th percentile, there was a decrease in the percentage of children in this category, but it was not statistically significant (Table 7).

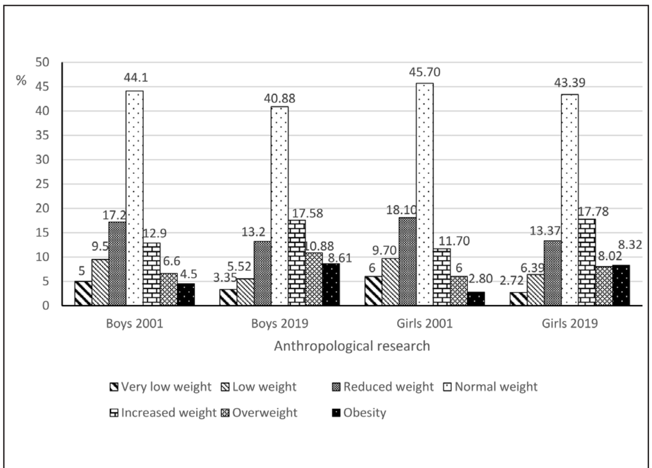

***Fig. 4.** Overall percentage of 7–15-year-old boys and girls in BMI categories.*

Normal or increased BMI values do not always mean a balanced body weight composition. The problematic use of BMI in body composition assessment has been highlighted by a number of experts (34).

Due to the already mentioned risks of determination of BMI body composition, we used the bioelectrical impedance method of body composition analysis in our study, using the InBody 230 diagnostic device (24).

For each individual body composition analysis was performed and the percentage of body fat was determined, an integral part of which is the amount of visceral fat expressed as an area, the so-called visceral fat area (cm^2). Experts agree that if the percentage of fat fraction is above 25% in boys and above 30% in girls, they should be diagnosed as obese (34–36).

Analysis of body composition using bioelectrical impedance has shown that as BMI increases, the percentage of body fat and the amount of intra-abdominal adipose tissue increase, indicating an increasing risk of abdominal type obesity (central obesity) (37, 38).

Table 8 shows that the percentage of obese boys 21.61% and obese girls 21.87%, as determined by the relative proportion of body fat in the same set of subjects, is higher than the percentage of boys (8.12%) and girls (7.71%) in the obesity category, which is determined only by measuring weight and height, then calculating BMI and placing them in the appropriate BMI percentile band (obesity defined as higher than 97th percentile). This finding also confirms the fact that attention should be paid to the overweight category 90th–97th percentile, but also to the increased weight category (75th–90th percentile). The results found (Table 8), i.e., the classification of subjects into the BMI category of obesity (7.91%) and by body fat percentage into the obesity category (21.74%), are very different. They show that BMI cannot be completely considered as an objective criterion for determining obesity. The results show that an increased BMI may not correspond to the amount of total body fat in the subject's body, in agreement with other authors (39).

Table 8 further shows that the percentage of boys and girls in the obesity category by relative amount of fat is 5.03% higher (21.74%) than the total number of boys and girls in the BMI overweight and obesity categories (16.71%). If we consider only the BMI category of obesity (more than 97th percentile),

Table 8. *BMI overweight and obesity categories based on height and weight measurements and obesity category based on body fat and visceral fat by bioelectrical impedance*

Sex	n	Evaluation of BMI percentiles		Body fat	
		Overweight 90th–97th n (%)	Obesity more than 97th n (%)	Body fat more than 25% (boys) 30% (girls) n (%)	Visceral fat area more than 100 cm^2 n (%)
Boys	2,180	225 (10.32)	177 (8.12)	471 (21.61)	130 (5.96)
Girls	2,295	169 (7.36)	177 (7.71)	502 (21.87)	188 (8.19)
Total	4,475	394 (8.80)	354 (7.91)	973 (21.74)	318 (7.11)

the difference is much higher – 13.83% of obese children were measured by relative body fat.

