The age difference in 2D:4D among the Polish population: An exploratory study

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ABSTRACT: In this study a widely debated association between 2D:4D digit ratio and age was investigated. The study material included 960 individuals (530 females and 430 males) from Central Poland aged between 6–79 years. The information about age was obtained via survey filled in by study participants or, if underaged, their parents. The direct measurements of the second and fourth finger were performed to assess the 2D:4D digit ratio. The 2D:4D digit ratios for the left hand were significantly correlated with age both among females and males. In women the 2D:4D digit ratios for the right hand were significantly correlated with age. There were also significant differences in digit ratio between age groups. The results of our study suggest that there might be an association between digit ratio and age, and the direction of the correlation might be related to the phase of the ontogenesis.

KEY WORDS: digit ratio, prenatal testosterone, prenatal sex hormones proportion.

Introduction

The second to fourth finger ratio (2D:4D) is a proportion known since the second half of the nineteenth century. It has been shown that the prenatal exposure to sex steroids affects the 2D:4D ratio. For instance, higher exposure to androgens affects longer fourth finger and in opposite more estrogens affect shorter fourth finger resulting in typically man (2D:4D<1) and woman (2D:4D≥1) proportion (Lutchmaya et al. 2004). However, it is not certain to what extent the 2D:4D ratio precisely indicates the current sex steroids proportion (Manning et al. 2014). Some studies suggest that prenatal sex steroid exposure is associated with neither the level of circulating androgens nor estrogens (Muller et al. 2011; Hönekopp et al. 2007; Kowal et al. 2020).

Numerous studies have reported that 2D:4D digit ratio does not change during human ontogenesis (Manning et al. 2014; de Sanctis V et al. 2017). Moreover, there are studies indicating that estrogen and androgens levels during postnatal period are not related to 2D:4D, and thus do not affect 2D:4D digit ratio during this period (Muller et al. 2011; Hönekopp et al. 2007; Kowal et al. 2020; Richards et al. 2017). However, some studies reported the opposite pattern showing that 2D:4D ratio may change with age (Kyriakidis 2021).

Hand morphogenesis occurs between 6 and 14 weeks of gestation and it consists of three main stages: shape forming (from 6 to 10 weeks), the appearances of creases (from 10 to 13 weeks), and development of ridges (from weeks 13 onward). This process is regulated by many biochemical factors, such as protein Sonic hedgehog (Shh) and wingless-type mouse mammary tumor virus integra-tion site family member 7a (Wnt-7a), which induces transcription of the factor LIM homeobox transcription factor that takes part in dorsalization of the limb bud (Lacroix et al. 1984).

Rodent studies investigating hand morphogenesis have shown that length of the fourth finger is determined by the balance of testosterone to estrogen during a small window in fetal development probable around 14th week of gestation. Androgen and estrogen receptor activity is greater in the development of digit 4 compared to digit 2. Sex steroids regulate a network of genes that are involved in chondrocyte proliferation which leads to the growth of digit 4 independently of sex. Higher levels of androgens simulate chondrocytes proliferation of the fourth finger and leads to an increased 2D:4D ratio and oppositely in the case of higher level of estrogen (Brown et al. 2002; Zheng and Cohn 2011). Beside the time of establishment of 2D:4D ratio, it is not clear whether 2D:4D proportion is changing from generation to generation.

The aim of this study was to evaluate the differences in digit ratio among Poles in three age groups: children, young adults and adults.

Material and methods

The data comes from three cohorts investigated in years 2015–2021 in Lodz (city in Central Poland, population 680,000). The information about individuals age was obtained via survey filled in by study participants or, if underaged, their parents.

Cohorts' characteristics

Our cross-sectional study included 960 ethnically homogeneous healthy Caucasians (530 females and 430 males) aged

between 6–79 years divided into three groups: children (6–13 years), young adults (18–29 years) and adults (30–79 years).

