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ORIGINAL RESEARCH ARTICLE

Intergenerational changes in limb circumferences in children and adolescents aged 3-18 from Kraków (Poland) from 1983 to 2010

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Objectives: Measurements of body circumferences are often used in anthropology. The research on this topic, however, rarely concerns limb girths or secular trends. The main aim of this study was to investigate the occurrence of secular trends in selected limb circumferences among children and adolescents.

Methods: The research was based on measurements from two cross-sectional studies carried out in 1983 and 2010 with children and adolescents aged 3-18 from Krakow, Poland. The circumferences of the arm, forearm, thigh and calf, as well as the sum of circumferences and selected indicators, were analyzed. The series were compared using the two-way ANOVA test.

Results: In most age groups of both sexes, a positive secular trend was observed for the majority of studied traits. The exception was the thigh circumference, for which, among girls, measurements in both series were similar, and negative intergenerational changes were recorded in the youngest age groups of both sexes as well as among the oldest girls. Most observed discrepancies were statistically significant in pre-school children and adolescents.

Conclusions: The presence of positive secular trends shows that limb circumferences were increasing in subsequent generations, especially in boys. Contemporary girls, particularly in the older age groups, were more determined to have a slim figure and practiced conscious weight control. Summarizing, observed tendencies resulted from the improvement of socio-economic conditions, but were also related to the low level of physical activity.

KEYWORDS

limb circumference, secular trend, socioeconomic changes

1 | INTRODUCTION

Human ontogenesis is influenced significantly by environmental factors, especially multidirectional modifiers such as the educational and professional status of parents, financial status and family structure, level of medical care, and diet (Eveleth & Tanner, 1990; Komlos & Baten, 2004; Meredith, 1979). Changes in these factors are inevitably reflected in the proportions of the human body, and observations about the direction and pace of these intergenerational changes are one of the key methods used in assessing the impact of socio-economic factors on the development of the human body. In this field, most authors focus mainly on analyzing height measurements or indicators of overweight and obesity, as well as the composition of the body (Kowal, Kryst, Sobiecki & Woronkowicz, 2013a; Kryst, Kowal, Woronkowicz, Sobiecki & Cichocka, 2012; Marques-Vidal, Madeleine, Romain, Gabriel & Bovet P, 2008; Nascimento et al., 2010).

The growing epidemic of overweight and obesity has become one of the most important health issues worldwide,

Limb circumferences-long-term changes in children.

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with 62%-76% of the world's population in industrialized and developing countries reaching a health-threatening level of body fat (Maffetone, Rivera-Dominguez & Laursen, 2017). Unfortunately, the growing prevalence of excessive body weight has also affected children and adolescents (Hales, Carroll, Fryar & Ogden, 2017; Kalies, Lenz & Von Kries, 2002; Moreno et al., 2001; Skinner, Perrin, Skelton, 2016; Smith & Smith 2016; Vijayakumar et al., 2016; Wedderkopp, Froberg, Hansen & Andersen, 2004; WHO 2017). The problem has also started to increase among children and adolescents in Poland, a country which - relative to other European countries - has a moderate to high level of overweight and obesity in younger age groups (Kułaga et al., 2016).

The increasing incidence of excessive body weight is visible in subsequent generations of children and adolescents worldwide. Increasing secular trends regarding body mass can be observed even in the youngest age groups (Olds, 2009; Sedlak, Pařízková, Daniš, Dvořáková & Vignerová, 2015). Furthermore, in many countries, including Poland, we observe a halt in the positive secular trend for body height, while there is still an increasing secular trend for body weight, resulting in the significant intergenerational growth in BMI (Freedman et al., 2012; Kryst et al., 2012; Sanna & Soro, 2000; Topçu, Orhon, Ulukol & Başkan, 2017; Zong et al., 2017).

