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ORIGINAL ARTICLE

Central overweight and obesity in Polish schoolchildren aged 7–18 years: secular changes of waist circumference between 1966 and 2012

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Abstract We investigated secular trends of body mass index (BMI) and waist circumference (WC) in Polish schoolchildren examined through a period of almost 50 years. Data on height, weight and WC came from four cross-sectional surveys conducted in Poland between 1966 and 2012, covering 34,005 boys and 34,008 girls. Raw data of BMI and WC were standardized for age classes. Statistical analyses included the Kruskal-Willis test and Pearson Chi-square test. BMI and WC increased during the studied period; however, the growth was higher for WC (increase by 0.56 and 0.44 SD scores for BMI and 1.05 and 0.77 SD scores for WC in boys and girls, respectively). In boys, secular changes in BMI and WC were similar across childhood, early and late adolescence, while in girls they differed, indicating change in the type of adipose tissue distribution to a more central one in late adolescent girls.

Conclusion: During 46 years, there was a tendency to a greater increase of the fraction of individuals with central obesity than the overall one. Since abdominal fat deposit is more connected with higher health risks than subcutaneous fat pattern, probably the number of metabolic complications in Polish children and adolescents will intensify in the future.

What is Known:
- *BMI has significant limitations related to fat distribution, while WC is a measure of central adiposity.*
- *Greater central fat deposition increases the risk of many diseases; therefore, WC may serve as a diagnostic measure for detecting central obesity in children at risk.*

What is New:
- *In girls, changes in BMI and WC indicate change in adipose tissue distribution to a more central one in late adolescence girls.*
- *Both general and abdominal obesity in Polish children increased significantly from 1966 to 2012, with the tendency to a greater increase of the fraction of individuals with central obesity than the overall one, implying the number of metabolic complications in Polish children and adolescents may intensify in the future*

Keywords Central overweight · Obesity · Waist circumference · Secular changes · Schoolchildren

Abbreviations

BMI	Body Mass Index
FFM	Fat-free mass
FM	Fat mass
NHANES	National Health and Nutrition Examination Survey
WC	Waist circumference

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Introduction

Anthropometric measurements are the preferred tool in screening large field studies, applied in preventing overweight and obesity in children populations. Body mass index (BMI) with standardized cut-off values is frequently used to diagnose overweight and obesity, but it has significant limitations in childhood and gives no information about fat distribution [16]. There is considerable evidence that in both adults and children, a greater central fat deposition increases the risk of many severe metabolic complications and elevated blood pressure [3, 16]. In view of the special risk of excessive abdominal fat deposition, waist circumference (WC) may serve as an easy diagnostic measure for detecting central obesity in children at risk [18]. A high correlation between WC and truncal adiposity in children has been confirmed in studies using magnetic resonance imaging or dual-energy X-ray absorptiometry [6]. WC also is tracked from adolescence into adulthood, and adolescent WC is significantly related to adult chronic medical condition [9, 11]. WC predicts mortality better than other anthropometric measures because of the association with fat distribution and metabolic abnormalities [12].

Although the tendency of growth in prevalence of overweight and obesity determined by BMI has slowed down in some countries recently [34], in many others, including Poland, it is still increasing [14, 19, 27]. Moreover, the steep positive secular trend of BMI is accompanied by a growing trend of secular WC at different phases of ontogenesis [8, 28]. Studies have indicated a larger secular increase in WC compared to BMI [15, 29], which could imply that using BMI exclusively in the evaluation of weight trends might lead to an underestimation in both the increase in fat amount and health risk. Examining secular trends in waist circumference in Polish children would add valuable comparative data to the evidence of trends in BMI and would be the first report of comparison of both trends. The aim of the work was to compare secular trends of both BMI and WC as well as to assess sex and survey differences in prevalence of overweight and obesity in four cohorts of Polish children and adolescents examined through a period of almost 50 years.

Material and methods

The anthropometric data comprised four cross-sectional surveys conducted in Poland in 1966, 1978, 1988 and 2012. Parts of the surveys had been analysed and described in other publications [4, 21, 26]. However, analyses concerning the studies in the context of excessive central overweight and obesity have not been presented yet.