The youngest cohort was instigated in years 2015–2017 in randomly selected primary schools in Lodz and included 611 children (319 girls and 292 boys). All measurements were carried out by the employees of the Department of Anthropology of the University of Lodz.

Individuals in the 18–30 years age range were measured in Lodz between September 2020 and March 2021 by medical students (Medical University of Lodz) and by the employees of the Department of Anthropology of the University of Lodz. There were investigated 167 individuals (104 females and 63 males).

The oldest cohort, aged over 29 years, included 175 adults (101 females and 74 males) investigated between July 2020 and September 2020 in Lodz was carried out by the employees of the Department of Anthropology of the University of Lodz.

Measurements

The direct measurements of the second and fourth finger were performed by qualified staff using a sliding calliper (Vernier calliper) with an accuracy of 0.001 m. Based on values of the fingers length, the 2D:4D index was calculated as a quotient of the length of the second digit and the fourth digit (mm).

The Consent of the Bioethics Committee at the Medical University of Lodz (RNN/374/19/KE and RNN/394/19/KE) and by the Ethical Commission at the University of Lodz (19/KBBN-UŁ/II/2016) were obtained. Written informed consent was obtained from all study participants or their parents in the case of children.

Statistical analysis

Due to lack of normal distribution of 2D:4D for right and left hand and age, the non-parametric tests were used.

The Kendall Tau correlation was applied to evaluate correlation between age and 2D:4D finger ratio for both hands.

Due to statistically significant differences between 2D:4D digit ratio for right and left hand (t=-2.106; p=0.035), further analyses were conducted separately for the right and left hand. However, among both sexes 2D:4D of left and right hand were positively correlated (females: r= 0.610; p<0.001; males: r=0.596; p<0.001).

The Mann Withney test was used to determine whether there were dimorphic differences in 2D:4D ratio of right and left hand with regards to age.

The Kruskal Wallis test (H) with Tukey's post hoc tests were used to calculate differences between the three age groups.

The Cohen's d values were calculated to calculate the effect size for each comparison.

All statistical analyses were performed using the Statistica ver. 13.0 software.

Results

Although there were no significant age differences between males and females, there were dimorphic differences regarding 2D:4D (R) and 2D:4D (L) ratios. For example, females were characterized by higher 2D:4D (R) and 2D:4D (L) compared to males (Table 1).

Table 1. Statistical characteristics of the age and finger index (2D: 4D) of the right and left hand in the studied groups

sex	varia-bles	N	Mean	Median	Mini-mum	Maxi-mum	Lower Quar-tile	Upper Quar-tile	Std. Dev.	Females vs Males		Coh-en's d
										Z	*p*-value	
Females	Age	530	20.365	11.641	5.936	79.000	8.494	22.000	17.729	1.390	0.164	0.110
Males		430	18.479	11.374	5.919	79.000	8.404	21.000	16.584			
Children F	Age	319	9.334	9.012	5.936	13.303	7.726	11.036	1.941	-1.278	0.201	0.102
Children M		292	9.534	9.163	5.919	13.148	7.866	11.442	1.994			
Young adults F	Age	104	21.356	21.000	19.000	28.000	20.000	22.000	1.751	0.469	0.639	0.074
Young adults M		63	21.508	21.000	19.000	29.000	20.000	23.000	2.341			
Adults F	Age	107	52.299	51.000	30.000	79.000	43.000	62.000	12.564	0.921	0.357	0.116
Adults M		75	50.760	47.00	30.000	79.000	40.000	64.000	13.946			
Females	2D:4D (R)	530	0.986	0.986	0.881	1.095	0.966	1.000	0.033	4.985	<0.001	0.333
Males		430	0.975	0.975	0.867	1.058	0.952	1.000	0.033			
Females	2D:4D (L)	530	0.987	0.986	0.838	1.097	0.970	1.000	0.031	4.457	<0.001	0.290
Males		430	0.978	0.978	0.883	1.092	0.961	1.000	0.031			

The 2D:4D digit ratios for the left hand were statistically significantly correlated with age both among females (Table 2) and males (Table 3). In the case of females, the 2D:4D digit ratios for the right hand were also statistically significantly correlated with age (Table 2). Correlation between digit ratio and age within each of the age groups was non-significant (Table 2 and 3).

