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RESEARCH ARTICLE

Changes in adiposity and fat tissue distribution among preschool children from Kraków, Poland, from 2008 to 2018

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Abstract

In the light of changes in the living conditions of populations, excess adiposity is currently a serious public health problem worldwide. The aim of this study was to assess the changes in the body fat ratio among preschool children aged 3–7 years from Kraków, Poland, between 2008 and 2018. The study group consisted of children examined in two cross-sectional studies. Analysed characteristics included triceps, calf, subscapular, abdominal and suprailiac skinfold thicknesses, and adiposity calculated according to Slaughter's equations. The trunk adiposity index and limbs-to-trunk fat ratio were also calculated. Statistical significance was obtained using two-way ANOVA and Tukey's tests. Lower-limb adiposity was largest in the 2008 cohort and trunk adiposity was greater in the 2018 cohort. The mean values of the trunk adiposity index and limbs-to-trunk fat ratio were lower in the 2018 cohort than in the 2008 cohort. The 2018 cohort was also characterized by a lower overall adiposity. Regardless of the lower body adiposity percentage, in 2018 there was a tendency towards the central allocation of fat tissue. This is a negative phenomenon because, especially when co-existing with reduced lower-limb adiposity, it is associated with an increased risk of metabolic and cardiovascular diseases, even in young children.

Keywords: Skinfolds; Adiposity; Secular trend

Introduction

In the light of the continuous progress of civilization and subsequent changes in the living and development conditions of populations, excess body weight, especially during childhood, is currently one of the most serious public health problems worldwide (Koebnick *et al.*, 2015; Kowal *et al.*, 2016, 2017; Arora *et al.*, 2017; Suder *et al.*, 2017; Rush *et al.*, 2018). However, body composition, particularly the fat tissue ratio, seems to be an equally important problem. It has recently been estimated that 62–76% of the world's population is reaching a level of adiposity that could be health-threatening (Maffetone *et al.*, 2017). Unfortunately, this affects even the youngest age groups. A change towards increasing body fat has already been observed in the Polish population, as well as among preschool children in the Czech Republic, Croatia and other European countries (Cattaneo *et al.*, 2010; Kowal *et al.*, 2014; Sedlak *et al.*, 2015; Horvat *et al.*, 2017). It is also important to stress that the observed secular trends of increasing body adiposity often coincide with a reduction in the development of lean mass and reduced bone density (Sedlak *et al.*, 2015).

Excess adiposity has negative health consequences for children as young as preschool age, including, among others, metabolic syndrome, which in recent years has been observed in increasingly younger age groups (Steinberger *et al.*, 2009; Graversen *et al.*, 2014). Moreover, excess fat

[#]Jan Sobiecki died on 27th November 2020.

tissue, especially in preschool children, is associated with significantly decreased cardiorespiratory fitness (Sedlak *et al.*, 2017). High body fat mass in preschool children can also negatively impact their gross motor skills and therefore their motor development (Kakebeeke *et al.*, 2017). It is particularly concerning that excess adiposity in 6- to 7-year-olds has been shown to be significantly associated with cardiovascular risk factors (Hansen *et al.*, 2005; Horvat *et al.*, 2017).

In recent decades physical activity became less of a necessity and more of a lifestyle choice, due to the progress of civilization and associated technological development. Lack of physical activity can, in turn, cause a significant decrease in muscle mass. This, if occurring simultaneously with increasing fat ratio, can lead to sarcopenic (latent) obesity (Sedlak *et al.*, 2017). Therefore, even a child with a perfectly normal body weight could have excess adiposity. This is not shown by BMI values, because these do not take indicate body tissue composition. Thus, it is important to study both abnormal body weight and body composition.

The phenomenon of increased fat tissue at the expense of muscle mass is associated with abnormalities in glucose metabolism, and consequently higher insulin resistance, as well as an increased risk of certain chronic diseases in later life. This is because muscle tissue is crucial for glucose uptake, storage and metabolism (Ylihärsilä *et al.*, 2007; Costa Machado *et al.*, 2016).

Another important issue associated with body adiposity is the distribution of fat tissue, and particularly its excessive accumulation in the waist area. Accumulation of fat around the waist during a child's development significantly increases their risk of developing metabolic syndrome, as well as cardiovascular problems, even in preschool children. It is important to stress that this can still be a problem for children of normal body weight (Mokha *et al.*, 2010). Abdominal obesity has also been shown to be closely correlated with a significantly increased risk of dyslipidaemia, excess insulin resistance, hyperglycaemia, pro-thrombotic and inflammatory states and high blood pressure (McCarthy *et al.*, 2003; Perenc *et al.*, 2016). At the end of the 20th century, increased abdominal obesity was observed, among others, in children and adolescents from Great Britain and Spain (Moreno *et al.*, 2001; McCarthy *et al.*, 2003). In Spain, it has even been observed even in 6-year-olds. Moreover, it was most pronounced in the youngest age groups (Moreno *et al.*, 2001). Sedlak *et al.* (2017), in their study among pre-school children in the Czech Republic, found that the strongest positive inter-generational changes in skinfold thickness were in the abdominal area, and Suder *et al.* (2017) descried the phenomenon in children from Poland, including Kraków.