Four subsequent surveys comprised data of boys and girls attending primary and all types of secondary schools, collected in three cities, four towns and villages located within the country districts of those towns [19]. The 1966 survey was nationwide. However, for the purpose of the present study, children from medium-sized cities (25,000–500,000 inhabitants) were eliminated to match the same categories of the level of urbanization as that in three subsequent surveys. Due to the legal requirements introduced after 1989, the written consent of parents or legal guardians of the children was required to conduct the examination in 2012. Therefore, in contrast to the previous mandatory surveys, this study did not cover all the children of the target population. The same schools were chosen in 1978, 1988 and 2012 and all the regions included in these surveys were represented in the 1966 survey. All four surveys are considered to be representative for all levels of urbanization in Poland and are the only systematic Polish surveys with such wide range for the last nearly 50 years.

All surveys included, among others, data on height (cm) and weight (kg) measured to the nearest 1.0 mm and 100 g, respectively. Body mass index (BMI; kg/m^2) was calculated as weight (kg) divided by height (meter), the quotient squared. Waist circumference (WC) was measured at the level of midway between the top of the iliac crest and the lower rib to the nearest millimetre using a steel or cloth tape. All measurements were carried out by trained staff of anthropologists. The present study included data of total 34,005 boys and 34,008 girls for BMI and 32,218 boys and 32,461 girls for WC (Table 1).

Raw data of BMI and WC were standardized on means and SDs for age classes of Polish reference population of children aged 7–18 collected in the course of the OLAF-PL0080 study titled "Elaboration of reference blood pressure ranges for children and adolescents in Poland", and is a nationally representative survey of growth and blood pressure [24]. Participants of reference population (N = 7544; children and adolescents 6.5–18.5 years of age) were examined between November 2007 and March 2009 in schools randomly selected using a two-stage sampling: schools from an all-schools-in-Poland sampling frame and pupils in schools [24]. Thus, the data are considered to be representative for the Polish population and provide the information on both BMI and waist circumference. Data for BMI come from the research by Kulaga et al. [24] and for WC from the study by Kulaga et al. [25]. Boys and girls with values of BMI above the 95th centile of the reference population for their age class were defined as overweight or obese and, by analogy, above the 95th centile for WC were defined as centrally obese.

Three periods of development in boys and girls were identified: childhood (7–12 and 7–10 years of age for boys and girls, respectively), early adolescence (13–15 and 11–13 years of age for boys and girls, respectively) and late adolescence (16–18 and 14–18 years of age for boys and girls, respectively) [5]. Such developmental categories refer to the changes and differences in the rate of growth during human life cycle as well as to the onset of puberty and adolescent growth spurt, with respect to both sex and years of age [5].

Since standardized BMI and WC did not have normal distribution, differences between surveys and age classes within both sex categories for those two features were assessed by the means of a Kruskal-Willis test for independent groups. Next, post hoc pairwise comparisons were done by the means of Dwass-Steel-Chritchlow-Fligner method applying

Table 1 Means, medians, values of the 25th and 75th quartiles and SDs of Z-BMI and Z-WC (standardized on reference OLAF population) by survey and sex

Survey	BMI						Waist circumference					
	Number	Mean	Median	Q25	Q75	SD	Number	Mean	Median	Q25	Q75	SD
Boys												
1966	9453	−0.35	−0.32	−0.81	0.14	0.78	9521	−0.84	−0.90	−1.25	−0.50	0.64
1978	9570	−0.27	−0.29	−0.82	0.25	0.84	9882	−0.33	−0.46	−0.83	0.01	0.76
1988	12,055	−0.18	−0.19	−0.72	0.35	0.84	9830	−0.28	−0.38	−0.78	0.05	0.78
2012	2927	0.21	0.18	−0.44	0.90	0.97	2985	0.21	−0.04	−0.56	0.72	1.10
	H = 8980.95 $p < 0.0001$						H = 4848.27 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p < 0.0001$ 1978 vs. 1988 $p < 0.0001$ 1988 vs. 2012 $p < 0.0001$						1966 vs. 1978 $p < 0.0001$ 1978 vs. 1988 $p < 0.0001$ 1988 vs. 2012 $p < 0.0001$					
Girls												
1966	9624	−0.29	−0.27	−0.85	0.31	0.87	9889	−0.58	−0.64	−1.10	−0.18	0.75
1978	9553	−0.13	−0.13	−0.71	0.45	0.88	9909	−0.18	−0.31	−0.74	0.24	0.82
1988	11,746	−0.07	−0.08	−0.67	0.53	0.91	9502	−0.20	−0.33	−0.76	0.24	0.87
2012	3085	0.15	0.13	−0.52	0.83	0.97	3161	0.19	−0.04	−0.59	0.73	1.13
	H = 546.53 $p < 0.0001$						H = 2182.49 $p < 0.0001$					
Post hoc comparison of cohorts	1966 vs. 1978 $p < 0.0001$ 1978 vs. 1988 $p < 0.0002$ 1988 vs. 2012 $p < 0.0001$						1966 vs. 1978 $p < 0.0001$ 1978 vs. 1988 $p = 0.1135$ 1988 vs. 2012 $p < 0.0001$					

