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Sexual Dimorphism at Different Stages of Ontogenesis Based on the Kraków – Longitudinal Growth Study, Poland

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Abstract

Introduction and Study Aim

The aim of the study is to assess the magnitude of changes in sexual dimorphism with respect to selected morphological traits and the results of physical fitness tests between the ages of 8 and 50.

Material and Methods

The data come from the Kraków Longitudinal Growth Study and pertain to the somatic development and physical fitness of individuals born in 1970 and 1972, conducted in Kraków from 1976 and 1980 up to 2022. The Mollison Index was used to calculate sexual dimorphism.

Results

The females were shorter, lighter and thinner than the males in all analysed age groups, and differed only with regard to body height in the 13-year-olds. They were characterised by lower stronger hand strength and lower limb explosiveness throughout the analysed period. With the exception of 8-year-olds, the females had smaller arm circumference, shoulder width and thigh circumference than the males at ages 32 and 50, and at age 17, the girls demonstrated larger thigh circumference. Up until adolescence, the girls had greater body fat under the scapula, on the triceps and in the abdomen compared to the boys. However, in both 32–34- and 50-year-olds, the men exhibited greater body fat under the scapula and in the abdomen.

Conclusions

A high degree of sexual dimorphism occurs during developmental age – at the end of the adolescence period, especially for fat folds on the triceps and abdomen. Greater dimorphism is observed later, in early adulthood, i.e., at the age of 32–34 years, in terms of height and body weight, as well as body mass index,

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circumferences – of the arm and thigh, shoulder width, and performance test results. In adulthood (around the age of 50), a noticeable decrease in the degree of sexual dimorphism is observed, which results from the nature of involutional changes.

KEYWORDS: morphological characteristics, physical fitness tests results, longitudinal study, childhood, adolescence, adulthood

Introduction

Dimorphism in humans, as established in the 1950s, is based on genetic determinism of development. Biologically, an individual's masculinity or femininity is established on the basis of XX chromosomes in females and XY chromosomes in males. The resulting different ratios between androgens and oestrogens secreted by both sexes determine the course of prenatal and postnatal development, leading to biological male and female development. It is worth noting that humans, compared to the majority of primates, exhibit slight dimorphism, but it is nevertheless visible from birth (Greil, 2006). Human sexual dimorphism relates to body structure, biochemical and physiological properties, neurohormonal activity, as well as behavior patterns and lifestyle.

During prenatal life and early childhood, body composition variation is small. Immediately after birth, morphological dimorphism is primarily expressed by shorter length and birth weight, and greater body fat in girls than in boys (Greil, 2006). Developmental differences related to sex during this period are estimated to be only 2–3% (Perenc & Radochońska, 2012). During childhood, on average up to 6 years of age, sexual dimorphism remains slight, and its intensity is observed at the onset of puberty (Wells, 2007). The sexual dimorphism that intensifies during puberty is mainly the result of different developmental rates (growth and maturation) in both sexes. On average, girls develop earlier than boys, therefore, between the ages of 9 and 14, they become significantly taller and heavier. After the pubertal growth spurt (at approximately age 14), girls' development slows down, while remaining rapid for their peers. This is due to the fact that the pubertal growth spurt begins later and lasts longer in boys than in girls. This different pace of development leads to the typical morphological differences between adults of the opposite sexes developing during this period – males become taller and heavier than females (Greil, 2006). Differences in body proportions also develop during this period – girls are taller than boys and begin to have a relatively wider pelvis. Boys, on the other hand, begin to have relatively longer lower limbs and comparatively wider shoulders than their peers. Differences in body composition also emerge during this period. Girls experience an increase body fat, while boys demonstrate an increase in lean body mass – particularly muscle and bone mass (Wells 2007; Sterkowicz & Żak, 2010). A consequence of these morphological variances are sex differences related to the physiology of movement. Females have a higher heart rate, lower stroke volume, cardiac output, haemoglobin, red blood cell counts, maximal oxygen uptake and vital lung capacity (Sterkowicz & Żak, 2010). At the end of puberty and the onset of young adulthood, dimorphism becomes most apparent and is estimated at approximately 8% (Greil, 2006; Perenc & Radochońska, 2012). After late adulthood, women experience apparent biological masculinisation and oestrogen dominance appears in men (Wolański, 2006). However, this does not eliminate dimorphism, but rather changes it. According to some researchers, dimorphism decreases in old age (Wells, 2007), while others believe it increases (Wolański, 2006). The ambiguous results of research on changes in body dimorphism with age may be related to the fact that they were obtained based on cross-sectional studies (Hägg & Jylhäva, 2021; Xiao et al., 2020). However, little is known about changes in dimorphism within populations throughout their lifetime.