Given the potential health consequences of increased child body adiposity, this study aimed to assess the changes in body fat ratio and distribution in preschool children aged 3–7 years from Kraków, Poland, between the years 2008 and 2018.

Methods

Data

The study group consisted of children aged 3–7 years from two cross-sectional studies conducted in 2008 and 2018. In each study, the measurements were carried out in 20 randomly selected kindergartens in Kraków, located in four traditional residential districts of the city: Śródmieście, Podgórze, Krowodrza and Nowa Huta.

The exact calendar age of the examined children was calculated as a difference between the date of the survey and the birth date, expressed as a decimal fraction. Each child was then classified into one of five age groups (for example, the 3-year-old group included children whose calendar age ranged from 2.49 to 3.50). The 2008 cohort consisted of 1037 children (515 boys and 522 girls) and the 2018 cohort included 1106 children (568 boys and 538 girls) (Table 1).

Data on the children's development environment and their family's socioeconomic status were collected in the two studies using a questionnaire. This included questions on the financial situation of the family, level of urbanization of the inhabited environment, the professional and educational status of the children's parents and number of individuals in the family.

Table 1. Number of individuals in each cohort, N=2143

Age group	2008 (N=1037)		2018 (N=1106)	
	Girls n (%)	Boys n (%)	Girls n (%)	Boys n (%)
3	17 (1.6)	13 (1.2)	20 (1.8)	13 (1.2)
4	104 (10.0)	101 (9.7)	123 (11.1)	126 (11.4)
5	137 (13.2)	140 (13.5)	122 (11.0)	122 (11.0)
6	130 (12.5)	127 (12.2)	133 (0.12)	136 (12.3)
7	134 (12.9)	134 (12.9)	140 (12.6)	171 (15.5)
Total	522 (50.3)	515 (49.7)	538 (48.6)	568 (51.4)

Anthropometric measurements

Analysed characteristics included five skinfold thicknesses, measured using a GPM (Switzerland) skinfold calliper with a constant spring pressure of 10 g/mm^2 (accuracy 0.5 mm). The triceps skinfold was measured with the arm muscles relaxed, in the middle part of the posterior surface of the upper arm, over the triceps muscle. The subscapular skinfold was measured below the inferior angle of the scapula, at 45° to the vertical, along the natural crease lines of the skin. The suprailiac skinfold was measured above the iliac crest, posterior to the mid-axillary line and parallel to the cleavage lines of the skin. The abdominal skinfold was measured 5 cm adjacent and 1 cm below the umbilicus. Lastly, the calf skinfold was measured on the side of the calf, at the point of the maximum girth, with the lower limb relaxed (Tanner, 1962).

Percentage body fat (%BF) was calculated according to Slaughter's equations (Slaughter *et al.*, 1988). Two adiposity indicators were calculated from the measured skinfold thicknesses:

$$\text{Trunk adiposity index} = (\text{subscapular skinfold}/\text{abdominal skinfold}) \times 100$$

$$\text{Limbs-to-trunk fat ratio} = [(\text{triceps skinfold} + \text{calf skinfold})/(\text{subscapular skinfold} + \text{abdominal skinfold})] \times 100.$$

Body height was measured using an anthropometer and humerus breadth was measured using a small spreading calliper (both tools GPM, Switzerland; accuracy 1 mm). Body weight was obtained using an electronic scale (Tanita, Japan; accuracy 0.1 kg). Mid-upper-arm, waist and hip circumferences were measured to an accuracy of 0.5 cm using an anthropometric tape. These measurements were then used to calculate the following: waist-to-hip ratio (WHR) (waist circumference/hip circumference); body mass index (BMI) (body weight [kg]/body height [m]^2); frame index (humerus breadth [mm]/body height [cm])×100); arm muscle area (AMA) in girls (mid-upper-arm circumference [cm]–(π×triceps skinfold [cm]))^2/4π)–6.5); arm muscle area in boys (mid-upper-arm circumference [cm]–(π×triceps skinfold [cm]))^2/4π)–10); muscle mass (MM, kg) (body height [cm]×(0.0264+(0.0029×AMA)).

Statistical analysis

The results of the 2018 survey were compared with the analogous data set collected in 2008 (Kowal *et al.*, 2013a, 2013b, 2014). The statistical differences between the two cohorts were assessed using two-way ANOVA and Tukey's tests. All analyses were performed using Statistica 13.0.

