



# Long-term changes in fat distribution in children and adolescents aged 3-18 from Krakow (Poland), within the last 30 years (from 1983 to 2010)

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**ABSTRACT:** In Poland, even in the late twentieth century, the problem of obesity was not significant. However, recent studies have shown an increase in the prevalence of overweight and obesity. Socio-economic changes, in last decades, approached Poland to Western Europe. A lifestyle of Poles (physical activity and diet) have changed radically. The aim of the study was to investigate changes in adiposity in children and adolescents over the last decades.

Two cross-sectional studies were made in 1983 and 2010. The analysis included 10,324 children and adolescents aged 3-18 living in Krakow (Poland). Data on selected skinfolds (triceps, subscapular, abdominal, suprailiac, calf) were collected and compared between the series of studies. The total body fat (sum of 5 skinfolds) was higher in contemporary boys. In girls, there were not noticed such changes. In both sexes, the adiposity of triceps and subscapular region decreased. In the case of abdominal skinfold - there were no significant changes in boys, while contemporary girls had a smaller abdominal adiposity. In boys, there were noticed reduction in suprailiac skinfold thickness. In the case of girls, the reverse trend was reported - contemporary girls were characterized by higher suprailiac adiposity. Children studied in 2010 were characterized by greater calf skinfold.

Changes in adiposity are worrying, especially in boys. The priority should therefore be effective prevention and intervention programs. They can prevent further deepening of the problem among Polish children, by the time it will be as severe as in Western Europe.

**KEY WORDS:** skinfolds, adiposity, children, secular trend

## Introduction

In the last decades, a significant increase in the number of children with overweight and obesity has been seen in a majority of the highly industrialized and developing countries (Lobstein et al. 2005; Vigneroová et al. 2008; Nishida

et al. 2010). One of the causes of this phenomenon is, indirectly, the progress of science and technology, which has improved living conditions in societies. This otherwise positive phenomenon has lead to a reduced physical activity in people of all ages, resulting in increased body fat.

At the end of the 20<sup>th</sup> century, the problem of excessive body weight and fat was not as significant among Polish children and adults as in other countries. However, research conducted in some Polish cities at the beginning of the 21<sup>st</sup> century showed that the prevalence of overweight and obesity has increased significantly (Gomula et al. 2015; Kowal et al. 2016). Political transformations in Poland and the resulting socio-economic changes that have taken place in recent decades have brought Poland closer to the countries of Western Europe. Westernization, however, did not always lead to positive changes, and has radically changed people's choices regarding diet, physical activity, spending free time or taking stimulants – decisive factors in the prevalence of overweight and obesity and its related diseases.

In most epidemiological studies, overweight and obesity are defined relative to BMI. This indicator does have its limitations; it does not reliably inform about body fat or the distribution of adipose tissue. It has also been shown that the BMI of children and adolescents is better for assessing changes in fat free mass than adipose tissue (Kolle et al. 2009). The levels and distribution of adipose tissue are better reflected by skinfold measurements, especially in the case of children and adolescents (Kurtoglu et al. 2010; Moreno et al. 2012).

A lot of research has concerned the well-documented secular trend of the BMI index in Poland and other European countries (Smpokos et al. 2011; Sousa et al. 2012; Kołodziej et al. 2015; Topçu et al. 2017). Unfortunately, there are relatively few studies on inter-generational changes in the distribution of body fat, with most of the works based on measurements of circumference and WHR.

Indeed, excessive trunk fat, especially in the lower parts, carries with it a greater health risk than gynoid (gluteofemoral) obesity (Goran and Gower 1998; Bailey et al. 2015; Kelishadi et al. 2015; Pischon et al. 2008). Its main causes include low physical activity, sedentary lifestyle, poor nutrition, and also hormonal or genetic diseases. However, the distribution of fatty tissue in other parts of the body is also significant in the context of children's health. For example, high fat content of the upper limbs in children is correlated with weaker bone tissue due to the increased ratio of body fat to muscle in this segment of the body (Ducher et al. 2009). Literature data also suggest a relationship between lower limb obesity and a reduced risk of metabolic and cardiovascular disease (Smith et al. 2001; Lawlor et al. 2002). That is why a comprehensive approach to the problem of body fat is so important.