The population of Kraków undergoes regular monitoring of parameters related to body size, proportions, and physical fitness (Chrzanowska et al., 1988; 2002; Gołąb et al., 2003; Jasicki, 1938; 1948; Kowal et al., 2011; 2013; Kryst et al., 2023; Woronkowicz et al., 2012; Żegleń et al., 2020 and others). These were mostly cross-sectional studies.

Conducted since the 1976s and 1980s by the Department of Anthropology at the Institute of Biomedical Sciences of the University School of Physical Education, two series of continuous studies, which were merged in 2004 as the Kraków Longitudinal Growth Study (KLGS), have enabled the analysis of numerous issues, including ontogenetic changes and sexual dimorphism in the distribution of subcutaneous fat a 12-year longitudinal study of children and adolescents from Kraków (Chrzanowska & Suder, 2008); predicting the timing of reaching maturity and peak height velocity (Malina et al., 2021); age at pubarche and the risk of developing cardiometabolic complications among men aged 50–52 from KLGS (Spring et al., 2024); predicting adult height in boys: the Zarow method and a comparative analysis of different methods (Żarów, 2001); body build and physical activity in adults and it's biological development in childhood youthfulness (Żarów et al., 2006) childhood and adolescence changes in physical fitness and body composition of women and men examined in 2004 and 2022 – a longitudinal study (Żarów et al., 2024) and many other research problems.

The aim of this article is to assess the magnitude of changes in sexual dimorphism in certain morphological traits and physical fitness test results from ages 8 to 50, using the example of the KLGS. The following research question was formulated: How does the course and magnitude of changes in sexual dimorphism in ontogeny (at ages 8–50) in terms of selected morphological traits and tests of static and explosive strength of the upper and lower limbs, considered indicators of human health condition? The presented analysis of the results is primarily descriptive and partially explanatory.

Material and methods

Approval was for this research was obtained from the Bioethics Committee at the District Medical Chamber in Kraków for the study in 2022 (Consent No. 65/KBL/OIL dated April 11, 2022). The research material consists of data from KLGS on the somatic development and physical fitness of people born in 1970 and 1972, conducted in Kraków in the years 1976–2022 (KLGS 1976–2022) by research teams of the Department of Anthropology, Institute of Biomedical Sciences at the University School of Physical Education in Kraków (currently the University of Physical Culture):

- 1st series of annual examinations in the years 1976–1988 (age 6–18);
- 2nd series of annual examinations in 1980–1990 (age 8–18);

The first series of studies concerned people born in 1970; at the age of 6 there were 485 boys and 455 girls, and by the age of 18, 180 boys and 145 girls remained. The second series of studies involved people born in 1972, and at the age of 8 there were 460 boys and 360 girls, and by the age of 18, 178 boys and 108 girls remained. The decrease in the number of participants in subsequent years is a natural consequence of longitudinal studies:

- two combined series of women and men examined in 2004 (age 32–34);
- re-examination, after 18 years, of the same women and men in 2022 (age 50–52).

In total, 103 females and 122 males participated in the study in 2004, and in 2022, 47 and 67, respectively. Of these participants, 35 females and 47 males were present for both measurements in 2004 and 2022. No morphological selection of the women or men who participated in the 2022 study was observed in comparison to the 2004 trial, as the height of 103 females examined in 2004 was 165.2 cm, and 37 examinees were 164.4 cm tall; and, respectively, 178.1 cm for 122 males and 178.3 cm for 53. In terms of body mass, the values were 59.8 kg and 58.5 kg for the females, and 80.7 kg and 79.6 kg for the males.

The study included data (Table 1) on the morphological characteristics of 83 females and 92 males aged 8 to 17 and 67 and 70 for physical fitness tests. Fewer boys and girls participated in the physical fitness tests due to the inability to perform a given test on the day of the examination for various reasons (e.g., temporary injury). And in the studies conducted in 2004 and 2022, 35 females and 49 males participated. No exclusion criteria were applied in subsequent years of the study. Spontaneous selection occurred – e.g., absence on the day of the study for various reasons, change of residence, not accepting the invitation to participate in the study despite multiple email, phone, and mail invitations, deaths, etc. All participants were residents of the city of Kraków. The studied sample represented the average population of the city of Kraków.

Table 1. The number of subjects included in our study (KLGS 1976–2022).

Age (in years)	Morphological characteristics		Physical fitness tests results	
	Females	Males	Females	Males
8*	83	92	67	70
13*	83	92	67	70
17*	83	92	67	70
32–34	35	47	35	47
50–52	35	47	35	47

*Age was calculated according to the following rule: for example, eight-year-olds were considered to be people aged from 7.50 to 8.49 years, and similarly for the categories of 13- and 17-year-olds.