Table 2. Co-variability with age of 2D:4D finger ratio for the right and left hand in females

Groups	N	2D:4D R & age			2D:4D L & age		
		Kendall Tau (τ)	Z	p	Kendall Tau (τ)	Z	p
Females (total)	530	0.082	2.834	0.005	0.137	4.716	<0.001
children	319	0.032	0.857	0.392	0.066	1.757	0.079
young adults	104	0.048	0.720	0.472	0.050	0.735	0.451
adults	107	0.027	0.413	0.679	0.049	0.748	0.454

Table 3. Co-variability with age of 2D:4D finger ratio for the right and left hand in males

Groups	N	2D:4D R & age			2D:4D L & age		
		Kendall Tau (τ)	Z	p	Kendall Tau (τ)	Z	p
Males (total)	430	0.039	1.221	0.222	0.083	2.579	0.010
children	292	0.027	0.710	0.480	0.043	1.092	0.275
young adults	63	-0.028	-0.329	0.742	-0.095	-1.103	0.270
adults	75	-0.145	-1.842	0.065	0.022	0.282	0.778

Kruskal Wallis test showed that young adult females had higher 2D:4D (R) compared to children and adults (Table 4, Figure 1). In the male group the 2D:4D (R) was higher in young adults than in children (Table 4, Figure 2). In the case of 2D:4D (L) there were the following differences according to age groups: female children had lower digit ratio (L) than young adults and adults (Table 4, Figure 3) and young adults males had higher digit ratio (L) compared to children (Table 4, Figure 4).

Table 4. Differentiation of 2D: 4D finger ratio of the right and left hand between the groups distinguished by age.

Age group	Varia-bles	N	Mean	Medi-an	Mini-mum	Maxi-mum	Lower Quar-tile	Upper Quar-tile	Std. Dev.	St. Error	H	p
					Females							
chil-dren		319	0.982	0.983	0.881	1.063	0.964	1.000	0.030	0.002		
young adults	2D:4D (R)	104	1.004	1.000	0.929	1.095	0.985	1.028	0.033	0.003	36.383	<0.001[1]
adults		107	0.982	0.986	0.892	1.060	0.958	1.000	0.035	0.003		
					Males							
chil-dren		292	0.973	0.976	0.867	1.058	0.950	1.000	0.033	0.002		
young adults	2D:4D (R)	63	0.986	0.986	0.922	1.054	0.961	1.013	0.032	0.004	6.053	0.049[2]
adults		75	0.974	0.974	0.893	1.042	0.949	1.000	0.035	0.004		
					Females							
chil-dren	2D:4D (L)	319	0.981	0.983	0.838	1.058	0.967	1.000	0.029	0.002		
young adults		104	0.998	1.000	0.920	1.097	0.972	1.016	0.033	0.003	21.338	p<0.001[3]
adults		107	0.994	0.986	0.910	1.057	0.971	1.015	0.033	0.003		
					Males							
chil-dren	2D:4D (L)	292	0.975	0.977	0.883	1.053	0.956	1.000	0.030	0.002		
young adults		63	0.989	0.986	0.938	1.056	0.971	1.014	0.029	0.004	9.097	0.011[4]
adults		75	0.982	0.977	0.902	1.092	0.960	1.000	0.034	0.004		

Statistically significant post hoc tests:
[1] 2D:4D (R) Females
young adults and children p<0.001
young adults and adults p<0.001
[2] 2D:4D (R) Males
young adults and children p=0.046