The aim of the study was to examine how the body fat in various individual body parts in children aged 3-18 have changed between measurements conducted in 1983 and 2010.

## Material and methods

The children analyzed in the study were included in two cross-sectional surveys conducted in randomly selected kindergartens and schools in Krakow in 1983 and 2010. All studied cohorts were a representation of each of the four traditional residential districts of Kraków: Śródmieście, Podgórze, Krowodrza and Nowa Huta. This city is second biggest in Poland (almost 1 million people) and the population from Kraków is a very good representation of the entire Polish population. Over the several decades the population living in Kraków has remained

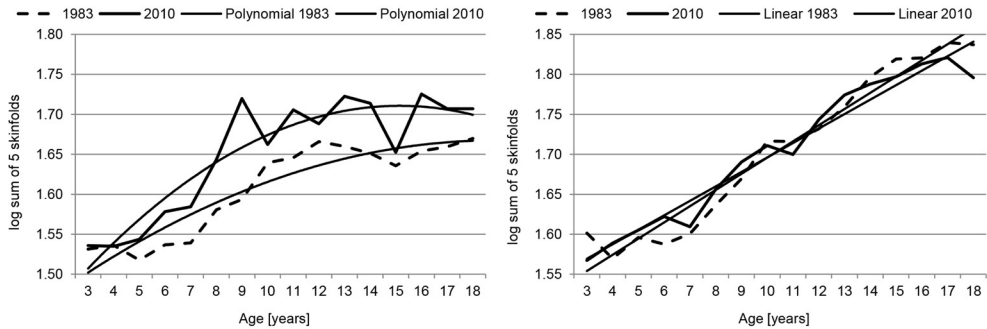


Fig. 1. Mean log sum of 5 skinfolds for Kraków boys (left) and girls (right), 1983 and 2010

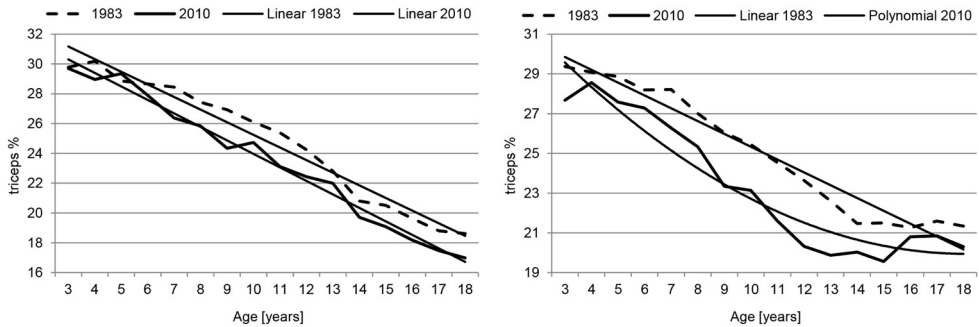


Fig. 2. Mean percentage of triceps skinfold in relation to the total body fat for Kraków boys (left) and girls (right), 1983 and 2010

homogeneous, so all the changes that occurred in the period from 1983 to 2010 concerned equally all citizens.

The age range of the survey was 3-18 years. The calendar age of the subjects, calculated as a difference between the date of the survey and the birth date, expressed as a decimal fraction, was a basis for classifying them as one of 16 age groups, e.g. the subjects aged 12.50-13.49 were in the group of 13-year-old children. The data from the 2010 survey series were compared with the results from previous survey series in 1983 (Chrzanowska et al. 1992). The sample sizes were the following: 3214 boys and 3250 girls in 1983, and 1889 boys and 1989 girls in 2010. The 2010 studies were conducted according to the procedures in force, i.e.

with the consent of the Bioethics Committee at the Regional Medical Association in Kraków (No 26/KBL/OIL/2007), and the written consent of children's parents or their legal guardians.