The following measurements were performed. Physical fitness tests included handgrip strength of stronger hand in both the right and left hand, and standing broad jump. Physical fitness tests were conducted according to the instructions of the ICSPFT test (Larson, 1974). Anthropometric measurements included:

- body height – measured according to Martin's technique using an anthropometer (GPM, Switzerland, to the nearest 1 mm);
- body mass – using an electronic scale, and since 1994 using a body composition analyser, Tanita TBF-300 (Japan), to the nearest 0.01 kg;

- thigh and mid-upper-arm (MUAC, in relaxation) circumferences measured with a non-stretchable anthropometric tape;
- of triceps, subscapular and abdominal skinfold thickness – measured with a skinfold caliper (Harpenden type with constant pressure of 10g/mm^2, to the nearest 1 mm)
- shoulder width – measured with a large spreading calliper (GPM, Switzerland, to the nearest 1 mm).

Body mass index (BMI) was calculated as the proportion of body mass in kilogrammes to body height expressed in metres squared. The level of sexual dimorphism was calculated via Mollison's Index (MI): MI = (Xf-Xm)/SDm (Drozdowski, 1998), where: Xf mean value of the parameter for females, Xm mean value of the parameter for males, SDm standard deviation of the parameter for males. Negative values of the index indicate a lower level of development of a given trait in women.

Basic descriptive statistics (means and measures of variability) were calculated. The statistical significance of the differences between the analysed sexes was estimated using the Student's t-test for independent samples. For variables where the assumption of homogeneity of variances was found to be violated – as verified using Levene's test – the Welch-corrected Student's t-test was used, which accounts for unequal variances. The calculations were performed using the Statistica 13.0 package.

Results

Table 2 shows the arithmetic means and standard deviations, which were the basis for calculating MI. The degree of sexual dimorphism according to MI of selected somatic features and physical fitness tests is presented in Figures 1–3.

Table 2. Characteristics of body features and motor skills at various stages of ontogeny of the KLGS 1976–2022 study.

	Girls N = 83; Boys N = 92			Women N = 35; Men N = 47	
	8 yrs.	13 yrs.	17 yrs.	32–34 yrs.	50–52 yrs.
	Mean; SD	Mean; SD	Mean; SD	Mean; SD	Mean; SD
	Body height [cm]				
Women	127.0; 5.6	156.0; 7.2	163.7; 6.0	164.4; 5.9	164.2; 5.9
Men	127.4; 5.3	155.8; 8.4	175.0; 6.5*	178.3; 5.8*	178.0; 5.9*
	Body mass [kg]				
Women	25.3; 4.3	44.2; 7.7	55.1; 6.4	58.5; 7.2	66.4; 10.9
Men	26.1; 3.8	44.7; 8.7	64.7; 7.8*	79.6; 10.7*	88.1; 16.0*
	Body Mass Index [kg/m^2]				
Women	15.6; 1.9	18.1; 2.2	20.6; 2.0	21.6; 2.5	24.6; 3.9
Men	15.9; 1.7	18.3; 2.3	21.1; 2.0	25.0; 2.9*	27.8; 4.6*
	Stronger hand grip strength [kG]				
Women	10.9; 3.0	23.3; 4.5	30.9; 6.0	37.4; 3.9	34.4; 4.5
Men	13.1; 4.0*	28.2; 6.7*	50.1; 9.0*	60.2; 6.9*	55.9; 7.4*

Table 2 (cont.)

	Girls N = 83; Boys N = 92			Women N = 35; Men N = 47	
	8 yrs.	13 yrs.	17 yrs.	32–34 yrs.	50–52 yrs.
	Mean; SD	Mean; SD	Mean; SD	Mean; SD	Mean; SD
			Standing broad jump [cm]		
Women	121.3; 17.4	161.8; 17.1	173.3; 17.3	163.9; 19.3	140.8; 19.8
Men	125.9; 17.3	177.5; 20.9*	218.4; 20.9*	212.2; 24.4*	182.1; 19.5*
			Arm circumference [cm]		
Women	18.5; 1.7	22.1; 2.3	25.2; 1.8	26.3; 2.3	28.5; 3.1
Men	18.4; 1.7	22.4; 2.4	27.4; 2.2*	31.0; 2.5*	32.4; 3.7*
			Thigh circumference [cm]		
Women	38.4; 3.8	48.1; 4.5	54.0; 3.6	53.0; 3.7	55.8; 5.1
Men	37.6; 3.7	46.2; 4.6*	53.2; 3.8	56.9; 4.2*	57.0; 5.3
			Biacromial diameter [cm]		
Women	27.4; 1.4	32.8; 1.7	35.3; 1.4	35.8; 1.3	36.3; 1.8
Men	27.9; 1.3*	33.2; 2.2	39.3; 2.1*	40.9; 1.6*	41.5; 1.7*
			Triceps skinfold [mm]		
Women	10.1; 3.5	11.5; 3.9	14.0; 4.1	13.7; 5.0	18.3; 5.4
Men	8.3; 2.4*	9.2; 3.1*	7.5; 2.3*	9.0; 3.3*	12.2; 5.4*
			Subscapular skinfold [mm]		
Women	7.4; 3.8	9.1; 3.7	12.1; 4.5	13.7; 6.2	19.8; 7.1
Men	5.9; 2.2*	7.3; 3.1*	8.5; 2.4*	15.3; 6.2	20.6; 7.0
			Abdominal skinfold [mm]		
Women	8.5; 5.4	10.3; 5.5	15.1; 5.5	13.2; 6.6	20.1; 6.5
Men	6.9; 3.7*	8.0; 4.8*	8.6; 3.6*	17.0; 7.5*	21.7 7.8