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Results

Socioeconomic characteristics of study children

Over the decade 2008–2018, the average number of people in the families of the studied children decreased, despite a slight, but clearly noticeable, increase in average number of siblings. In 2018, the average number of working people in a family, and the self-assessed financial situation of the family, were both slightly higher than in 2008 (data not shown).

There were very significant differences in the reported levels of education of the children's parents. In 2008, 56% of women and 49% of men had higher education, while in the 2018 cohort these percentages were 89% and 74%, respectively. In most cases, this had happened at the expense of the number of people with primary, vocational and secondary education. However, it should be noted that in the 2018 cohort, a slightly higher (by 1 percentage point) percentage of fathers had technical secondary education (data not shown).

Secular changes in skinfold thicknesses and fat tissue distribution of children

Mean triceps skinfold thicknesses were smaller in children in the 2018 cohort than in the 2008 cohort. The differences were significant for all age groups except the very youngest. The differences between cohorts were similar for the majority of age categories in the case of boys (Table 2, Figure 1). For girls, the largest differences were seen in 5-year-olds, and the smallest in 3-year-olds (Table 2, Figure 2).

Similarly, mean calf skinfold thicknesses were smaller in the 2018 cohort than in 2008 cohort for most age groups, except for the youngest boys. However, the differences were not statistically significant. Among boys, the greatest, negative trend was noted at 6 years of age and the smallest difference was seen for 5-year-olds (Table 2, Figure 1). For girls, the largest differences between cohorts were noted among 3-year-olds and the smallest ones among 4-year-olds (Table 2, Figure 2).

Contrary to the observations for the lower and upper limbs, trunk adiposity was generally greater in the children examined in 2018 than in 2008. Differences in mean subscapular skinfold thickness over time were clearly noticeable in both sexes, but were not statistically significant. Also, mean subscapular skinfold thickness was larger in the 2018 cohort in most of the age categories, with the exception of 5- and 6-year-old girls. In boys, the greatest differences were observed for 7-year-olds and the smallest for 6-year-olds (Table 2, Figure 1). For girls, the largest, positive trend was observed in the youngest category and the smallest for 7-year-olds (Table 2, Figure 2).

The 2018 cohort was also characterized by a greater mean suprailiac skinfold thickness. This was the case for both sexes, and almost all age groups, apart from 3-year-old boys. For boys, the largest difference was noted at 5 years of age, and the smallest at 6 years of age. In girls, the greatest difference was observed in 4-year-olds, and the smallest in 6-year-olds. However, the differences between cohorts were not statistically significant, with the exception of 5-year-old boys and girls aged 4 (Table 2, Figures 1 and 2).

Children's mean abdominal skinfold thicknesses were larger in the 2018 cohort than in the 2008 cohort. This trend was present in both sexes and for all age categories. Among the boys, the largest difference was in 5-year-olds and the smallest in 6-year-olds. In girls, the greatest difference was observed at the age of 4, and the smallest at the age of 6. However, these differences were not significant in most age groups, except for boys at the age of 5, as well as 4- and 7-year-old girls (Table 2, Figures 1 and 2).

The secular trends in subscapular and abdominal skinfold thicknesses were mirrored by changes in the mean trunk adiposity index. This was noticeably lower in the children examined in 2018 than in the 2008 cohort. This was due to the increase in mean abdominal skinfold thickness being greater than that of mean subscapular skinfold thickness. This suggests that in 2018 there was a tendency towards the central (androidal) allocation of fat tissue. This change occurred in both sexes and was significant in most age categories, with the exception of 3- and 6-year-old

Table 2. Mean skinfold thicknesses and their differences between the 2008 and 2018 cohorts and within age groups

	Triceps (mm)			Calf (mm)			Subscapular (mm)			Suprailiac (mm)			Abdominal (mm)		
Age group	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018
Girls															
3	10.1	8.8	−1.31	7.2	6.4	−0.80	6.1	6.8	0.72	6.2	7.4	1.11	6.9	8.4	1.47
4	10.5	8.0	−2.42***	7.3	6.9	−0.36	6.5	6.9	0.36	6.3	8.0	1.73*	6.5	8.6	2.17***
5	10.8	7.9	−2.84***	7.6	6.9	−0.64	6.9	6.5	−0.31	7.2	8.1	0.93	7.6	8.5	0.83
6	10.7	8.2	−2.58***	7.5	6.9	−0.62	6.9	6.6	−0.31	7.5	7.9	0.41	7.6	8.6	0.94
7	10.8	8.4	−2.39***	7.5	7.1	−0.40	7.5	7.7	0.22	8.1	9.1	1.02	8.1	9.7	1.56*
Boys															
3	10.3	8.1	−2.22	3.0	6.4	0.87	5.4	5.8	0.44	5.5	5.5	−0.01	5.9	6.9	1.06
4	9.7	7.9	−1.87***	4.0	7.0	−0.35	5.8	6.1	0.28	5.6	6.5	0.87	5.9	7.2	1.34
5	9.8	7.8	−1.97***	5.0	7.0	−0.03	5.6	6.2	0.57	5.8	7.3	1.52*	6.0	7.9	1.90**
6	10.0	8.1	−1.87***	6.0	7.6	−0.65	6.0	6.1	0.12	6.3	6.7	0.41	6.6	7.5	0.87
7	10.1	8.3	−1.78***	7.0	7.2	−0.04	6.5	7.2	0.65	7.1	8.0	0.84	7.5	8.7	1.23