All the survey series were conducted by a team of academic researchers of the Department of Anthropology at the University of Physical Education in Kraków. Skinfold thickness was measured on the right side of the body by using of Harpenden skinfold caliper GPM (Switzerland) with a constant spring pressure of 10g/mm<sup>2</sup>. Five skinfolds: triceps, subscapular, suprailiac, abdominal and calf were measured. For the measurements of the triceps skinfold, the midpoint of the rear of the upper arm between the tips of the olecranal and acromial processes

Table 1. Results of two-way analysis of variance - comparison between cohort of 1983 and 2010 for boys and girls

Variable	Subscapular		Triceps		Abdominal		Suprailiac		Calf		Sum of 5 skin-folds		
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls		
Boys	SS	6978	474	73679	44708	15511	22655	20791	13237	8329	4952.7	153091	545541
Age	F	50.9	3.1	224.4	144.1	52.69	71.16	79.98	50.56	28.08	20.54	19.57	82.26
	p	0	0	0	0	0	0	0	0	0	0	0	0
	SS	265	368	1446	2438	110	1034	692	2575	8303	2497	19605	146
Cohort	F	30.9	38.6	70.5	125.7	5.99	51.97	42.61	157.38	447.81	165.71	40.11	0.35
	p	0	0	0	0	0.014	0	0	0	0	0	0	0.553
	SS	892	243	604	908	496	2729	1277	3511	827	1553.4	11846	7651
Interaction	F	6.5	1.6	1.8	2.9	1.68	8.57	4.91	13.41	2.79	6.44	1.51	1.15
	p	0	0.062	0.021	0	0.042	0	0	0	0	0	0.085	0.298

Table 2. Results of post hoc (Tukey’s HSD Test) - comparison between cohort of 1983 and 2010 within age classes for boys and girls

Age	Subscapular skinfold		Triceps skinfold		Abdominal skinfold		Suprailiac skinfold		Calf skinfold		Sum of 5 skinfolds (log)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
3	-1.80	-0.27	-0.08	-1.70	0.02	-0.35	-0.74	-0.44	2.60	2.76*	0.00	-0.03
4	-1.37*	-1.20	-1.23	-0.52	-0.15	-0.12	-0.61	-1.10	3.35***	2.94***	0.00	0.02
5	-1.98***	-0.43	0.48	-1.28	0.03	0.57	-1.41	-1.20	2.88***	2.35***	0.03	0.01
6	-1.44**	-1.30*	-0.76	-0.91	-0.30	-0.57	-1.31	-0.36	3.82***	3.14***	0.04	0.03
7	-0.90	-0.30	-2.07*	-1.94	0.69	0.11	-0.02	0.67	2.29***	1.46	0.05	0.01
8	-0.64	0.31	-1.58	-1.68	0.89	-0.06	0.26	0.80	1.07	0.62	0.06	0.02
9	-0.42	-0.62	-2.60***	-2.70***	0.46	1.51	0.26	2.23**	2.29**	-0.43	0.13***	0.02
10	-0.05	-0.94	-1.36	-2.31*	-0.64	0.30	-0.90	1.85	2.96***	1.11	0.02	-0.01
11	0.30	-0.18	-2.27*	-2.94***	-0.45	0.32	0.44	2.59***	1.99	0.21	0.06	-0.02
12	0.28	-0.49	-1.81	-3.32***	-0.55	-0.50	0.29	4.54***	1.80	-0.24	0.02	0.01
13	0.90	-0.38	-0.81	-2.74***	-0.60	-1.38	-2.63***	3.29***	3.14***	1.21	0.06	0.01
14	0.02	-1.40**	-1.09	-1.44	-0.52	-1.96*	-2.39***	3.91***	3.97***	0.89	0.06	-0.01
15	0.44	-0.92	-1.43	-1.94**	0.17	-2.30***	-2.35***	4.08***	3.17***	1.09	0.02	-0.02
16	0.73	-0.58	-1.45	-0.46	-0.03	-3.66***	-1.70	1.88**	2.45***	2.82***	0.07	-0.01
17	-1.05	-0.82	-1.32	-0.74	-0.56	-2.51***	-0.54	2.25***	3.47***	1.82**	0.05	-0.02
18	-1.42	-1.05	-1.63	-1.04	-0.77	-3.36***	-0.22	2.05**	4.04***	3.40***	0.04	-0.04