* statistically significant differences ($p<0.05$) between 8, 13 and 17-year-old boys and girls

Sexual dimorphism in body height, mass and BMI, as well as two physical fitness tests results, for individuals aged 8, 13, 17, 32–34 (2004 series) and 50–52 (2022 series) are presented in Figure 1. We considered that the age of 8 years is a good moment to indicate the pre-pubertal period for both boys and girls, 13 years old is the period of adolescence, and 17 years old is practically the end of the pubertal period. The developmental status of children aged 6 and 7 was not included in this study (Gołąb et al., 1993).

The results obtained for the females were normalised to the arithmetic mean and standard deviation of the males. Data analysis revealed that the females were shorter, lighter and slimmer compared to the males in all of the analysed age groups. The exception was height among the 13-year-olds, when girls were slightly taller than boys. The smallest differences between the sexes for all analysed traits were found at age 13, at 0.02, 0.05 and 0.07 standard deviations, respectively. In subsequent years, the level of sexual dimorphism increased until age 32–34, while at age 50–52, it decreased for all the traits under analysis.

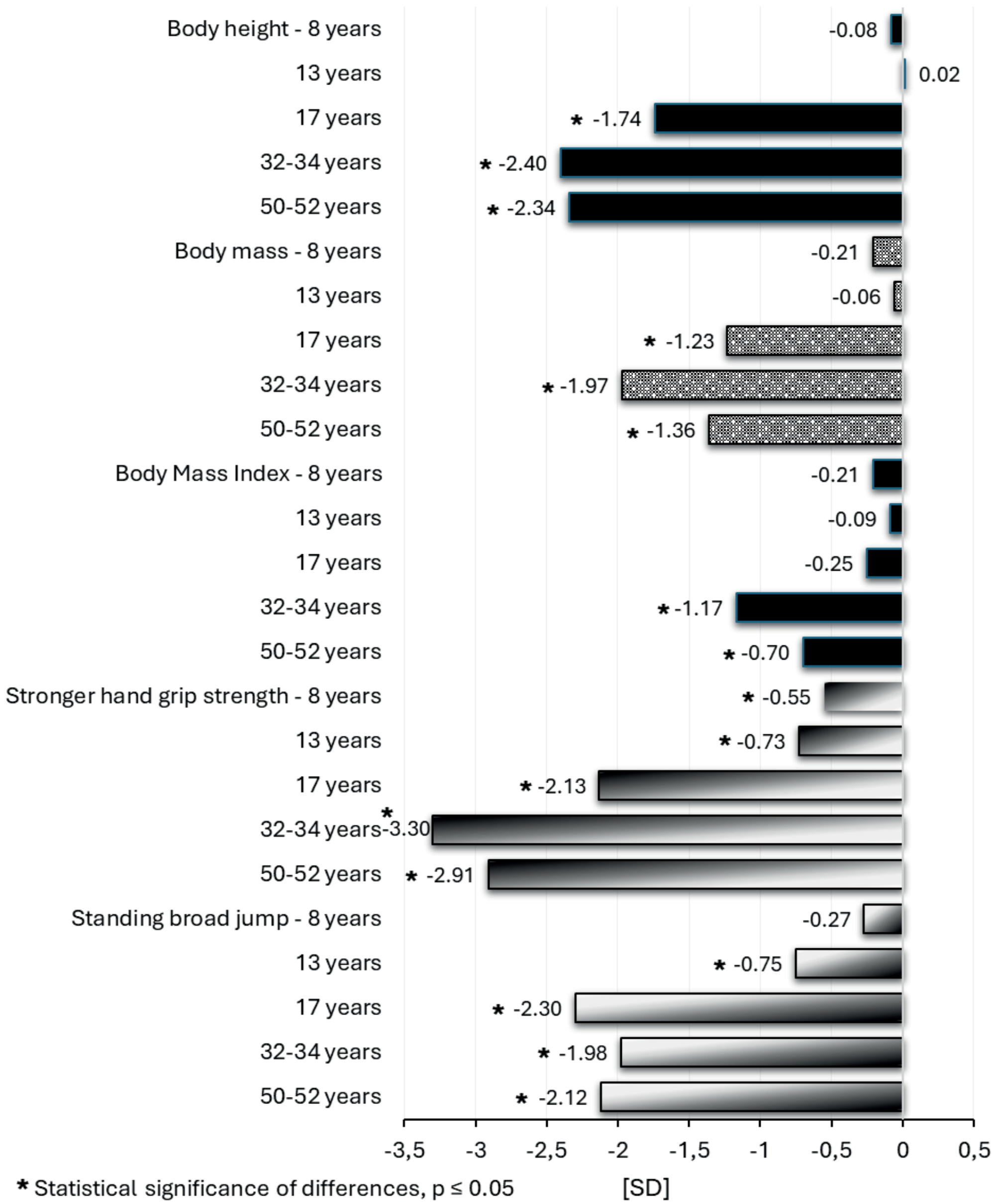