Fat fraction analysis, which includes the determination of visceral fat area (Table 8), points to another important health risk factor. Exceeding the health risk threshold for visceral adipose tissue deposition in the abdomen was found in 5.96% of boys and 8.19% of girls. For completeness, we report that of the total subjects (n = 318) who were found to have above borderline amounts of visceral fat (100.01–150.00 cm^2), there were 16 (12.31%) boys and 11 (5.85%) girls who had values greater than 150.01 cm^2 representing extreme levels of visceral fat area. The distribution of body fat around internal organs is a risk factor that makes organs less sensitive to insulin, with subsequent development of insulin resistance and cardiovascular diseases (40). In particular, visceral adipose tissue produces adipokines, regulatory proteins that play a critical role in the development of metabolic syndrome (41). Visceral adipose tissue has a much higher metabolic turnover and effect than subcutaneous fat and thus poses a higher health risk (40, 42). The chronic, inflammatory response of adipose tissue also contributes significantly to severe cardiovascular diseases in obese individuals (39).

The reported trend of increasing prevalence of obese boys and girls in the study population confirms the earlier statement of experts that the percentage of obese children in the Czech Republic more than doubled from 1991 to 2011 (43).

The WHO COSI study from 2015–2017 reports the following results in the Czech Republic in the group of 7-year-old children (N = 1,002): 11% of boys obese, 23% of boys overweight, and 6% of girls obese and 19% of girls overweight. The study (44), which was based on a survey of 3,517 children (ages 5, 7, 9, 11, 13, 15 and 17 years, boys n = 1,759, girls n = 1,758) in paediatric outpatient clinics in the Czech Republic in 2019 and 2021, found a significant increase in the BMI category of overweight and obesity in both sexes at ages 7, 9, 11 and 13 years. They conclude that there was an alarming increase in the percentage of severely obese boys aged 9 and 11 years during follow-up in 2019 and 2021. In 2021, 17.1% of 7-year-old boys were found to be overweight and 16.0% obese, while 19.3% of girls were overweight and 9.5% obese. These results were determined according to the WHO methodology and the definition of Z-scores (44).

Epidemiological studies confirm a gradual increase in the prevalence of obesity in other countries. In Australia, there has been a 3–4.6-fold increase in the prevalence of childhood obesity, in the UK a 2.8-fold increase in obesity, and in the USA, there has been a 3-fold increase in obesity over the past 25 years (45). Italian data from the 2015–2017 Okkio alla Salute research document that 20.4% of children aged 8 to 9 years are overweight and 9.4% are obese (46). They state that most clinical forms of childhood obesity are caused by unhealthy eating habits, sedentary lifestyle with prolonged time spent in front of the television, reduced sleep time, and poor lifestyle choices.

Obesity is not only associated with a different body composition but is often accompanied by a number of metabolic abnormalities compared to normal weight individuals. In particular, abdominal fat deposition, the so-called android type of obesity, is associated with the risk of hyperinsulinism, diabetes mellitus, hypertriacylglycerolemia, risk of atherosclerosis and hypertension, insulin and triacylglycerol blood levels, and higher blood pressure values (12, 13, 16).

Our results and the cited studies point to the disturbing fact that there is a significant increase in the number of obese children in the prepubertal and puberty periods, which carries the risk of earlier onset of health complications in adulthood related to the excessive development of body fat in relation to the fat free mass represented in body weight (13).

Obesity also brings other long-term complications in the growth and development of boys and girls. In girls, obesity is associated with early onset of puberty and menarche; in boys, obesity affects pubertal maturation in boys, where it can lead to precocious or delayed puberty. Pubertal gynaecomastia is often seen in obese boys. In addition, obesity in men is associated with low testosterone levels, which correlate with high visceral fat (47). This affects the imbalanced leptin level, which results in higher estrogen levels. Ultimately, it negatively affects the hypothalamic-pituitary gonadal axis and can lead to hypogonadism in obese boys (48).

For girls, the increasing prevalence of obesity in childbearing age is a serious health problem. Obesity adversely affects their reproductive health and fertility, and it negatively affects the course of pregnancy (gestational diabetes mellitus, increased incidence of pre-eclampsia), and impairs embryo and foetal development (49). Ultimately, it affects the health of their children, such as the development of type 1 diabetes in childhood and the susceptibility of children to obesity, which is continuously carried over to subsequent generations (50).