The growing incidence of obesity is an extremely important health issue. Even 6- to 7-year-old children with excessive fat may be exposed to risk of cardiovascular diseases, hypertension, as well as elevated glucose and insulin levels in the blood (Hansen, Hasselstrøm, Grønfeldt, Froberg & Andersen, 2005).Children in the 8- to 15-year age group with similarly high-fat content experience elevated cholesterol levels or elevated blood pressure associated with their reduced physical activity (Ribeiro et al., 2004). A sedentary lifestyle also results in the increasing frequency of so-called latent obesity, associated with an increasing level of body fat at the expense of muscle mass caused by insufficient physical activity (Sedlak et al., 2015; Pařizková, 2016). Hypokinesis is also a cause of excessive body fat in muscles which can be observed in people with high, as well as normal, BMI values. Low levels of physical activity can lead to the reduction of the muscle mass and lower the strength of the muscles. At the same time, this can cause an increase in the amount of fat tissue and weight gain, and a reduction in metabolic rate (Stenholm, Harris, Rantanen, Visser, Kritchevsky & Ferrucci, 2008). Coexistence of such phenomena is known as sarcopenic obesity, because of the presence of diagnostic criteria for sarcopenia (eg, low muscle mass) and obesity (eg, high body fat) (Lee, Shook, Drenowatz & Blair, 2016). This type of obesity is most often associated with elderly patients. However, it can also affect children and adolescents, especially those leading a sedentary lifestyle (Kim, Hong, Kim, 2016). Sarcopenic obesity can often be hard to diagnose because decreased muscle mass can be masked by an increased amount of fat tissue. Therefore, the child's body build and tissue composition may appear normal (Cauley, 2015; Steffl, Chrudimsky & Tufano, 2017). This is an especially important problem because this type of obesity is associated, for example, with increased insulin resistance and a higher risk of the development of the metabolic syndrome (Kim et al., 2016; Steene-Johannessen, Anderssen, Kolle, & Andersen, 2009).

The growing trend in the proportion of children and adolescents affected by overweight and obesity is manifested not only in the results of total body weight measurements or indicators of body fat. Children with higher values of these parameters are characterized by larger circumferences of the limbs than their peers with a normal mass (Almeida et al., 2016; Dasgupta et al., 2010). This shows the usefulness of these traits as predictors of excessive body weight and body fat (Chaput et al., 2016; Jaiswal, Bansal & Agarwal, 2017; Mazıcıoğlu et al., 2010).For example, arm circumference measurement is characterized by 95% sensitivity and 90% specificity with regard to body fat. Calf circumference, though previously used for a similar purpose mainly in the elderly population, may also be useful for children (Gavriilidou, Pihlsgård & Elmståhl, 2015; Júnior et al., 2016). Therefore, determination of the direction and pace of secular trends for selected body circumferences is a relevant and significant research problem. The aim of this study was to investigate secular trends in selected limb circumferences among children and adolescents in Kraków, based on measurements taken in 1983 and 2010.

2 | MATERIAL AND METHODS

The children analyzed in this study had been included in two cross-sectional surveys conducted in randomly selected kindergartens and schools in Kraków (Poland) 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. Kraków is the second biggest city in Poland (almost 1 million people), and the population from Kraków is a very good representation of the entire Polish population. Over several decades, the population living in Kraków has remained homogeneous, so all of the changes that occurred in the period from 1983 to 2010 concerned all citizens equally.

The age range of the survey was 3 to 18 years (Table 1). The calendar age of the subjects, calculated as the difference between the date of the survey and the birth date, expressed as a decimal fraction, was the basis for classifying participants into one of 16 age groups, for example, subjects aged 11.50 to 12.49 were in the group of 12-year-old children. Data from the 2010 survey series were compared with the results from a previous survey series in 1983 (Chrzanowska, Gołąb, Bocheńska & Panek, 1992). The sample sizes were the following: 3214 boys and 3250 girls in 1983, and 1889

TABLE 1 The number of children from Kraków in age groups, in both series of study (1983 and 2010)

	1983		2010	
Age	**Boys**	**Girls**	**Boys**	**Girls**
3	45	65	60	72
4	171	133	128	121
5	153	148	127	131
6	211	209	136	142
7	218	204	137	116
8	209	203	126	108
9	204	212	112	103
10	234	192	90	90
11	194	236	80	97
12	215	220	64	68
13	229	213	182	173
14	238	218	197	161
15	223	257	157	171
16	244	215	106	178
17	185	243	78	131
18	150	193	83	113

boys and 1989 girls in 2010. The studies had been conducted with the consent of the Bioethics Committee at the Regional Medical Association in Kraków (No 26/KBL/OIL/2007), and with the written consent of the parents or legal guardians.

The survey series had been conducted by a team of academic researchers from the Department of Anthropology at the University of Physical Education in Kraków.

Four circumferences were measured: mid-upper arm circumference - measured with the muscles relaxed, in the middle of the upper arm; forearm circumference - measured with the muscles relaxed, at the point of the largest circumference, below the elbow joint; thigh circumference - measured standing up, with the weight evenly distributed, at the point of the largest circumference below the gluteal-fold; calf circumference - measured standing up, with the weight evenly distributed, at the point of the largest circumference. For the measurement of all circumferences, a non-stretchable measuring tape was used (accuracy 0.5 cm).