Figure 1. Mollison's Index results for height, body mass and BMI, as well as strength of stronger hand and standing long jump at ages 8, 13, 17, 32–34 and 50–52 part of the Kraków Longitudinal Growth Study.

Statistically significant differences between the sexes were found for body mass and height in the 17-year-old groups and for all analysed characteristics in the 32–34- and 50–52-year-old groups ($p<0.001$). Based on the results of physical fitness tests, it was found that throughout the analysed period, the females were characterised by lower strength in the stronger arm and lower explosive strength in the lower limbs. The level of dimorphism in explosive strength of the lower limbs increased throughout the analysed period, reaching its highest value in the 50-year-old group (2.67 standard deviations). However, the level of dimorphism in arm strength increased until the age of 32–34 and then began to decline. Statistically significant differences between the sexes were found for both characteristics in all age groups ($p<0.001$). The exception was explosive strength of the lower limbs in the 8-year-old group.

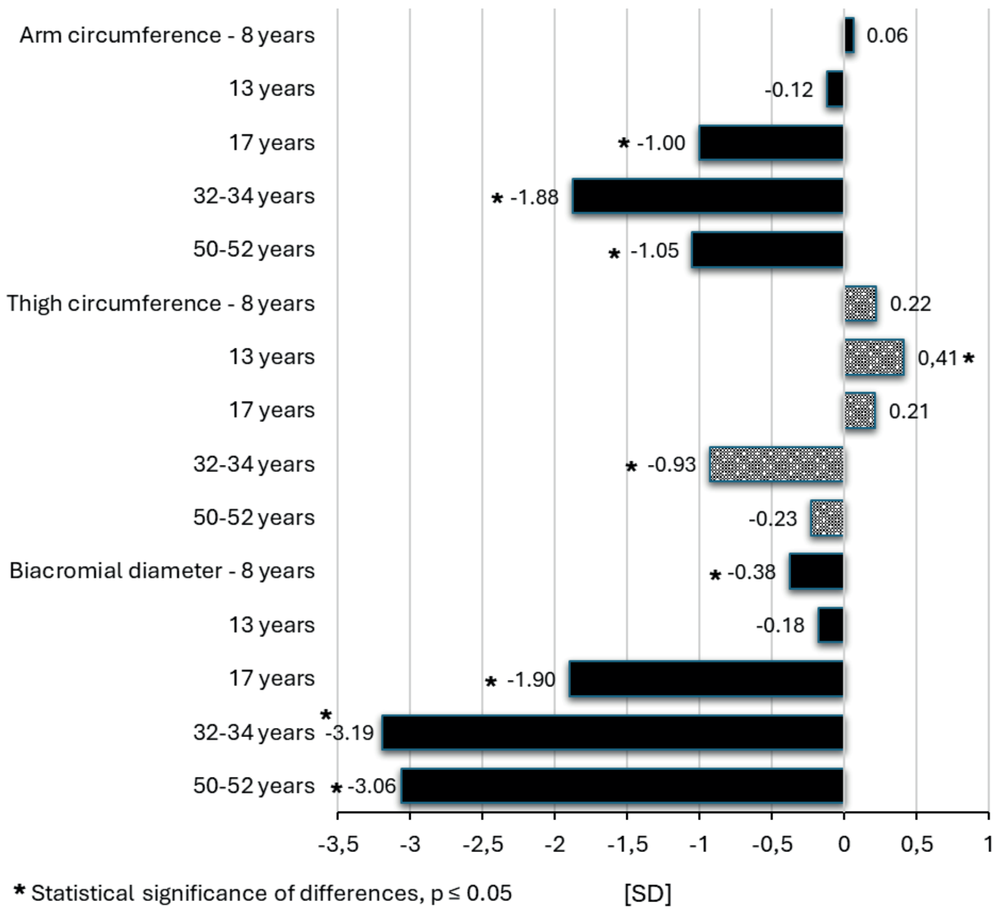

Figure 2. Mollison's Index results for arm and thigh circumference as well as biacromial diameter at ages 8, 13, 17, 32–34 and 50–52 part of the Kraków Longitudinal Growth Study.