[a] Post hoc pairwise comparison by the Dwass-Steel-Chritchlow-Fligner method; critical q (range) = 3.63316

StatsDirect 3 application. Sex and survey differences in prevalence of obesity and central obesity were assessed by the Pearson Chi-square test. Statistical calculations were also done using Statistica 10.0.

Results

Table 1 presents the means, medians and SDs for standardized values of BMI and WC on reference OLAF population in boys and girls by survey. In both boys and girls, for these two features, the means gradually and significantly increased from 1966 to 2012. However, the increase was much greater in WC than in BMI, where the mean values rose by 1.05 and 0.77 SD's scores in boys and girls, respectively. Similar trend was evident for BMI, accounting for 0.56 for boys and 0.44 for girls. Both for BMI and WC, the increase was greater in boys than in girls. Pairwise comparisons showed that there were significant differences between all subsequent surveys for BMI and WC, except for differences between surveys from the years 1978 and 1988 for WC in girls.

Table 2 shows the means, medians values of Q25 and Q75 and SDs for standardized values of BMI and WC on reference OLAF population in boys and girls by developmental periods and survey. In all three developmental periods, both for boys and girls and in both features, there was a gradual increase in means from 1966 to 2012. There was a clear regularity in the pattern of changes. In both boys and girls, the increase in means was greater in WC than in BMI regardless of the developmental period. In boys, secular changes in BMI were nearly in the same relative size from childhood through early up to late adolescence, with slightly greater size in early adolescence, accounting for 0.56, 0.62 and 0.53 SD scores, respectively. The increase in WC showed the same pattern, accounting for 1.03, 1.12 and 1.03 for three developmental periods, respectively. However, in girls, the increase in means differed by developmental periods. In childhood and early adolescence, means of BMI and WC increased by comparative size, accounting for 0.73 and 0.78 SD scores for BMI and 0.92 and 0.95 SD scores for WC, respectively. In late adolescence, i.e. in age 14–18 years, for BMI, the increase of means between 1966 and 2012 was nearly negligible, and equalled 0.08 SD score; whereas, at the same time, in WC, increase accounted for 0.54 SD score. Pairwise comparisons showed that, in boys, all gradual changes between cohorts were significant for BMI and WC, except for cohorts between 1966 and 1978, as well as 1978 and 1988 in the late adolescence group, for BMI and WC, respectively. In girls, no significant differences were observed between cohorts from 1978 and 1988 for BMI and WC in the early adolescence group, and from 1966 and 1978, and 1988 and 2012 for BMI in late adolescence group.

Changes in percentage of normal and overweight or obese children, defined as below, equal and above the value of the 95th centile by sex and age classes, calculated for reference OLAF

Table 2 Means, medians, values of the 25th and 75th quartiles and SDs of Z-BMI and Z-WC (standardized reference OLAF population) by survey and sex in three developmental periods