Statistically significant at p-level \*≤0.05, \*\* ≤0.01, \*\*\* ≤0.001

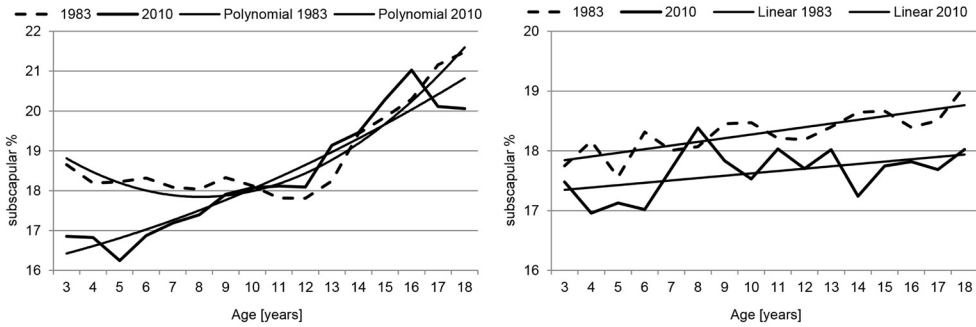


Fig. 3. Mean percentage of subscapular skinfold in relation to the total body fat for Kraków boys (left) and girls (right), 1983 and 2010

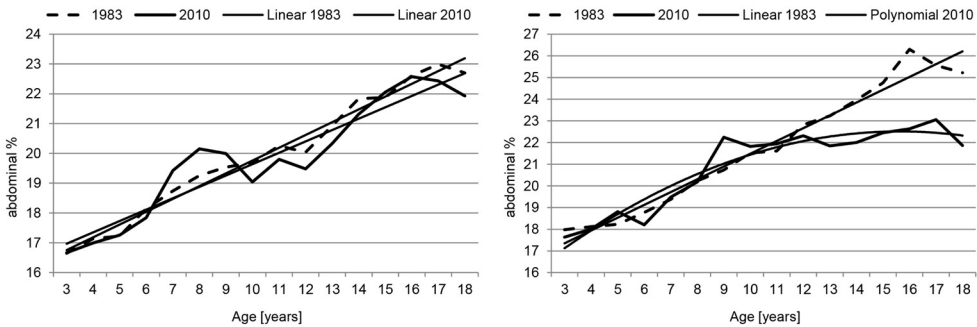


Fig. 4. Mean percentage of abdominal skinfold in relation to the total body fat for Kraków boys (left) and girls (right), 1983 and 2010

was determined with the arm flexed anomial of all lines was matched by means 90°. With the arm hanging freely at thøf the F-Snedecor test result. Skinfold side, the caliper was applied verticallythickness is distinguished by skewed above the olecranon at the marked leveldistribution, and that is why direct data At the subscapular site, the skinfold was(sum of five skinfolds) were expressed selected just below the inferior angle ofn a logarithmic scale. Changes in mean the scapula at 45° to the vertical along thøshare of every skinfold in total fatness natural cleavage lines of the skin. The suøf successive cohorts within age groups prailiac skinfold was measured above thøwere analyzed using two-way analysis of iliac crest, just posterior to the mid axilvariance where age and cohort were fac-lary line and parallel to the cleavage linesøtors (independent variables) and values of the skin. The abdominal skinfold wasøf skinfolds were dependent variables. measured 5 cm adjacent and 1 cm belowTukey's HSD test was used for post hoc to the umbilicus (Tanner, 1962). comparisons between cohorts from 1983

Measurements of sum of five skinfoldsand 2010.

and the mean percentage of the every in- All the statistical analyses were made dividual skinfold for two survey seriesusing the Statistica 12.0 and GraphPad presented as the graphs, were matchedPrism 5.01 software. with a trend line. The degree of a poly-