It was found that throughout the analysed period, with the exception of 8-year-olds, the females had smaller upper arm circumferences than the males (Fig. 2). The level of dimorphism was lowest in the youngest age group, reaching 0.06 standard deviations. In subsequent years, the level of dimorphism increased, reaching a maximum value of 1.88 standard deviations in 32- to 34-year-olds, after which it decreased to 1.03 standard deviations. Differences between the sexes were statistically significant ($p<0.001$), except for the 8- and 13-year-olds. Based on the results, it was found that until the age of 17, the girls had larger thigh circumferences. The level of dimorphism in this trait was small, with statistically significant differences found only in the 13-year-olds ($p<0.01$). With age, the males began to dominate in this trait and the level of dimorphism increased statistically significantly among 32–34-year-olds ($p<0.001$), and then slightly decreased.

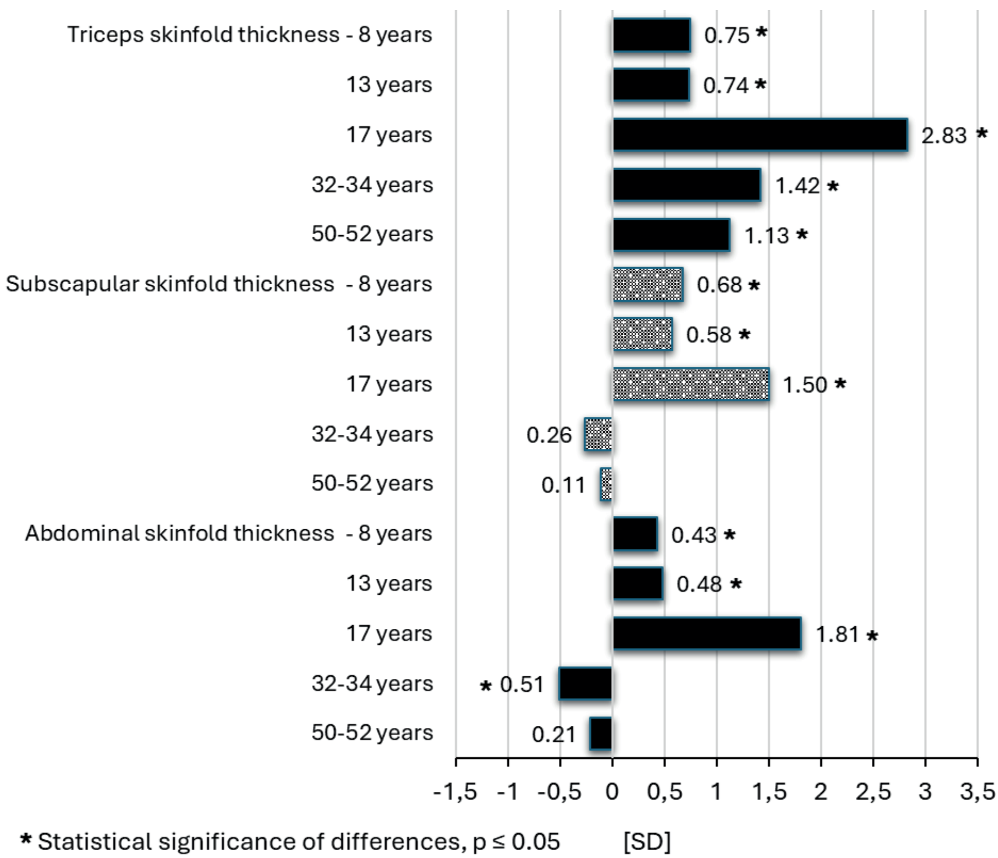

Figure 3. Mollison's Index results for body fatness at ages 8, 13, 17, 32–34 and 50–52 part of the Kraków Longitudinal Growth Study.

It was demonstrated that throughout the analysed period, the females had smaller shoulder widths than the males. The level of dimorphism in this trait during childhood was low, reaching its lowest value in the 8-year-olds. In subsequent years, the level of dimorphism in this trait increased, reaching its highest values at ages 32–34, before decreasing slightly. Statistically significant differences were found in all age groups except for the 13-year-olds.

Analysing differences in body fat levels and fat distribution (Fig. 3) revealed that until adolescence, the girls demonstrated greater body fat than the boys in the subscapular, triceps and abdominal regions. In 8-year-olds, the level of dimorphism was 0.68, 0.74 and 0.43 for standard deviations, respectively, and the differences between the sexes were statistically significant ($p<0.05$). In 13-year-olds, the level of dimorphism remained similar, but in adolescence, it reached the highest values of 0.9, 2.82 and 1.82 for standard deviations, respectively. The differences were statistically significant ($p<0.001$). In adults, the level of dimorphism decreased, reaching the lowest values in the latter age group. Importantly, both in the 32–34- and 50-year-olds, the men had higher levels of subscapular and abdominal fat. Statistically significant differences were found in triceps ($p<0.001$) and abdominal skinfold thicknesses ($p<0.05$) in the age range of 32–34, whereas in 50-year-olds, these variations were only noted in triceps skinfold thickness ($p<0.001$).