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

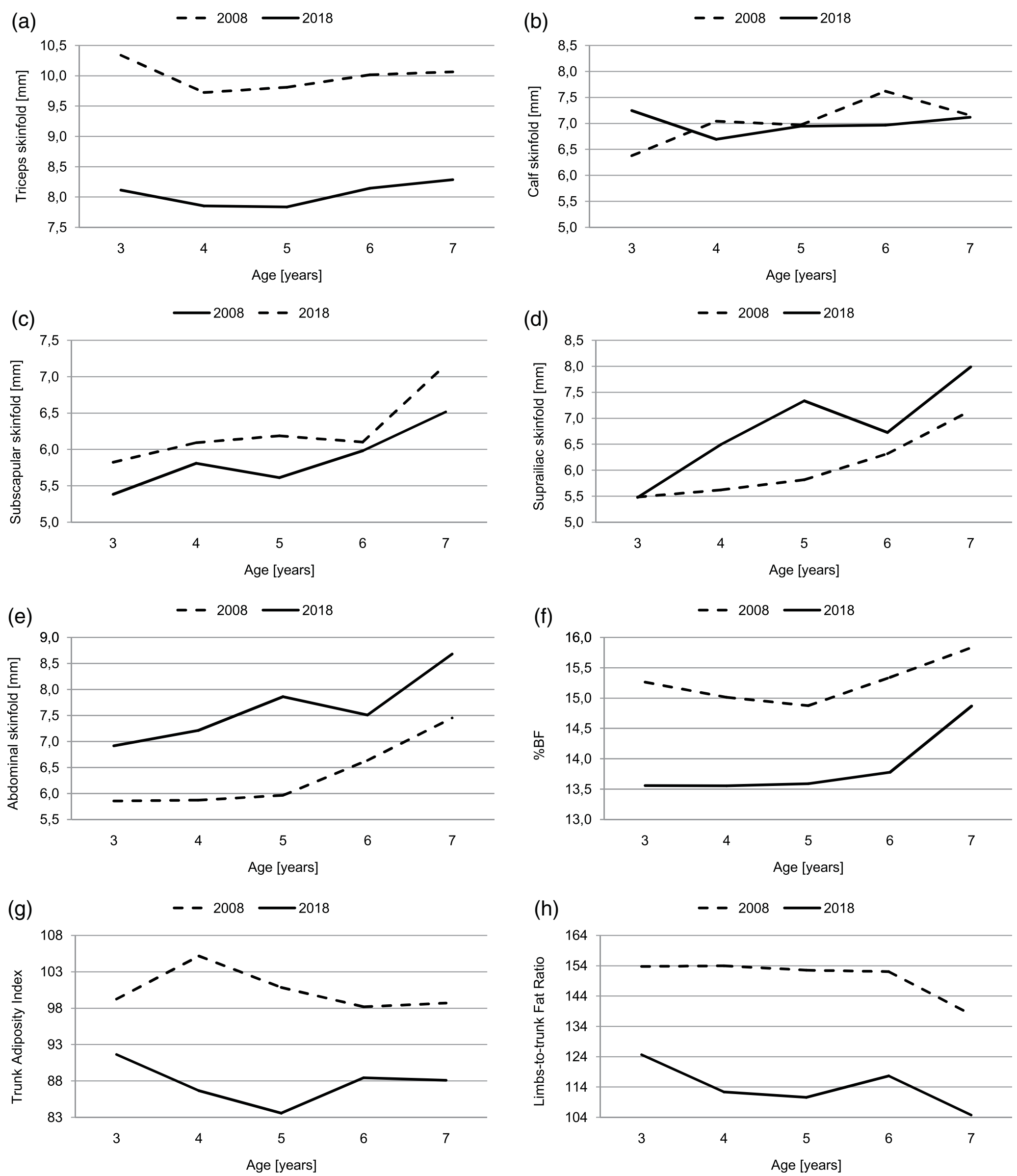

Figure 1. Thickness of triceps (a), calf (b), subscapular (c), suprailiac (d) and abdominal (e) skinfolds, body fat percentage (f), trunk adiposity index (g) and limbs-to-trunk fat ratio (h) in boys by age group and cohort.

boys. The largest differences were seen in 4-year-olds and the smallest among the youngest children (Table 3, Figures 1 and 2).