Survey	BMI						Waist circumference					
	Number	Mean	Median	Q25	Q75	SD	Number	Mean	Median	Q25	Q75	SD
Boys												
Childhood 7–12 years												
1966	4287	−0.40	−0.37	−0.84	0.05	0.76	4301	−0.86	−0.92	−1.22	−0.54	0.57
1978	4943	−0.32	−0.36	−0.87	0.20	0.84	5109	−0.32	−0.46	−0.83	0.01	0.77
1988	6344	−0.25	−0.28	−0.78	0.25	0.83	5268	−0.29	−0.39	−0.75	0.02	0.74
2012	1730	0.16	0.12	−0.49	0.88	0.96	1749	0.17	−0.09	−0.58	0.66	1.07
	H = 497.057 $p < 0,0001$						H = 2712.968 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p = 0.006$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p < 0.0001$						1978 vs. 1988 $p < 0.0001$					
	1988 vs. 2012 $p < 0.0001$						1988 vs. 2012 $p < 0.0001$					
Early adolescence 13–15 years												
1966	2856	−0.38	−0.36	−0.86	0.12	0.78	2849	−0.86	−0.88	−1.34	−0.49	0.67
1978	2513	−0.29	−0.31	−0.83	0.25	0.86	2517	−0.36	−0.47	−0.86	−0.02	0.78
1988	3157	−0.18	−0.17	−0.75	0.37	0.88	2494	−0.29	−0.38	−0.84	0.04	0.83
2012	514	0.24	0.24	−0.39	0.92	0.98	517	0.26	0.04	−0.51	0.72	1.14
	H = 238.734 $p < 0.0001$						H = 1219.572 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p = 0.0074$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p < 0.0001$						1978 vs. 1988 $p = 0.0166$					
	1988 vs. 2012 $p < 0.0001$						1988 vs. 2012 $p < 0.0001$					
Late adolescence 16–18 years												
1966	2310	−0.22	−0.17	−0.67	0.31	0.80	2371	−0.77	−0.81	−1.22	−0.40	0.71
1978	2114	−0.14	−.013	−0.64	0.34	0.78	2256	−0.32	−0.40	−0.81	0.01	0.72
1988	2554	0.00	0.00	−0.49	0.50	0.77	2068	−0.26	−0.40	−0.81	0.15	0.83
2012	683	0.31	0.31	−0.35	0.97	0.96	719	0.26	0.00	−0.55	0.83	1.15
	H = 212.369 $p < 0.0001$						H = 947.606 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p = 0.1861$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p < 0.0001$						1978 vs. 1988 $p = 0.3410$					
	1988 vs. 2012 $p < 0.0001$						1988 2012 $p < 0.0001$					
Girls												
Childhood 7–10 years												
1966	2633	−0.53	−0.50	−1.05	0.03	0.84	2715	−0.63	−0.64	−1.10	−0.33	0.67
1978	3069	−0.27	−0.29	−0.85	0.28	0.89	3240	−0.25	−0.37	−0.79	0.12	0.80
1988	4040	−0.20	−0.22	−0.79	0.35	0.87	3431	−0.20	−0.34	−0.72	0.16	0.80
2012	1150	0.20	0.17	−0.49	0.92	0.98	1179	0.29	0.03	−0.50	0.86	1.14
	H = 484.002 $p < 0.0001$						H = 936.922 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p < 0.0001$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p = 0.0008$						1978 vs. 1988 $p = 0.0095$					
	1988 vs. 2012 $p < 0.0001$						1988 vs. 2012 $p < 0.0001$					
Early adolescence 11–13 years												
1966	2693	−0.50	−0.50	−0.99	0.01	0.80	2730	−0.76	−0.85	−1.22	−0.32	0.71
1978	2420	−0.27	−0.27	−0.86	0.33	0.89	2425	−0.29	−0.42	−0.85	0.14	0.84
1988	3154	−0.21	−0.22	−0.82	0.37	0.90	2456	−0.23	−0.32	−0.76	0.15	0.86
2012	781	0.18	0.19	−0.54	0.90	0.96	782	0.19	−0.01	−0.61	0.75	1.10
	H = 355.064 $p < 0.0001$						H = 948,366 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p < 0.0001$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p = 0.1125$						1978 vs. 1988 $p = 0.1056$					
	1988 vs. 2012 $p < 0.0001$						1988 vs. 2012 $p < 0.0001$					
Late adolescence 14–18 years												
1966	4298	−0.01	0.05	−0.54	0.59	0.85	4444	−0.45	−0.49	−0.96	0.00	0.79
1978	4064	0.05	0.08	−0.46	0.60	0.84	4244	−0.07	−0.16	−0.60	0.33	0.81
1988	4552	0.13	0.15	−0.44	0.74	0.90	3615	−0.17	−0.32	−0.75	0.27	0.92
2012	1154	0.07	0.06	−0.54	0.70	0.95	1200	0.09	−0.15	−0.66	0.55	1.14
	H = 46.333 $p < 0.0001$						H = 550.773 $p < 0.0001$					
Post hoc comparison of cohorts[a]	1966 vs. 1978 $p = 0.0744$						1966 vs. 1978 $p < 0.0001$					
	1978 vs. 1988 $p = 0.0001$						1978 vs. 1988 $p < 0.0001$					
	1988 vs. 2012 $p = 0.0535$						1988 vs. 2012 $p < 0.0001$					