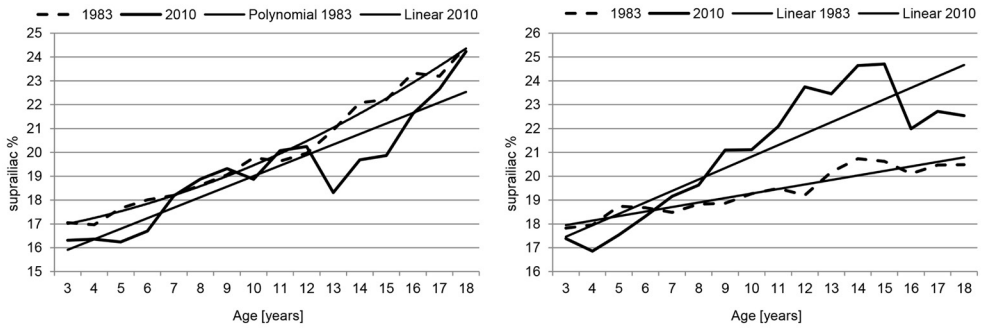


Fig. 5. Mean percentage of suprailiac skinfold in relation to the total body fat for Kraków boys (left) and girls (right), 1983 and 2010

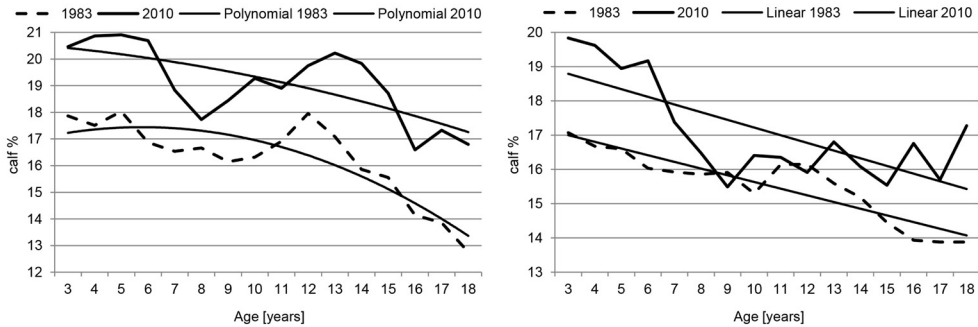


Fig. 6. Mean percentage of calf skinfold in relation to the total body fat for Kraków boys (left) and girls (right), 1983 and 2010

## Results

Analyzing the total fat content from all body segments, there were clear intergenerational differences in the case of the boys (Fig.1).

Only the youngest of those examined in 1983 and 2010 (3 and 4 year olds) had similar levels of total fat. In the other age categories, boys in 2010 were characterized by greater body fat, although due to large standard deviations these differences were statistically significant only for 9-year old boys. The situation was different in the case of the girls – in the vast majority of age categories, total fat did not change sig-

nificantly. In younger girls (3-9 years), the total of five skinfolds was slightly higher in those tested in 2010. A similar situation could be observed for adolescents. In the older age categories, the girls examined in 1983 were characterized by greater total body fat than those in 2010. The difference was largest but not statistically significant (Table 1 and Table 2).

The above mentioned results refer to total body fat and do not show how the distribution of fat tissue had changed over the analyzed 27 year period. However, this can be established by examining changes in the average percentage share of each skinfold in the previously ana-

lyzed total of five skinfolds.

In the case of the triceps skinfold, the average percentage in total body fat decreased between 1983 and 2010 (Fig.2).

The relative share of this skinfold among boys examined in 2010 (except 5-year-olds) was lower than in 1983 and in some age categories this difference was statistically significant (Table 1 and Table 2). Similar differences were observed for the girls.

The average percentage share of subscapular skinfold was lower in the children from 2010 (Fig.3).

In the boys, the biggest differences (usually statistically significant) could be found in the youngest age categories. The only exception was the period of adolescence when a relatively larger share of this measurement in the general body fat was noted in 1983. In the case of the girls, in almost all age categories, a lower subscapular skinfold was observed among the girls examined in 2010 – these differences varied depending on the age group (Table 1 and Table 2).

Another analyzed feature was abdominal fat. In the case of boys, the differences between 1983 and 2010 were not large. Nevertheless, in older age categories (above 9 years of age), there was a tendency for a relatively smaller skinfold thickness in this part of the body in the boys examined in 2010 (Fig.4).