By using these measurements, three indices were calculated:

$$\text{Limb Circumference Index (LCI)} = (\text{forearm circumference} + \text{calf circumference})/(\text{mid}-\text{upper arm circumference} + \text{thigh circumference}).$$

$$\text{Upper Limb Circumference Index (ULCI)} = \text{forearm circumference}/\text{mid}-\text{upper arm circumference}$$

$$\text{Lower Limb Circumference Index (LLCI)} = \text{calf circumference}/\text{thigh circumference}.$$

Also, two skinfolds were measured: triceps skinfold (TSF) - vertical skinfold, measured with the muscles relaxed, in the middle part of the posterior surface of the upper arm over the triceps muscle; calf skinfold (CSF) - vertical skinfold, measured with the leg bent, below the *popliteal fossa*, at the level of the largest circumference of the calf. Skinfold thickness was measured using a Harpenden skinfold calliper GPM (Switzerland) with a constant spring pressure of 10 g/mm^2.

Moreover, two corrected circumferences were calculated:

$$\text{Mid}-\text{Upper Arm Muscle Circumference (MUAMC)} = \text{mid}-\text{upper arm circumference} - [(\pi \times \text{TSF})]$$

$$\text{Corrected Calf Muscle Circumference (CCMC)} = \text{calf circumference} - 2\pi \times \text{CSF}.$$

Measurements of every individual circumference, their sum and corrected circumferences (for mid-upper arm and calf) for two survey series, presented as graphs, were matched with a trend line. The degree of a polynomial of all lines was matched by means of the F-Snedecor test result. Changes in mean circumferences in successive cohorts within the age groups were analyzed using two-way analysis of variance where age and cohort were factors (independent variables) and values of circumferences were dependent variables. Tukey's HSD test was used for post hoc comparisons between the cohorts from 1983 and 2010. All statistical analyses were made using Statistica 12.0 and GraphPad Prism 5.01 software.

3 | RESULTS

A positive secular trend in mid-arm circumference was visible in boys aged 5 to 18 years and girls aged 4 to 16 years. Outside these age groups, the children from the 1983 series had higher values than those surveyed in 2010. Statistically significant negative differences occurred mainly in the periods of older childhood and in 18-year-olds of both sexes (Figure 1, Table 2).

Similarly, in the case of the MUAMC, in both sexes, a positive secular trend was observed in most age groups. Statistically significant differences occurred in girls in peripubertal ages. Among boys, however, discrepancies in most age groups did not reach statistical significance (Figure 1, Table 2).

A positive secular trend in forearm circumference was observed in almost all age groups in both sexes. Statistically significant differences between the study groups were recorded for both sexes, aged 6 to 15 years, and in 18-year-old boys (Figure 1, Table 2).

Thigh circumference was similar in all age groups in girls from both studied series (Figure 2).Any differences were minimal and statistically insignificant (Table 2). Among boys, however, higher values of this measurement were found in the study group in 2010, and were statistically