[a] Boys

population in boys and girls between 1966 and 2012 are presented in Table 3. For both features in both sexes, the percentage of children above the referenced value of the 95th centile significantly and gradually increased from 1966 to 2012. In boys, the percentage of overweight and obese individuals increased between 1966 and 2012, respectively, from 0.55 to 7.00%, and individuals with central obesity from 0.49 to 10.39%. Similar trends were observed in girls: increase in the percentage ranged from 0.98 to 6.61%, and from 1.02 to 10.53% of individuals with overweight or obesity and central obesity, respectively. However, prevalence of individuals above the 95th centile for BMI between 1966 and 2012 increased 12.7 and 6.7 times in boys and girls, respectively, whereas for WC 21.2- and 10.3-fold increase for boys and girls, respectively, was observed.

Changes in percentage of boys and girls above the value of the 95th centile for BMI and WC of reference OLAF population in three developmental periods are presented in Fig. 1. Nearly in all developmental periods, the increase of fraction of individuals with central obesity was greater than individuals with overall obesity. In every developmental periods, the highest prevalence of both types of obesity was observed in 2012, regardless of sex. Among girls in 2012, the highest percentage of obese individuals, in the context of both BMI and WC, was found during childhood (Fig. 1a). After this period, it was decreasing, reaching the lowest value, among both sexes in 2012, in late adolescence (Fig. 1c). Regarding boys, this pattern was rather different: during childhood, prevalence of both obesities presented the lowest level (Fig. 1a), and since this period, BMI gradually increased (Fig. 1b), reaching the highest value in late adolescence boys (Fig. 1c), while WC remained relatively constant, increasing slightly in early adolescence and then decreasing slightly in late adolescence.

Table 3 Percentage (*N*) of children with values of BMI and WC lower (normal) and greater (overweight and obese) than the value of the 95th centile for reference OLAF population by Survey and sex

	BMI		Waist circumference	
	Normal	>95 centile	Normal	>95 centile
Boys				
1966	99.4% (9401)	0.6% (52)	99.5% (9474)	0.5% (47)
1978	98.6% (9434)	1.4% (136)	97.6% (9649)	2.4% (233)
1988	98.2% (11834)	1.8% (221)	97.3% (9566)	2.7% (264)
2012	93.0% (2722)	7.0% (205)	89.6% (2675)	10.4% (310)
	$\chi^2 = 538.15$ $p < 0.0001$		$\chi^2 = 867.036$ $p < 0.0001$	
Girls				
1966	99.0% (9530)	1.0% (94)	99.098% (9788)	1.1% (101)
1978	98.1% (9368)	1.9% (185)	96.5% (9564)	3.5% (345)
1988	97.2% (11412)	2.8% (334)	96.4% (9163)	3.6% (339)
2012	93.4% (2881)	6.6% (204)	89.5% (2828)	10.5% (333)
	$\chi^2 = 535.351$ $p < 0.0001$		$\chi^2 = 652.913$ $p < 0.0001$	