Most often, however, these differences were small and statistically insignificant. In girls in younger categories (4-11 years) it varied depending on the age group. Clear discrepancies, however, could be found in older girls. During adolescence and later, girls examined in 2010 were characterized by relatively less fat on the abdomen than their peers from 1983 – those differences were statistically significant (Table 1 and Table 2).

The mean percentage share of suprailiac skinfold in total body fat varied depending on gender. In the case of boys, a relative decrease was observed in 2010 – the largest differences occurred in the pre-school age and during and after puberty (Fig.5). Significantly, in 15+ boys surveyed in 2010 the share of the suprailiac skinfold decreased sharply compared to the 1983 series. In the case of girls, the trend was different. Between 3 and 7 years of age, the share was similar in girls from both series. However, in later years of life, the girls in 2010 were characterized by definitely greater share of the suprailiac skinfold – differences were statistically significant (Table 1 and Table 2). It was only in the oldest girls, after adolescence, that a relative reduction in this skinfold could be observed.

The last of the analyzed folds was the calf skinfold. Boys examined in 2010 were characterized by a much greater calf skinfold their peers examined in 1983 (Fig.6). This was evident in all age categories and these differences were statistically significant (Table 1 and Table 2). Also in the case of girls, a similar tendency was observed – in 2010 they were characterized by a larger share of the calf skinfold. The biggest differences were noted for girls in preschool and during adolescence.

## Discussion

Analysis of the obtained results concerning body fat showed a change between 1983 and 2010. Changes in the distribution of adipose tissue were dependent on the location of the skinfold and the gender of the examined children.

In boys examined in 2010, total fat was greater than in 1983. A detailed analysis of fat distribution showed increased fat on the lower limb in 2010, with the

remaining skinfolds similar to or lower than 1983. This result differs from those studies that suggest the increased body fat percentage in the trunk is responsible for the increase in overall body fat in successive generations (Godina et al. 2016; Kryst et al. 2016; Martinez-Tellez et al. 2016).

In girls, total body fat varied with age. The girls examined in 2010 were characterized by slightly greater fat content than in 1983 until the onset of puberty. In the older age categories, this trend reversed and girls from 2010 had less fat than in 1983. In the case of the distribution of adipose tissue, we found a relatively greater suprailiac skinfold, which had previously been observed in the studies of Kowal et al. (2014), and calf skinfold, a trend similar to that observed in a study by Sedlak et al. 2017. In the Czech population it also concerned the examined 3-5-year-old boys and girls. An increase in total adipose tissue content in subsequent generations was also observed in 6-year-olds in the Croatian population, surveyed in 1998, 2003 and 2013 (Horvat et al. 2017).

Negative changes in lifestyle, mainly in physical activity, diet, workload and the way of spending free time, cause changes in body morphology and motor abilities. These changes result, among other things, in increased body fat and changed distribution of body fat. This was observed in children and adolescents in many countries, e.g. Spain, Norway, Russia and Australia (Moreno et al. 2007; Kolle et al. 2009; Olds et al. 2010). However, the intensity of these phenomena vary, depending on the place of study, age and gender.

Analysis of fat distribution among children from the Kraków population shows many interesting regularities,

rarely found in other countries. The vast majority of countries have seen an increasing trend towards abdominal obesity. This is a very unfavorable phenomenon, because, if untreated, it can lead to long-term disorders of many systems, causing, among others, cardiovascular or metabolic diseases, hypertension, diabetes, cancer, or diseases of the locomotor system (Bodenant et al. 2011; Brun et al. 2011; Hong et al. 2012; Goh et al. 2014). This problem concerns mainly highly developed countries, but at the beginning of the 21st century, it also emerged as a serious issue in developing and poorer countries (Nishida et al. 2010).