The health complications caused by obesity significantly reduce quality of life in both childhood and adulthood (13). The problem cannot be seen only at the level of an individual; it is necessary to look at this negative trend from a societal, economic and health perspective. The consequences of the national economic losses due to the health complications that accompany obesity will increasingly place a financial burden on the state budget, which will be underfunded. As the number of obese people increases, so does the cost of treating them. For example, the health insurance company reports that in 2016 it paid CZK 16,074,708 for the treatment of 2,538 obese insured persons under 18 years of age, while in 2020 the number of such insured persons increased to 3,237 and the cost of their treatment amounted to CZK 19,128,045 (Czech Health Insurance Company).

The past period of the COVID-19 pandemic and the associated epidemiological measures have significantly affected the way of life, especially the movement of the population in the broadest sense. Movement, which is one of the basic biological expressions and necessities of human life, was already greatly reduced before the pandemic due to scientific and technological developments and was even more inhibited during the lockdown (51), while sedentary lifestyles (online education, television viewing, computer games, etc.) and mental demands on the general population increased (52). These external obesogenic factors lead to increased food intake, overeating and consumption of foods high in fat, sugar and salt (53). The restrictive measures lead to a combination of sedentary lifestyle and overeating which results in a positive energy balance, where energy intake is higher than energy expenditure, causing obesity with all the negative consequences in terms of somatic changes in the current and future populations (especially in the body composition of the fat free mass and fat component), and health, social and economic consequences.

Tackling obesity is a key to achieving the objectives of the programme “Ensuring healthy lives and promoting well-being for all people in all life situations” and is one of the priorities in the European Work Programme, which aims to stop the rise in obesity by 2025 (54).

The presented results of anthropological research with 6–15-year-old boys and girls and other research before the “covidobesity” pandemic suggest, on the contrary, that the European programme will not be fully achieved. Emphasis must be placed on primary prevention, which must include all age groups, to reduce the national economic losses due to obesity treatment and to promote health literacy and responsibility for health.

Limitations of the Study

The transversal anthropological research brings results for the period before the COVID-19 pandemic in the Czech Republic. The authors of the paper intended to continue the research during the COVID-19 pandemic and especially after the end of pandemic measures in 2022. Unfortunately, the stricter sanitary measures and the cautious and restrained attitudes of managements in primary schools after the experience of epidemic measures did not make it possible to have access to schools or continue the anthropological research that was aimed at preventing obesity in primary schools. This trend is likely to continue for some time. For these reasons, the results of this research are presented now.

In the upcoming period, the collaboration of paediatricians and anthropologists can play an important role in obesity prevention by monitoring the prevalence of obesity in the current population of children and implementing effective primary measures along the axis: children – paediatrician/anthropologist – school – parents – children. This is followed by general practitioners for children and adolescents, specialists in obesitology, and obesity centres. We also recommend that regular anthropometric measurements of children and adolescents be introduced in kindergartens and primary schools, and the results evaluated and communicated to parents, school management and paediatricians. Measures would thus be aimed at identifying early signs of overweight and possibly obesity in children.

CONLUSIONS

The results of the research confirm the rise of overweight and obesity among 6–15-year-old boys and girls in the Olomouc Region from 2002 to 2019 in the Czech Republic. Over the period, the percentage of obese boys increased by 3.62% and girls by 7.71%. Worryingly, the number of children with excessive development of the fat fraction (21.74%) and especially visceral adipose tissue is increasing; 7.11% of the subjects were found to be at health risk of developing abdominal adipose tissue. This condition cannot be evaluated only in terms of the negative effects on somatic growth and development, but it is necessary to take into account the problems that obesity brings with it. Obesity affects quality of life in childhood, and it is associated with physical and mental health problems, and ultimately it increases the likelihood of being obese in adulthood and having limiting comorbidities in adulthood. The past period of the COVID-19 pandemic has also shown that obesity is an important risk factor that reduces the body’s resistance to the viral epidemic with all its consequences on the health and quality of life of individuals in all age groups with all its implications in the future.

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Conflicts of Interest

None declared

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