The directions of the observed trends in limb and trunk adiposity were considerably different, and this was reflected in the mean limbs-to-trunk fat ratio, which was notably lower among the children examined in 2018 than in the 2008 cohort, due to the observed increase in trunk adiposity. Those changes were seen in both sexes and were significant in the majority of age groups, except the youngest boys. The greatest differences were seen in 5-year-old boys and in girls at the age of 4, and the smallest were in the youngest boys and 5-year-old girls (Table 3, Figures 1 and 2).

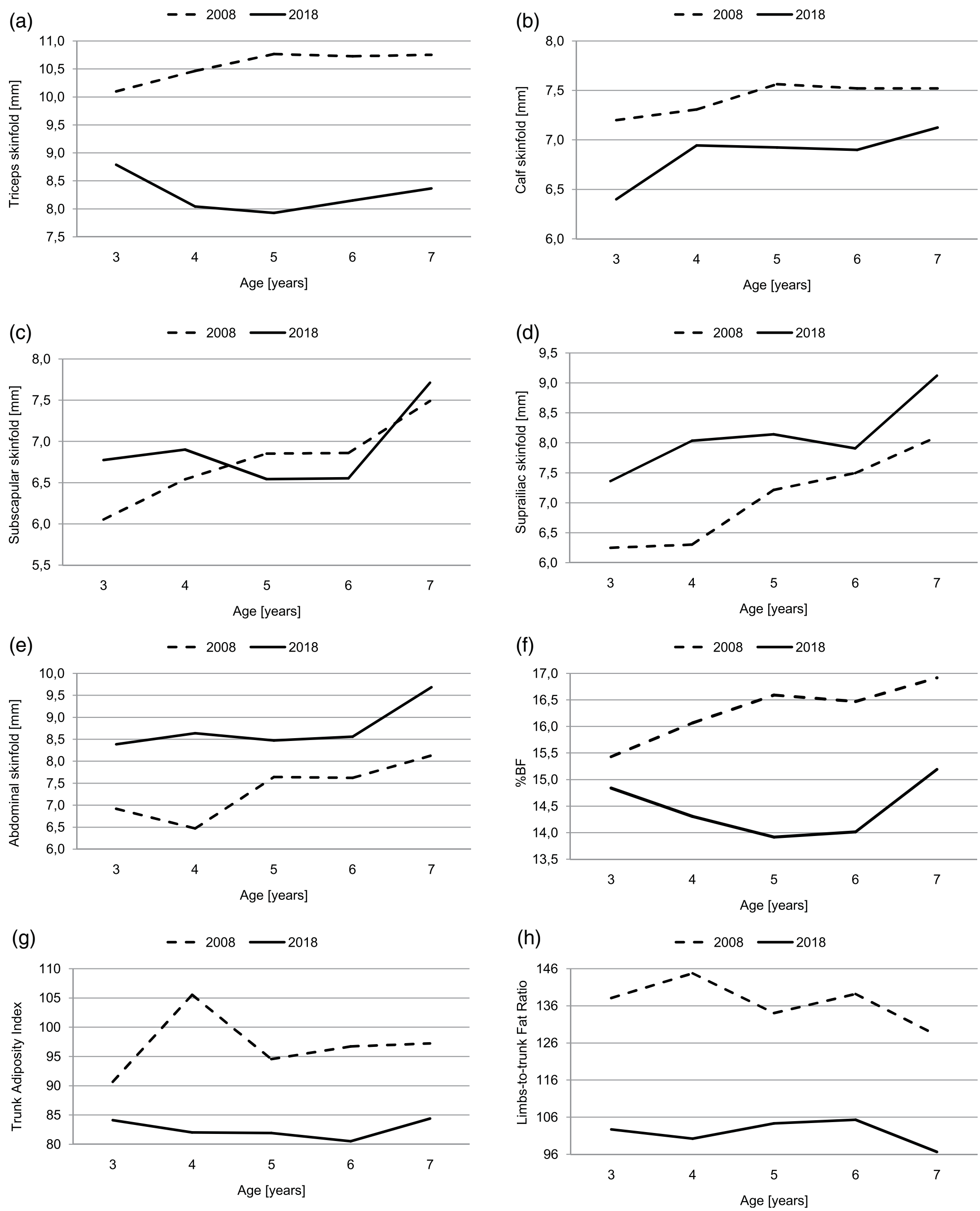

Figure 2. Thickness of triceps (a), calf (b), subscapular (c), suprailiac (d) and abdominal (e) skinfolds, body fat percentage (f), trunk adiposity index (g) and limbs-to-trunk fat ratio (h) in girls by age group and cohort.

Despite the increase in trunk adiposity, the 2018 cohort was characterized by a lower percentage body fat. This was the case for both sexes and all age groups, but the differences were only significant among girls older than 3. For girls, the greatest differences were observed in 5-year-olds, while the smallest were noted among the youngest girls (Table 3, Figure 2). For boys, the largest differences were seen in 3-year-olds and the smallest in 7-year-olds (Table 3, Figure 1).