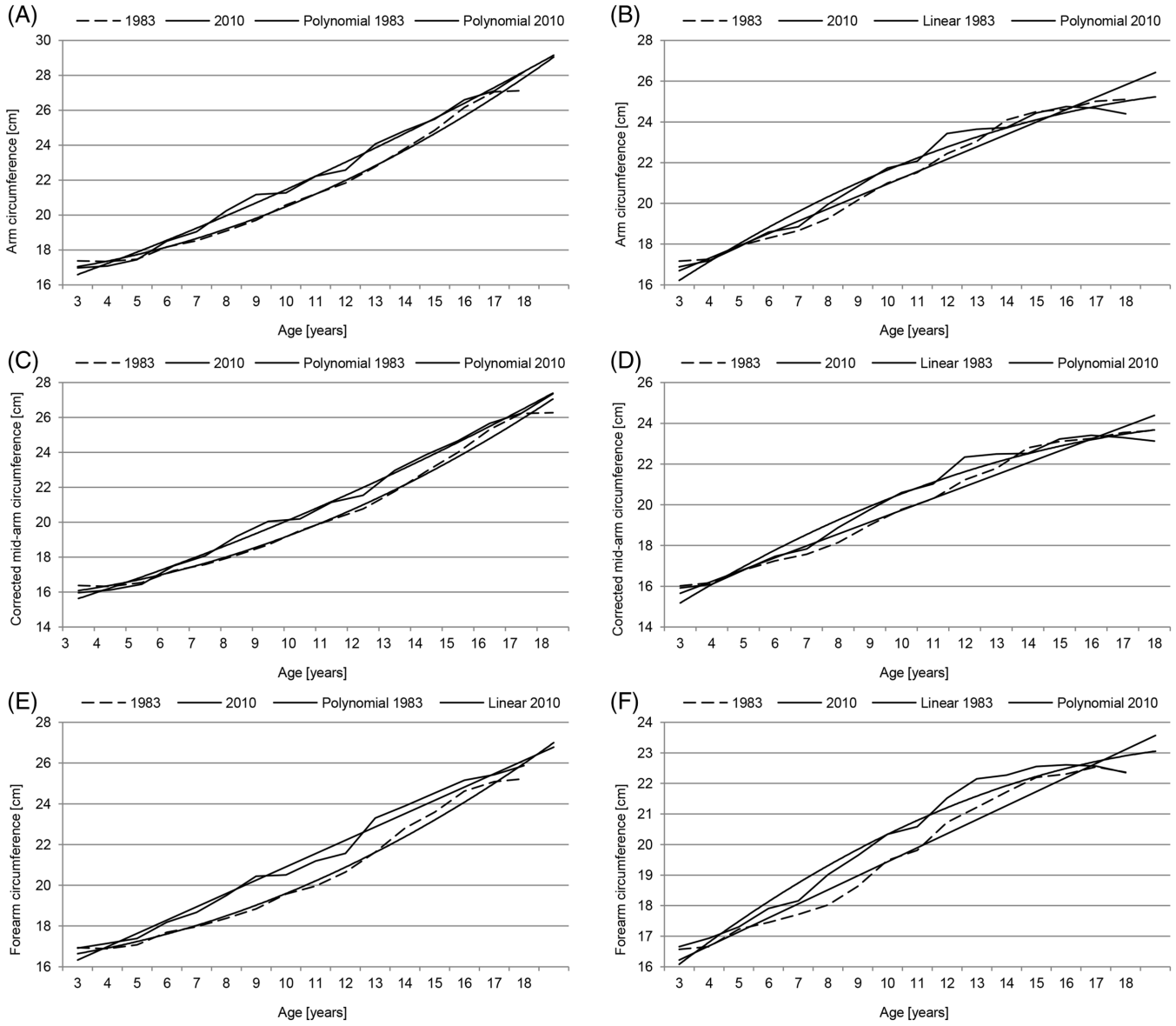

FIGURE 1 Mean circumferences of: mid-upper arm (boys A, girls B), corrected mid-upper arm (boys C, girls D), forearm (boys E, girls F)

significant in the period of older childhood, and in 18-year-olds (Figure 2, Table 2).

Calf circumference among boys was higher in the population from 2010 in all age groups (Figure 2), with statistically significant differences mainly in older childhood. In girls, the positive secular trend was present from 3 to about 14 years of age, when the results for both series began to show almost equal values. In these girls, differences between the series were not statistically significant in most cases (Figure 2, Table 2).

In the case of CCMC, in the majority of age groups, the presence of a negative secular trend was observed, although in most cases the differences were not statistically significant (Figure 2, Table 2). In girls, negative intergenerational changes were observed for pre-school, early-school and post-adolescent age. In the peripubertal period, however, girls from the 2010 series showed higher values than their peers from 1983. Again, however, these differences were not statistically significant in most age groups.

For all analyzed measurements, limb circumferences increased from 2010 to 1983. For this reason, the total of 4 circumferences showed a positive secular trend in both sexes in most age groups. The differences were statistically significant in older children and adolescents (Figure 3, Table 3).

In children examined in 2010, increases in the circumference of the upper limb were to a greater extent caused by an increase in forearm circumference than the mid-arm circumference. The upper limb circumference index showed higher values in both sexes and in almost all age groups from 2010. Statistically significant differences between the analyzed series were found for pre-school-aged children and the majority of the age groups in girls (Figure 3, Table 3).

In girls and boys up to the age of 15 years from 2010, increases in calf muscle circumference were greater than for

TABLE 2 Results of two-way analysis of variance - comparison between cohort of 1983 and 2010 for boys and girls

		Mid-arm circumference		Corrected mid-arm circumference		Forearm circumference		Thigh circumference		Calf circumference		Corrected calf circumference		Sum of 4 circumferences	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Age	SS	54 140	36 165	55 608	33 359	39 561	21 462	226 396	231 763	107 455	91 180	105 216	85 597	1 518 998	1 250 998
	F	511.7	399.8	640.6	463.4	781.9	520.7	658.7	705.3	883.6	868.2	977	913.2	790.6	746.7
	p	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
Cohort	SS	452	27	406	60	675	203	1108	57	679	154	380	96	11 343	1552
	F	68.3	4.8	74.9	13.4	213.4	78.9	51.6	2.8	89.3	23.4	56.5	16.3	94.5	14.8
	p	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
Interaction	SS	330	244	303	237	240	139	715	487	293	265	255	279	5091	3594
	F	3.1	2.7	3.5	3.3	4.7	3.4	2.1	1.5	2.4	2.5	2.4	3.0	2.6	2.1
	p	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001

thigh circumference, which resulted in a positive secular trend in the lower limb circumference index shown in these groups. In older boys, an increase in thigh circumference was prominent, which resulted in the presence of an intergenerational decreasing trend in the lower limb circumference index. Statistically significant differences occurred in boys aged 10 and 13 years and in girls in the youngest age group and in the early school period (Figure 3, Table 3).