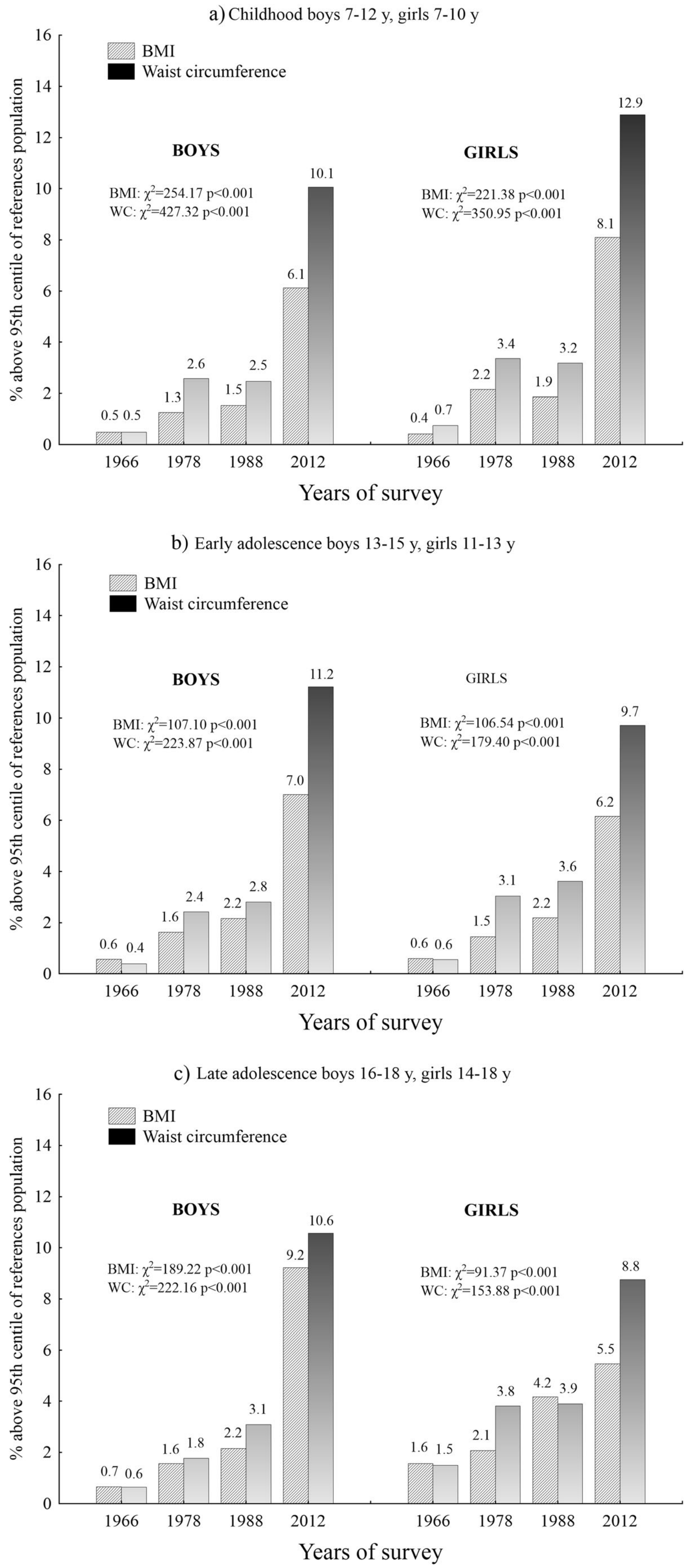
What is interesting is in girls, the pattern of prevalence of both considered types of obesities was reversed before political transformation when compared to the one observed in 2012: the highest percentage of girls with central and overall obesity was found during late adolescence, while the smallest proportion occurred during childhood. Increase in the percentage of obesity in this sex between 1988 and 2012 was, therefore, the highest in childhood (4.4-fold in BMI and 4.1-fold in WC), and the smallest in late adolescence (1.1-fold in BMI and 2.5-fold in WC).

Discussion

A recent systematic increase of mean values of BMI in populations of children and adolescents has been confirmed in many studies in Poland [19] and worldwide [1, 10, 28]. The presented results show that for the last nearly 50 years, the increase included not only mean values of BMI but also waist circumference (WC), and, what are new findings, the growth is much higher for WC than BMI. Namely, the mean values increased by 0.56 and 0.44 SD scores for BMI, while for WC, the increases were 1.05 and 0.77 SD scores in boys and girls, respectively. Similar results, indicating possible higher health risks than detected by BMI trends alone, were observed in previous researches [29, 30]. Between 1985 and 2007, central adiposity also increased at a faster rate than total adiposity in a sample of Australian schoolchildren [15]. Currently, in contrast to these results, other researchers emphasize that proportional changes in WC were similar to those in BMI and that only one fourth of the secular increase in WC for boys and a half for girls were independent of BMI [13]. The very strong correlation between BMI and WC complicates the assessment of independent effects of body fat distribution [22].