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Table 3. Mean body fat percentage (%BF) and fat tissue distribution indicators and their differences between the 2008 and 2018 cohorts and within age groups

	%BF			Trunk adiposity index			Limbs-to-trunk fat ratio		
Age	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018
Girls									
3	15.4	14.8	−0.59	90.7	84.1	-6.54	138.1	102.7	−35.33*
4	16.1	14.3	−1.76*	105.5	82.0	−23.50***	144.7	100.3	−44.49***
5	16.6	13.9	−2.67***	94.6	81.9	−12.65***	134.0	104.4	−29.68***
6	16.5	14.0	−2.46***	96.7	80.5	−16.17***	139.1	105.3	−33.81***
7	16.9	15.2	−1.73*	97.2	84.4	−12.84***	128.1	96.7	−31.38***
Boys									
3	15.3	13.6	−1.71	99.2	91.6	−7.61	153.7	124.6	−29.12
4	15.0	13.6	−1.46	105.2	86.7	−18.48***	153.9	112.3	−41.59***
5	14.9	13.6	−1.29	100.8	83.6	−17.27***	152.5	110.6	−41.96***
6	15.3	13.8	−1.56	98.2	88.4	−9.76	152.0	117.6	−34.39***
7	15.8	14.9	−0.96	98.7	88.1	−10.61*	137.9	104.7	−33.16***

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

Because of the observed trends in fat tissue distribution, additional analysis of changes in body size and composition were performed. In both sexes and almost all age groups there was a decrease in mean waist circumference over time, but this was only significant in 6-year-old girls. Interestingly, WHR values were greater in children examined in 2018 and this difference was significant in girls at 4 and 7 years of age. In both sexes and almost all age categories there was a decrease in body height as well as in BMI over time. These observations, in conjunction with the described trends in adiposity, suggest the possibility of secular changes in other body tissue components. There was a decrease in skeletal robustness, as indicated by the frame index. This was lower in the children examined in 2018, and was the case for both sexes and the majority of age groups. The differences were significant in 5-year-old boys and in 4-year-old girls. Similarly, in both sexes and for all age groups there was a decrease in overall muscle mass in 2018. However, the observed differences were not significant (Table 4).

Discussion

The study results suggest that there has been a decrease in limb adiposity in contemporary preschool children in Poland. Similar tendencies have been observed in recent years among 5- and 6-year-old girls in the Czech Republic, examined between 1990 and 2012, as well as in 6-year-olds in Croatia (Sedlak *et al.*, 2015; Horvat *et al.*, 2017). In addition, a study of preschool children in Hungary found that average calf skinfold thickness had decreased between 1998 and 2008, as had triceps adiposity (Suskovics & Tóth, 2011). However, Sedlak *et al.* (2015) observed a positive trend in triceps skinfold thickness among boys in the Czech Republic. In a later study, Sedlak *et al.* (2017) found that 3- to 5-year-olds examined in 2014–16 had significantly greater limb adiposity than those of a 1957–63 cohort, shown by increasing triceps and patella skinfold thicknesses.

Interestingly, the present findings were only partially in line with those of a previous study conducted in the Kraków population (Kryst *et al.*, 2018). Here, 3- to 6-year-olds examined in 2010 had a lower triceps adiposity in relation to total body fat than their counterparts from

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Table 4. Mean values of body height, waist circumference, BMI, WHR, frame index, muscle mass and their differences between the 2008 and 2018 cohorts, within age groups

Age group	Body height (cm)			BMI			Waist circumference (cm)			WHR			Frame index			Muscle mass (kg)		
	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018	2008	2018	2008 vs 2018
Girls																		
3	983.53	967.30	−16.23	16.18	15.78	−0.40	507.06	487.25	−19.81	0.90	0.91	0.01	43.08	41.59	−1.49	44.89	44.53	−0.36
4	1031.15	1021.10	−10.05	15.73	15.85	0.12	502.66	494.54	−8.12	0.88	0.90	0.02*	42.46	42.58	−0.28**	55.18	55.21	−0.05
5	1095.62	1095.29	−0.33	15.84	15.65	−0.19	520.58	507.40	−13.18	0.87	0.88	0.00	41.56	41.53	−0.12	55.97	55.88	−0.09
6	1168.27	1156.44	−11.83	15.89	15.35	−0.54	532.33	509.63	−22.70***	0.85	0.86	0.01	40.03	40.31	−0.04	66.87	66.41	−0.45
7	1227.07	1219.63	−7.44	16.37	16.04	−0.33	542.76	541.40	−1.36	0.83	0.86	0.02**	39.74	39.35	−0.39	77.74	77.48	−0.26
Boys																		
3	1006.50	982.15	−24.35	16.62	15.90	−0.72	512.14	489.23	−22.91	0.89	0.95	0.06	44.45	43.15	−0.36	4.18	3.78	−0.30
4	1039.04	1036.51	−2.53	16.04	15.80	−0.24	514.46	497.99	−16.46	0.90	0.90	0.01	42.32	41.70	−0.53	4.28	4.12	−0.22
5	1112.59	1111.56	−1.04	15.72	15.95	0.23	527.60	516.72	−10.87	0.88	0.89	0.00	40.66	44.09	0.30*	4.90	4.90	−0.04
6	1175.28	1168.82	−6.46	16.13	15.74	−0.39	540.77	525.59	−15.18	0.87	0.87	0.01	43.05	42.62	−0.61	5.80	5.37	−0.48
7	1236.90	1235.70	−1.20	16.16	16.24	0.07	557.56	550.98	−6.58	0.86	0.86	0.00	41.41	40.40	−0.26	6.55	6.25	−0.30