Upper limb circumferences in 2010 of girls and boys up to 16 years of age increased more than lower limb circumference. Therefore, the values of the limb circumference index exhibited a positive secular trend in these groups. In older boys, both series of measurements showed similar results, which is due to similar increases in thigh and calf circumferences. Statistically significant differences were recorded in younger boys and in almost all age groups of girls (Figure 3, Table 3).

4 | DISCUSSION

In the presented analysis, upper limb circumferences showed a positive secular trend. Similar results were obtained between 2003 and 2013 in the Croatian population. There, among 6-year-old girls, there were positive intergenerational changes in the circumferences of both the mid-arm and the forearm (Horvat, Harski & Sindik, 2017). Analogous results, confirming the occurrence of general intergenerational transformations, were also obtained for an Iranian population studied in 1988 and 2003 (Ayatollahi, Pourahmad & Shayan, 2006).Opposite results were, however, obtained by Sedlak, Pařízková J, Procházková L, Cvrčková L, Dvořáková (2017) who observed a negative secular trend for mid-upper arm circumference (from 1990 to 2014).

At the same time we noted that, in 1983, the youngest children of both sexes had a greater mid-upper arm circumference than those observed today. This phenomenon in preschool children is confirmed by the results obtained by Aberle, Blekić, Ivaniš & Pavlović (2009). They observed a negative secular trend in 4-year-old children between study groups from 1985 and 2005. Analogous results were also presented in another study, where the lesser result in the modern population was caused by a relatively smaller muscle mass (Sedlak et al., 2017). In the Kraków children, however, a similar phenomenon was associated with a general decrease in the mid-upper arm circumference in these age groups. As shown by previous studies, 3- to 4-year-old children from 2010 were characterized by a lower triceps skinfold thickness than their peers in 1983 (Kowal et al., 2013b; Kryst et al., 2017). Additionally, the 3- to 4-year-old boys showed a positive secular trend in mid-upper arm muscle circumference. Such information is crucial because the anthropometric characteristics of the mid-upper arm area are particularly important in children. The content of adipose tissue as well as muscle mass in the arm is positively correlated