Discussion

Analysis of the results from our longitudinal research on body height and mass revealed that the females were, on average, lighter, shorter (with the exception of the average height of girls at age 13) and slimmer than the males throughout almost the entire ontogenetic period under review. However, the level of dimorphism in these traits during childhood and the onset of puberty was not statistically significant. Among 17-year-olds (the stage of puberty completion), sex differences in body mass, height and BMI became statistically significant and increased up until the age of 32–34, when they were most pronounced. They then decreased slightly after the next two decades, at the age of 52.

It is well known that at birth, boys are approximately 1 cm (approx. 1–2%) longer and slightly heavier than girls (Wells, 2007). During childhood, dimorphism of body height and mass remain slight until the onset of puberty. Therefore, girls are shorter than boys until about 9 years of age, and then, during the pubertal period—between 9 and 12 years of age—they begin to exceed their peers by approximately 0.1%–0.6%. This is due to the earlier onset of the pubertal growth spurt in boys. The height advantage in boys, leading to a more pronounced lead in this trait in adulthood, begins at 0.4% after age 13 and becomes more marked with each subsequent year. It is most noticeable in early adulthood (19–30 years), when women are 7.4%–7.6% shorter than men of the same chronological age. This height difference decreases once more in later adulthood. By age 60, women are only 6.0% shorter than men (Greil & Lange, 2007). Our results are therefore consistent with other data. Similar results were obtained in Germany, where in cross-sectional research conducted among children and adults from birth to age 60, it was shown that the level of height dimorphism increased until age 30, after which it began to decrease (Greil & Lange, 2007). Similarly, in Austrian research conducted among individuals between 20 and 85 years, it was demonstrated that the level of height dimorphism was the highest in the youngest age group, and began to decrease starting approximately age 30. Interestingly, in these studies, it has been demonstrated that the level of body mass dimorphism increases with age, but the rate of change in body mass and height results in a decrease in BMI dimorphism (Peter et al., 2014).

A slightly varying result was achieved in a Norwegian cross-sectional study, conducted among 20–80-year-olds. These researchers showed that the level of height dimorphism increased throughout the analysed period, while the level of body mass dimorphism decreased from around the age of 30 (Drøyvold et al., 2006). Contrastingly, in longitudinal research conducted in the USA, it was noted that the level of height dimorphism among individuals above the age of 50 increased with age (Gallowye et al., 1990), while in research performed in the Netherlands, the opposite phenomenon was exhibited. It was shown that the level of height dimorphism increased until approximately the age of 30, and then began to slightly decrease (Nooyens et al., 2008). In a longitudinal study conducted in Sweden, It has been shown that the level of body dimorphism in terms of body massiveness (assessed using BMI) initially increased until around the age of 30 and then began to decrease (Caman et al., 2013). Similar results were obtained in a Norwegian study, which found that body mass dimorphism in individuals aged 20–35 did not change, but began to increase around the age of 35, whereas the level of body massiveness dimorphism slightly decreased (Nooyens et al., 2008).

Analysing differences in body fat levels and its distribution, we noted that up until adolescence, the examined girls had greater body fat under the scapula, on the triceps and in the abdomen than the men. The level of body fat dimorphism increased during the analysed period, reaching its highest values in adolescence. In adults, the level of dimorphism decreased with age, reaching the lowest values in the oldest group. Importantly, in both the 32–34- and 50-year-olds, men had greater body fat under the scapula and in the abdomen (Fig. 3). These results appear to confirm the observations of the researchers mentioned earlier.

It is known that body fat decreases in both sexes between the ages of 1 and 6, and then increases more rapidly in girls and to a lesser extent, in boys. During puberty, an even greater contrast in the pattern of body mass gain is evident between girls and boys. In this period, girls experience primarily increased body fat, with a slight increase in lean mass, while for boys, the opposite phenomenon is observed. These differences are primarily due to steroid hormone levels. In adults, women exhibit greater lower limb fat than men, with similar levels of upper limb and trunk fat (Wells, 2007). Therefore, in our study, we found that the level of dimorphism in body fat began to decrease after puberty. The increase in abdominal fat in males is also consistent with the observations of other authors. In research conducted in the Netherlands, it was shown that males accumulate abdominal fat after puberty (Seidell et al., 1988). Similar results were obtained in Japan, where researchers demonstrated that post-pubertal men accumulate abdominal fat 2.5 times more intensely than pre-menopausal women. Visceral fat accumulation in women increases only at the onset of menopause (Kotani et al., 1994). In our study, the increased abdominal fat in the men may have been due to the fact that the examined women were just entering the phase of menopause.