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

1983 (a finding in line with the present study), but an opposite tendency was found for the calf adiposity – in the 2010 cohort it was larger in relation to total body fat than in 1983.

It is important to mention that a decreasing triceps skinfold thickness seems to be a positive phenomenon as elevated triceps skinfold thickness has been shown to be associated with high serum lipid and lipoprotein profiles (Freedman *et al.*, 1985; Kromeyer-Hauschild *et al.*, 2012). On the other hand, a decrease in lower-limb adiposity is not a good thing, as it has been demonstrated that the accumulation of fat tissue in the lower limbs in children can significantly reduce the risk of cardiovascular and metabolic diseases and positively influence the blood lipid profile (Staiano *et al.*, 2014; Samouda *et al.*, 2016). It has also been suggested that fat deposited in the lower extremities can help to prevent atherosclerosis and have a positive effect on liver enzymes levels, which can protect the liver in the long term (Perlemuter *et al.*, 2008).

Unlike limb adiposity, trunk skinfold thickness had increased in 2018 cohort. Analogous results were obtained by Sedlak *et al.* (2015) among Czech preschool children, who found that both boys and girls examined in 2012 had greater subscapular and suprailiac adiposity than those examined in 1990. A similar phenomenon was also noted in the later study in the Czech Republic, which found that there was a significant increase in suprailiac and subscapular skinfold thicknesses in preschool children examined in 2014–16 (Sedlak *et al.*, 2017). In addition, the present results were in line with the findings of earlier research carried out in Hungary, which found that, among 3- to 7-year-olds, there was an increase in subscapular and suprailiac skinfold thicknesses between 1998 and 2008 (Suskovics & Tóth, 2011). Opposite tendencies were noted among Croatian 6-year-olds, where girls examined in 2013 were characterized by lower subscapular and abdominal skinfold thicknesses than their counterparts in the 2003 cohort (Horvat *et al.*, 2017). Also, a study of children aged 3–7 years in Kraków found a secular decrease in suprailiac and abdominal adiposity in relation to total body fat (Kryst *et al.*, 2018).

The described secular changes in the thickness of individual skinfolds in Poland suggest that in the 2018 cohort there was a shift in fat tissue distribution towards more central allocation. This was also indicated by the decrease in the mean values of limbs-to-trunk fat ratio and trunk adiposity index occurring between 2008 and 2018. Those findings are in line with trends previously observed among Russian children and adolescents, where a secular increase in trunk fat layer co-existed with a decrease in adiposity accumulated in the extremities. Moreover, the Russian study found that the increase in fat tissue on the trunk was most evident on the abdomen, which was also noted in the current study (Godina *et al.*, 2016). A similar phenomenon has previously been demonstrated in the Polish population by Suder *et al.* (2017), who noted a secular increase in abdominal fat tissue deposition, presented as increased waist circumference. However, in the present study, there was an opposite tendency regarding waist circumference, which decreased between 2008 and 2018. Interestingly, there was also a slight increase in WHR values, which suggested that in the 2018 cohort there was, in fact, an increased tendency towards androidal fat deposition. The decrease in waist circumference could have been caused by the reduction in general body size of the contemporary population – children examined in 2018 were characterized by a lower mean body height than those observed in 2008.

A tendency towards increasing central adiposity was observed among children in Peru examined in 2001 and 2015, as well as boys and girls in Australia, and the changes co-existed with a secular increase in body weight and BMI (Garnett *et al.*, 2011; Cossio-Bolaños *et al.*, 2017). However, in the present study's population, central adiposity was lower in the 2018 cohort than in the 2008 cohort, indicating that the secular decrease in body weight was more significant than that observed for body height. Żegleń *et al.* (2020) also demonstrated that there has been an intergenerational decrease in the prevalence of overweight/obesity (on the basis of BMI) among preschool children in Kraków. However, in recent years the secular increase in the abdominal fat ratio has generally been greater than that of BMI (Garnett *et al.*, 2011; Freedman *et al.*, 2015; Visscher *et al.*, 2015). Moreover, in recent decades, the secular increase in skinfold thicknesses have been especially apparent in normal weight, and even underweight, children, and not necessarily among

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those with excess body weight (Moreno *et al.*, 2001; Wells *et al.*, 2002; Nagel *et al.*, 2009; Kromeyer-Hauschild *et al.*, 2012).