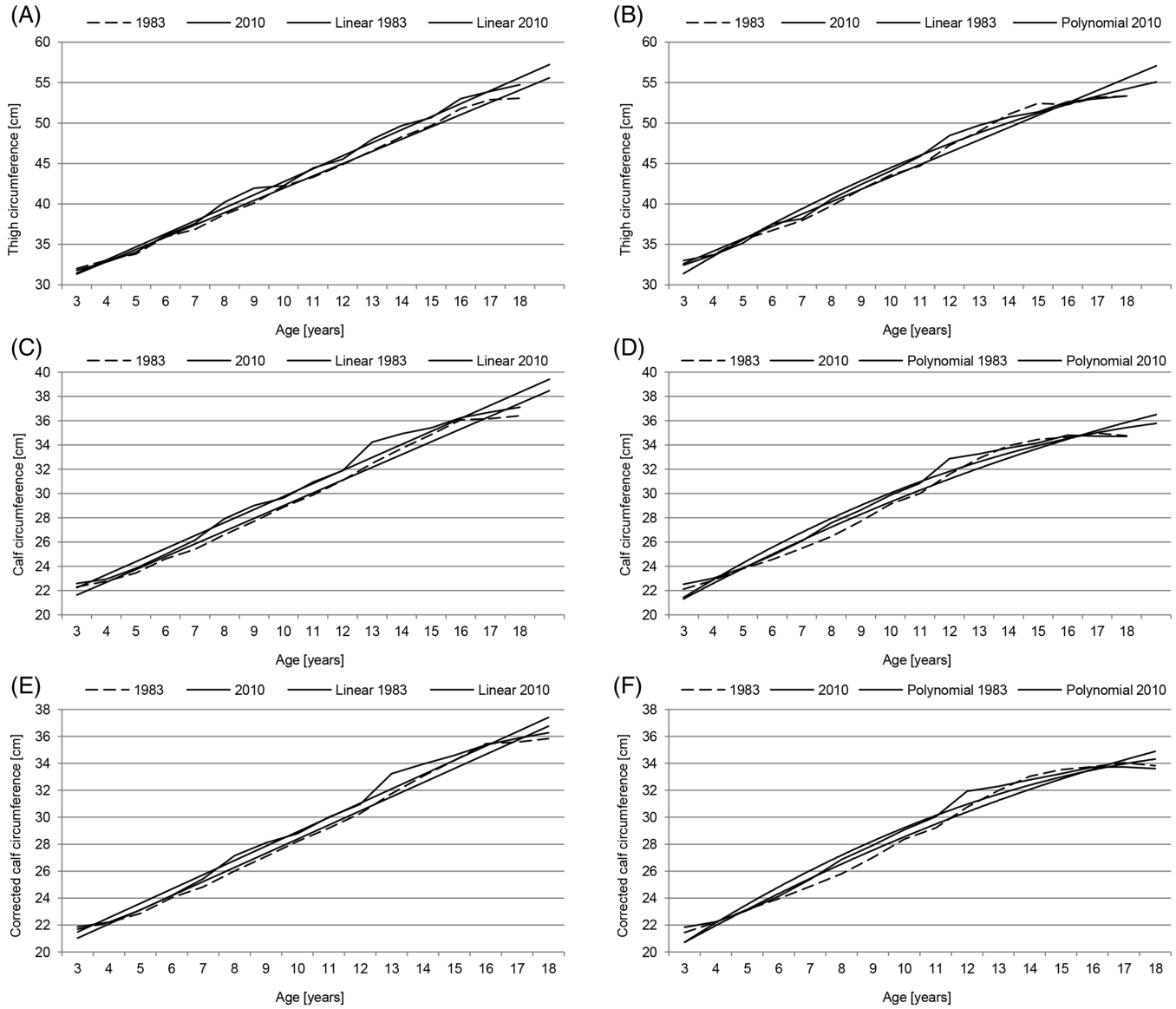

FIGURE 2 Mean circumferences of: thigh (boys A, girls B), calf (boys C, girls D), corrected calf (boys E, girls F)

with total body fat measured by the skinfold thickness and fat-free mass (Fricke et al., 2008). Therefore, mid-upper arm circumference is useful not only as a diagnostic tool for malnutrition or underweight, but also for excessive weight and the prediction of overall body composition (de Almeida et al., 2003; Debnath, Mondal & Sen, 2017; Mazıcıoğlu et al., 2010).

In terms of thigh circumference, girls from both series had very similar values in all age groups. These results are consistent with another study, where girls examined in 1998, 2003 and 2013 did not exhibit any significant differences (Horvat et al., 2017). At the same time, in girls from the Czech population, a positive secular trend in the group of 4-year-olds and a negative one in 6-year-olds were observed (Sedlak et al., 2017). The same team also noted the presence of negative intergenerational changes between the 1990 and 2014 series in 5- and 6-year-old boys. In our study, however, in the majority of boys, the thigh circumference in 2010 was higher than in 1983. These results are consistent with those of Lintsi & Kaarma (2006). The calf circumference among boys was also higher in 2010. In girls, a similar trend was visible from 3 to about 14 years of age, when the results for both series began to show almost equal values. Similarly, a study by Horvat et al. (2017) showed positive intergenerational changes in calf circumference in 6-year-old girls between 2003 and 2013. Importantly, in a previous study on the Kraków population, almost all age groups of both sexes showed a significant increase in the thickness of the calf skinfold (Kryst, Bilińska, Kowal, Woronkowicz & Sobiecki, 2017). This suggests that the previously described greater calf circumference in the series from 2010 may result from a larger share of adipose tissue. In addition, this is evidenced by the negative secular trend of the corrected calf muscle circumference in the majority of age groups presented in our study.

The general positive direction of intergenerational changes in most limb circumferences is, therefore, obviously