In our research, we used arm strength measurements to analyse ontogenetic changes in physical fitness among males and females in terms of sex differences (this measurement is considered one of the best biomarkers (predictors) related to the aging process with regard to the musculoskeletal system (Rezaei, 2024). We noted that the males had greater strength in their stronger arm than the females. The differences between the sexes were smallest in the youngest age group, increasing with age up to 32–34 years. In the oldest participants, these differences slightly decreased (Fig. 1). Similar results were achieved in the USA for research carried out among adults aged 18–85. It was demonstrated that men dominated in this trait throughout the analysed period, and the strength of both the dominant and non-dominant arms decreased with age. However, sex differences remained similar until age 70, and their reduction was observed later than in our study, around the age 75 (Wang, 2018). In the case of research conducted in the UK, it was also observed that both men and women had similar arm strength until puberty. After this period, the strength in men increased more rapidly, reaching its peak between the ages of 29 and 39. In women, the increase in arm strength was less rapid after puberty, reaching its peak between the ages of 26 and 42. In subsequent years, arm strength in women and men, as well as the sex-related differences, decreased (Dodds, 2014). This declining dissimilarity may be related to the fact that the aging process of muscle tissue, which results in a decrease in muscle mass and, consequently, muscle strength, begins—on average—around the age of 45 (Janssen, 2000). However, the process of muscle strength loss is greater in men than in women (men lose more muscle strength than the latter) (Goodpaster et al., 2006).

However, our observations regarding the level of sexual dimorphism measured using another criterion of physical fitness—explosive lower limb strength—showed that its level increased with age, reaching its highest level (Fig. 1) in young people, i.e., at the age of 17, after girls had completed puberty and before boys had finished growing in height.

Similar results were obtained in Spain, where the influence of selected factors (e.g. sex, age, level of physical activity) was analysed on the standing long jump distance. The study results indicated that sex played a significant role in differentiating this characteristic, which is likely due to differences in body composition (lean body mass content), muscle strength and neuromuscular as well as glycolytic efficiency (Mayhew et al., 1990). It is probable that age has significant impact on standing long jump distance in children, as their central nervous system is maturing, which may play a role in muscle strength. Anthropometric factors (i.e. body height and mass) and kinematic variables may also significantly influence performance of fitness tests in children (Fernandez-Santos et al., 2017). However, in adults, cognitive decline appears to take time to manifest itself in changes related to physical performance (i.e. slower movements or reduced strength due to the natural aging process) (Grosprêtre et al., 2018; Marin-Jimenez et al., 2024). Our study results seem to confirm these relationships and show that age-related changes in physical fitness dimorphism are similar to changes in overall body composition (body height, mass and their proportions – BMI), as well as shoulder width and upper arm circumference. Although there is greater trunk fat in adulthood (32–34 years) and in old age (50–52 years), males still clearly dominate the results of fitness tests.

Undoubtedly, the study has a few limitations. Its drawbacks include the small sample size and the restricted number of analysed anthropometric characteristics. The influence of socio-economic factors on dimorphism was also not taken into account, because the population came from areas with standard housing conditions, school facilities, and relatively homogeneous living conditions, presenting a certain population model characteristic of larger industrial centers in Poland (Bochenska and Chrzanowska, 1993). Its advantage, however, is that it is a longitudinal study conducted annually from age 6 and 8 to age to 18, then at age 30–32 and later, at 50–52 years of age.

Conclusions

Based on the conducted research and the assessment of sexual dimorphism in individuals aged 8, 13, 17, 32–34 and 50–52, it can be concluded that:

1. Sexual dimorphism increased during development, reaching its highest level at the end of adolescence, particularly in terms of traits related to the differently developed fat and muscle distribution in both sexes.
2. Final dimorphism, however, develops later (as confirmed by our studies of people aged 32–34) and concerns bone characteristics (body height, shoulder width), relative body mass and circumferences.
3. In adulthood, at the threshold of aging (approximately at the age of 50), a significant reduction in the degree of sexual dimorphism is noted, which results from the nature of involutional changes that differ between the sexes.

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Author contributions

All participated in the conducted research, RŻ was responsible for the concept and design of the study, critical revision of the article, and final approval of the article, MK wrote the article, AW analysed data and conducted statistical analyses.

Ethics Statement

All examinations were conducted with the written, informed consent of the parents of minor children and adult participants. Approval was also obtained from the Bioethics Committee at the District Medical Chamber in Kraków for the study in 2022 (Consent No. 65/KBL/OIL dated April 11, 2022). All procedures contributing to the study were in accordance with the ethical standards of the relevant national and institutional human research committees and with the 1975 Declaration of Helsinki, as revised in 2008.

Data availability statement

Data are available from the corresponding author on reasonable request.

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Conflict of interest

None to declare.

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