Similar findings have been seen in children and adolescents in China, where the trend towards increasing androidal adiposity distribution has been associated with increased urbanization (Inoue *et al.*, 2018). Changing socioeconomic environment could also be the cause of the differences between subsequent generations in Poland observed in the present study. In the decade between the two cohorts, the average number of people in a family decreased, despite the slight, although clearly noticeable, increase in average number of siblings among the studied children. This suggests a decrease in the popularity of the multi-generational family model. Moreover, in 2018, the average number of people in a family that were working, as well as the self-assessed financial situation of the family, were also slightly higher, in comparison with the cohort examined in 2008. There were also major difference in the reported levels of education declared by the parents of the examined children. In 2008 they less often reported higher education, which, in most cases, occurred at the expense of the number of people with primary, vocational and secondary education. A similar phenomenon has been observed in the general Polish population. Between 2008 and 2018, there was a decrease in the unemployment rate from around 9% to about 6%. Moreover, average salary, as well as GDP (Gross Domestic Product), increased and the at-risk-of-poverty rate was reduced from 20.5 in 2005 to 17.3 in 2016. There was also an increase in the general education rate of society. For example, in 2002, 9.9% of Poles had higher education, when in 2016 this percentage reached 25.3%. Additionally, between 2008 and 2018 the number of young people who did not pursue further education after primary school decreased significantly (Central Statistical Office, 2018). Interestingly, contrary to what was observed in the current study, among East German children and adolescents changes in the economic and political situation occurring over time were associated with feminization of the fat tissue distribution, on the basis of the observed secular increase in limb adiposity in both sexes, underweight as well as those with normal weight subjects. At the same time, in a German study group characterized by excess body weight, an increase in prevalence of an android distribution of body fat was observed (Scheffler & Dammhahn, 2017).

Regardless of the increase in trunk adiposity, preschool children examined in 2018 were characterized by a lower body fat percentage than their counterparts in 2008. This may be due to the fact that the Slaughter equation, which was used to calculate adiposity, is based only on triceps and subscapular skinfolds. In the present research, between 2008 and 2018 there was a decrease in triceps thickness, and only a slight increase in subscapular fat tissue. Therefore the adiposity percentage may not fully represent current circumstances and should definitely be interpreted in conjunction with the rest of the obtained results. However, it is also important to mention that the results were in line with those of Horvat *et al.* (2017), who found that 6-year-old girls measured in 2013 had lower total body adiposity, than their peers examined in 2008. The currently observed decrease in total body adiposity is also in line with an earlier study of preschool children from Kraków, which found a general decrease in the prevalence of excess adiposity (Żegleń *et al.*, 2020). However, it is also important to stress that the contemporary population was characterized by lower muscle mass and less-robust bones, and these may contribute to the secular decrease in BMI values. Sedlak *et al.* (2017) had similar findings, with the more contemporary population being characterized by a slightly lower BMI, which co-existed with a decreased muscle mass. Additionally, a secular decrease in bone dimensions has also been found in children from Russia as well as other European countries, and were said to be associated with a greater degree of hypokinesia, typical in modern populations (Godina *et al.*, 2016).

In conclusion, the observed changes in the total fat percentage and BMI in Polish children can be regarded as positive and beneficial for their health and further development. However, the secular increase in abdominal adiposity and WHR, as well as decrease in muscle mass and skeletal robustness, are very unfavourable. As demonstrated in earlier research, even at such a young age there is a negative association between cardiorespiratory fitness and the central allocation of fat

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tissue (Martinez-Tellez *et al.*, 2016). This distribution is also considered a risk factor for diabetes, elevated insulin resistance and cardiovascular diseases (Demerath *et al.*, 2011; Godina *et al.*, 2016). Moreover, elevated skinfold thickness in children, especially in the trunk area, is an important predictor of various health problems later in life, including, among others, high blood pressure and increased concentration of serum triglycerides (Freedman *et al.*, 2007; Wohlfahrt-Veje *et al.*, 2014). The present results confirm that research on the time trends in children's body size and body composition should be examined in conjunction, to ensure a full understanding of their nature. Similar research on older age categories should be performed, to assess the presence and direction of changes over time.

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Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. The study was conducted with the consent of the Bioethics Committee of the Regional Medical Association in Kraków (No. 2/KBL/OIL/2018) and with the written consent of the children's parents or legal guardians, as well as verbal assent from the children themselves. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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