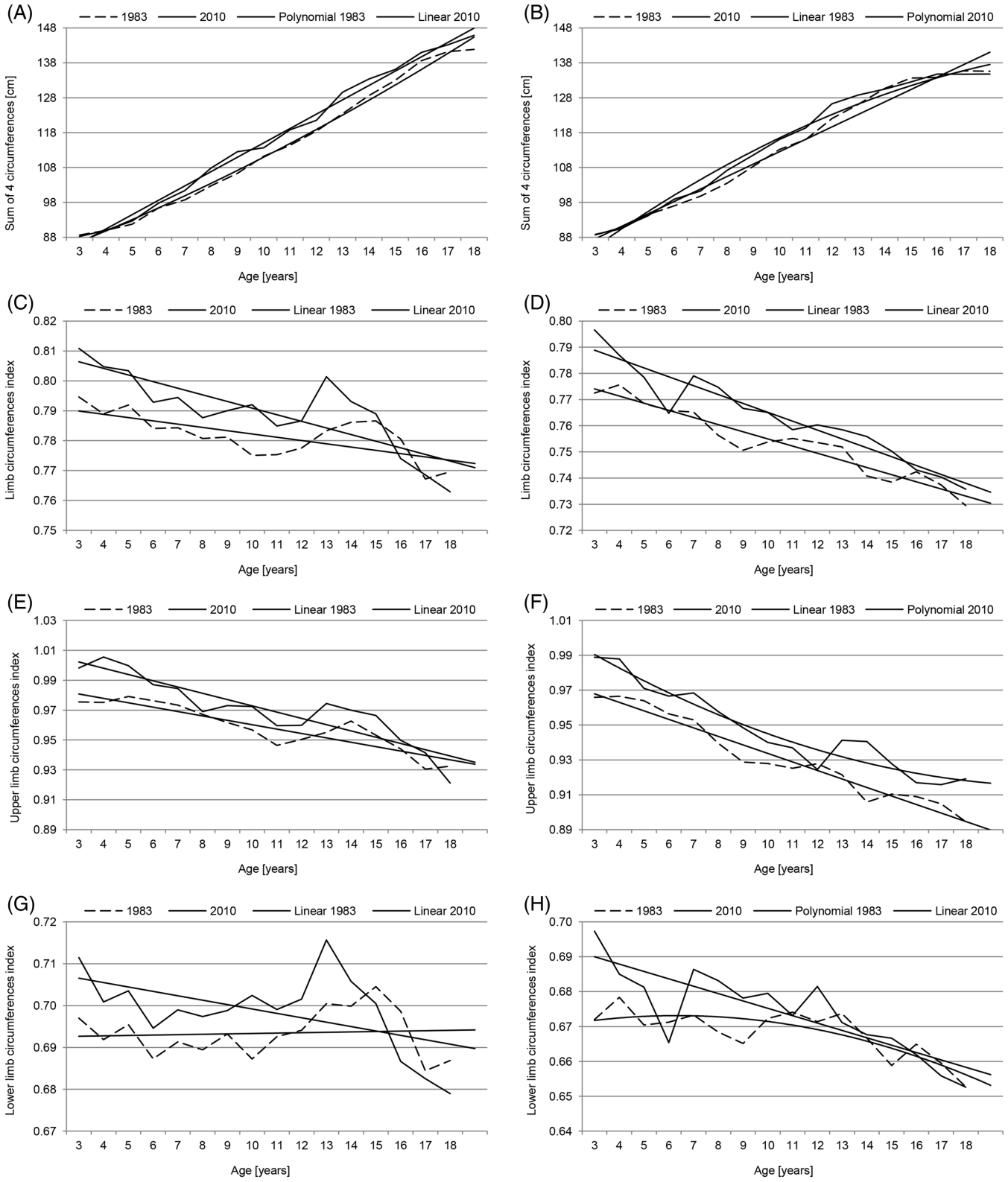

FIGURE 3 Mean values of: sum of 4 circumferences (boys A, girls B), limb circumference index (boys C, girls D), upper limb circumference index (boys E, girls F), lower limb circumference index (boys G, girls H)

also associated with changes in body composition. For example, Olds (2009) suggestedthat the positive secular trend with regard to the circumferences of the limbs in recent decades is present due to an increase in body fat. However, in the populations of Kraków, boys have shown an increase in fat and muscle mass as well as a decrease in bone mass (Kowal et al., 2013b). It was different in girls, where the total body fat did not change significantly between 1983 and 2010 (Kowal, Kryst, Woronkowicz & Sobiecki, 2014). Therefore, the increased circumferences of limbs are a result

TABLE 3 Results of two-way analysis of variance - comparison between cohort of 1983 and 2010 for boys and girls - cont

		Limb Circumference Index (LCI)		Upper Limb Circumference Index (ULCI)		Lower Limb Circumference Index (LLCI)	
		Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Age	SS	0.4	0.9	1.4	2.3	0.2	0.3
	F	16	46	30	52	6.7	13
	p	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Cohort	SS	0.04	0.1	0.1	0.2	0.01	0.03
	F	28	65	38	76	7.9	22
	p	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Interaction	SS	0.1	0.04	0.1	0.1	0.1	0.1
	F	3.0	2.0	2.0	2.0	2.4	3.0
	p	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001

of an increased share of muscle and bone tissue, or a general increase in these measurements, and not changes in body fat alone.

The positive intergenerational changes observed in our study concerned mainly children of early school age and adolescents, which can be attributed to the accelerated maturation in the Kraków population reported in previous studies (Kryst et al., 2012; Woronkowicz, Cichocka, Kowal, Kryst & Sobiecki, 2012). In the girls' population from 2010, there was an acceleration of weight gain in the peri-pubertal period (Woronkowicz et al., 2012). Similarly, in boys from the Kraków population examined in 2010, especially those over 12 years of age, a significant increase in body weight accompanied the acceleration of sexual maturation (Kryst et al., 2012).