In our study we did not observe any relative increase in abdominal fat, either among boys or girls. In girls in older age categories examined in 2010, we even found a gradual relative decrease in the abdominal skinfold. Most likely, this was the result of increased conscious body control among modern girls, especially between the ages of 15 and 18. In addition to body weight and fat content control through diet, girls are more willing to participate in various physical activities. Other authors also point to this phenomenon (Tutkuvienė 2005; Goldfield et al. 2007). However, in our study it did not apply to relative suprailiac skinfold thickness – in girls in 2010 it was greater than in their peers from 30 years ago. This is worrisome despite the observed reduction in the thickness of other skinfolds, for example in subscapular and abdominal skinfolds. An increase in the share of suprailiac skinfold in total fat may also increase the incidence of abdominal obesity. A similar trend has been observed in many countries, including Czech (Sedlak et al. 2015; 2017), Russia (Godina et al. 2016), Brazil (Leal et al. 2015) and Spain (Moreno et al. 2012).



Significantly, in our study, boys and girls revealed a marked increase in lower limb fat between 1983 and 2010. In boys, this phenomenon was so large that it may even distort the interpretation of results concerning the total of five skinfolds. Unfortunately, data regarding intergenerational changes in this skinfold are quite scarce in literature, as authors usually focus on the trunk and arms. However, it is well known that while excessive abdominal fat is extremely unfavorable for the health of people of all ages, a large accumulation of adipose tissue in the lower extremities has been described as beneficial and protecting against many diseases. Research conducted in the last decade has shown that the accumulation of adipose tissue in children in this part of the body can act protect and reduce the risk of cardiovascular and metabolic diseases (Zhang et al. 2013; Staiano et al. 2014; Samouda et al. 2015). Analysis of fat content, lipid profile and other biochemical features among children with overweight/obesity has shown that leg fat mass is associated with insulin resistance and positively influences lipid profile of the blood (Samouda et al. 2016). Similar conclusions were drawn from studies among students in Spain – the lipid profile of people with high leg fat was definitely better than the profile of people with excessive trunk fat (Sánchez-López et al. 2013). Studies on adults in France have shown that this type of fat cover protects against atherosclerosis and has a positive effect on the level of liver enzymes, which in the long term can protect this organ (Perlemuter et al. 2008). However, although the phenomenon of fatty tissue accumulation in the lower limbs is now considered positive, the overriding reason for this is most likely the reduced physical activity among chil-

dren and adolescents. Analysis of the secular changes in the fatness of this part of the body clearly shows that in girls in the older age categories, calf skinfold thickness did not differ significantly between the cohorts examined in 1983 and 2010. The percentage of adipose tissue on legs also has a clear tendency to decrease with age. In 18-year-old girls in 2010 leg fat was similar to that observed in their peers in 1983. This was in line with previous observation regarding abdominal fat and other features of body structure (Kryst et al. 2017). The main reason was probably increased physical activity of girls after puberty and a conscious control of their weight and body composition.

Therefore, in the studied population from Kraków we can observe various tendencies. As described above, over the course of almost three decades, obesity in the lower extremities increased significantly in both sexes, more so in the boys. The distribution of fat in other areas of the body also changed. In general fat content decreased, apart from the suprailiac skinfold in girls. The observed phenomena are not as disturbing as those noted in many other countries (Al-Sendi et al. 2003; Moreno et al. 2007; Olds et al. 2009; Leal et al. 2015). Poland still seems to be still in an initial phase when the percentage of children with overweight/obesity is not as significant yet, but shows a steady upward trend. Between 1983 and 2010, the percentage of overweight boys increased from 11.7% to 15.9%, and obese from 2.6% to 4.9% (Kowal et al. 2013). The percentage of overweight/obese girls did not change much, although this strongly varied across age categories (Kowal et al. 2014).

It seems that the unfavorable phenomena related to the increase in the percentage of children with overweight/obesity,

similar to Western European countries, will now be intensified and it will be difficult to stop. As one can imagine, it will also be associated with an increase in body fat. However, continued research on body fat in children and youths may allow us to discover and better understand the mechanisms and factors responsible for this phenomenon.

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### Authors' contributions

LK conceived of the presented idea, was an investigator in the research project and wrote the working and final versions of the manuscript; AW was an investigator in the research project, performed statistical analyses, drafted and worked on the final version of the manuscript; MK was in charge of the research project and drafted the manuscript; JS was an investigator in the research project and drafted the manuscript. All authors discussed and accepted the final version of the manuscript.

### Conflict of interest

The authors declare that they have no conflict of interests regarding publication of this paper.

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