It is interesting that although both BMI and WC in schoolchildren have gradually increased since 1966, the level of these changes varied, depending on the period when the survey was conducted as well as on the developmental category. These changes reflect the effect of improvement or deterioration in the living conditions within the historic context as well as different sensitivities to environmental influences, related to the period of development. Children investigated in 1966 were born shortly after World War II, during the unfavourable period of communism and growing economic stagnation, accompanied by food shortages, which is reflected by the lowest BMI and WC values. Economic improvement, which appeared during the first half of the 1970s, is visible in the slight increase in these measures in 1978. However, at the end of the 1970s, the economic crisis started to deepen. These unfavourable circumstances might have influenced the lack or the smallest increase in BMI and WC between 1978 and 1988. The economy did not improve until the fall of communism in Poland after 1989. Since then, economic development, followed by the changes

Fig. 1 Changes in percentage of boys and girls above the value of the 95th centile for BMI and WC of the reference OLAF population in three developmental periods: **a** childhood boys 7–12 years, girls 7–10 years; **b** early adolescence boys 13–15 years, girls 11–13 years; **c** late adolescence boys 16–18 years, girls 14–18 years



in lifestyle has resulted in the rapid growth of the percentage of overweight and obese children visible in 2012 [19].

Conducting analyses in three developmental periods allowed to notice some regularities in changes of standardized mean values of both features, i.e. BMI and WC in both sexes. In boys, secular changes in BMI and WC were nearly in the same relative size from childhood through early to late adolescence. However, in girls, the increase in standardized means differed by developmental periods. During early stages of ontogenesis, a comparable growth in standardized mean values of BMI and WC was observed. In late adolescence, the increase in standardized mean values of BMI within the research period was slight (0.08 SD score), whereas the increase of WC was almost seven times higher in the same period of time. Therefore, the results of the present work suggest that for the last 46 years, the type of adipose tissue distribution has been changing to a more central one in late adolescence girls. It is the first report of such a phenomenon in Poland.

In the studies of British children and adolescents, an increase of central fatness was observed, but it was slightly greater for girls than boys [29]. Also, among American children, the increment in WC was higher for girls than for boys; nevertheless, since 1999, there has been no statistically significant increase in the mean waist circumference of boys [13]. On the other hand, the results of the present tests show that amounts of growths in standardized mean values of BMI were close for both sexes, but in the case of WC, the growths were higher for males than for females at each phase of ontogenesis and they exceeded 1 SD score. These differences between the above-mentioned studies may result, however, from the different methods of measurements as in the study on American children [13], measurements of waist circumference were taken just above the iliac, while in the present study it was midway between the top of the iliac crest and the lower rib. The increases in abdominal obesity have been attributed to various factors, including maturation timing, changes in energy intake and physical activity, the prevalence of endocrine disruptors and treatments for depression or changes in socio-demographic life [2, 17, 23, 31–33]. However, the effect of the endocrine disruptors was also discussed as leading to feminisation of the body fat distribution pattern—more gynoid than android one—in children in recent years [20]. Wells and colleagues [35] found that by increasing BMI, both fat mass (FM) and fat-free mass (FFM) increased, but FM tended to increase more in the truncal region, while FFM increased equally in the truncal region and lower extremities. Extra fat mass may be deposited more centrally with a concurrent decrease in fat-free mass, possibly due to a decrease in skeletal muscle mass. Thus, the assessment of WC, along with BMI, may add to identifying children and adolescents at increased risk of subsequent obesity-related disease.

It can be worrying that the percentage of children qualified to the group of above the 95th centile for BMI increased in the years 1966–2012 almost 13 times among boys and seven times in girls, while WC grew more than 21 times for boys and 10 times for girls. It means that over the 46 years, there was a greater increase of fraction of individuals with central obesity than the overall one. McCarthy and co-workers [29] stressed that prevalence of obesity determined with the use of BMI only has been systematically underestimated in British children. BMI alone may therefore lead to an underestimation of the corresponding health risks [7].

As WC reflects the growth in both visceral adiposity and centrally located subcutaneous fat, it can be expected that the number of metabolic complications in Polish children and adolescents will intensify in the future.

Some limitations of the study should be taken into account when analysing its results. A cross-sectional design makes it difficult to assess the direction and causality; however, it was methodologically appropriate for solving the research question. Additionally, the last survey from 2012 included relatively lower number of children, which could have biased the results. However, apart from the higher error of means, it is difficult to identify the direction and range of biases. Also, the waist measurement in the present study, in midway between the top of the iliac crest and the lower rib, could make the raw values of waist less comparable with other studies using different methods of measuring the waist.

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Authors' contributions The original idea came from Slawomir Koziel, who also ran the data analysis and described the results. Agnieszka Suder drafted the manuscript and prepared the final version. Aleksandra Gomula participated in data collection, data digitalizing, database preparation and manuscript preparation.

Compliance with ethical standards

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all the parents of the individual participants included in the study.

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