At the same time, in the oldest age groups of girls, the measurements for the series from 1983 exceeded those from 2010. This may be due to the growing popularity of the conscious control of weight and level of body fat, associated with a greater focus on appearance and figure. This phenomenon has already been described in the Polish population, as well as specifically in Kraków (Goluch-Koniuszy & Heberlej, 2015; Kowal et al., 2013; 2014). According to the literature, contemporary girls usually spend relatively less time in a sitting position and are more determined to have a slim figure (Tutkuviene, 2005). Additionally, the secular trends observed in the oldest age groups may be due to the differences in the forms of physical activity chosen by each sex. Girls tend to choose exercises designed to reduce the size of individual parts of the body (Alonso, 2016; Furnham, Badmin & Sneade, 2002; McCreary & Sasse, 2000; Wronka, Suliga & Pawlińska-Chmara, 2013; Zaccagni, Masotti, Donati, Mazzoni & Gualdi-Russo, 2014;). Young men, on the other hand, usually prefer exercises that allow them to increase muscle mass, and thus obtain increased limb circumferences (Alonso, 2016; Frederick et al., 2007; Furnham et al., 2002). In addition, both sexes, except for differences in the goal of the preferred exercise, also seem to place special emphasis on different parts of the body. Young women focus more on obtaining the desired proportions of lower limbs, particularly slimmer thighs (Wronka et al., 2013). On the other hand, men are more likely to aspire to have a silhouette perceived as typically male, which is associated, for example, with the building of muscle mass within the shoulders and arms (Frederick et al., 2007).

The recorded intergenerational changes regarding limb circumferences can also be related to the significant sociopolitical changes occurring in Poland between 1983 and 2010, which influenced parents' educational and professional status, inhabited environment, level of medical care and hygiene. However, in the context of the analyzed limb circumferences, the most important factors were changes with regard to diet and physical activity. Studies suggest that contemporary populations are characterized by relatively healthier eating habits than those surveyed in the earlier years (Fismen, Smith & Samdal, 2014; Larson et al., 2014; Levin, Kirby, Currie & Inchley, 2012; Zaborskis, Lagunaite, Busha & Lubiene, 2012). For example, in the Lithuanian population between 2002 and 2010, the percentage of teenagers reporting daily fruit consumption increased from 24.2% to 31.0% (Zaborskis et al., 2012). Similarly, a significant improvement in the quality of meals and general eating habits was found among teenagers studied by Levin et al. (2012) as well as Fismen et al. (2014). The described improvement in the diet is also reflected in the decline in fast-food consumption. In the American population, between 1999 and 2010, the proportion of children frequently eating this type of meal changed from 25% to 19%, and the consumption of high-calorie, low-nutrient meals and beverages decreased (Larson et al., 2014; Larson, Story, Eisenberg & Neumark-Sztainer, 2016). Analogous tendencies may also be expected in the Polish population due to the sudden high availability of a variety of food products in the 1990s, and a growing diet awareness in society in the later years (Decyk-Chęcel, 2017). This is also confirmed by statistical data on the nutritional habits of children and adolescents in Poland, according to which, between 2009 and 2014, there was a significant increase in fruit and vegetable consumption (Piekarzewska, Wieczorkowski & Zajenkowska-Kozłowska, 2016). Therefore, the observed increase in limb circumferences can be attributedto a more sedentary lifestyle, lower level of

physical activity, or the amount of time spent in front of a computer or TV, rather than unhealthy eating habits (Jago, Baranowski, Baranowski, Thompson & Greaves, 2005; Prentice-Dunn & Prentice-Dunn, 2012; Tremblay et al., 2011; Wareham, van Sluijs & Ekelund, 2005).

Improvement in the living conditions of the population obviously has a beneficial effect on human development, allowing individuals to better fulfill their genetic potential. At the same time, not all effects of such changes are positive. Along with socio-economic development, which brings with it numerous facilities, there is also a decline in the general level of physical activity (Maffeis, 2000). In addition, changes related to leisure time and diet have become decisive factors in increasing the incidence of so-called "diseases of civilization" related to the body fat ratio and excess weight such as obesity, diabetes, cardiovascular diseases, or the metabolic syndrome (Goh, Dhaliwal, Welborn, Lee & Della, 2014; Hoey, 2014; Ostojic, Stojanovic, Stojanovic, Maric & Njaradi, 2011). Therefore, the multi-faceted analysis of intergenerational changes in the composition and proportions of the human body is still an important and relevant research topic.

AUTHOR CONTRIBUTIONS

ŁK designed the experiment. ŁK, AW, MK, JS made the measurements and collected the data. ŁK, AW did all the calculations. ŁK wrote the first draft of this paper. ŁK, MK interpreted the results and contributed to later drafts, including the present manuscript. ŁK, AW, MK, JS were involved in critical revisions of the paper. AW, ŁK collected literature. ŁK, AW, MK, JS read and approved the final revised draft for publication.

DISCLOSURE STATEMENT

The authors report no conflicts of interest.

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