[3] 2D:4D (L) Females
Adults and children p=0.005
young adults and children p<0.001
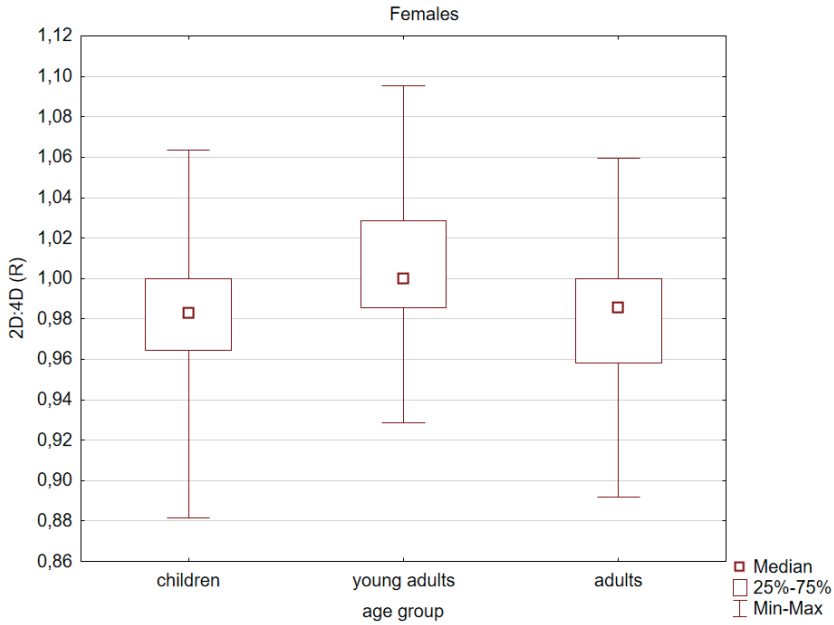[4] 2D:4D (L) Males
young adults and children p=0.011

Fig. 1. Differentiation of 2D: 4D finger ratio of the right hand between the three age groups. Statistically significant effects: young adults and children ($p<0.001$) and young adults and adults ($p<0.001$)
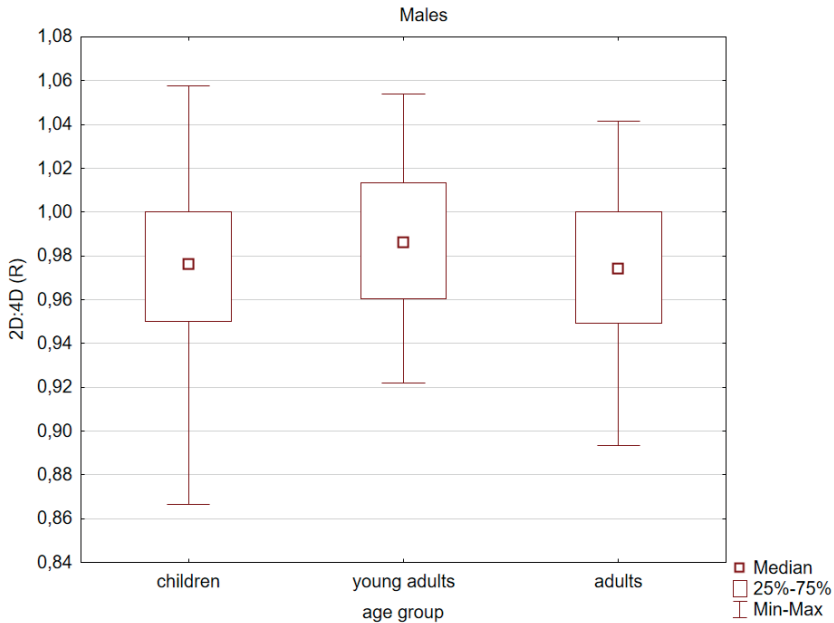

Fig. 2. Differentiation of 2D: 4D finger ratio of the left hand between the three age groups among males. Statistically significant effects: young adults and children ($p=0.046$)
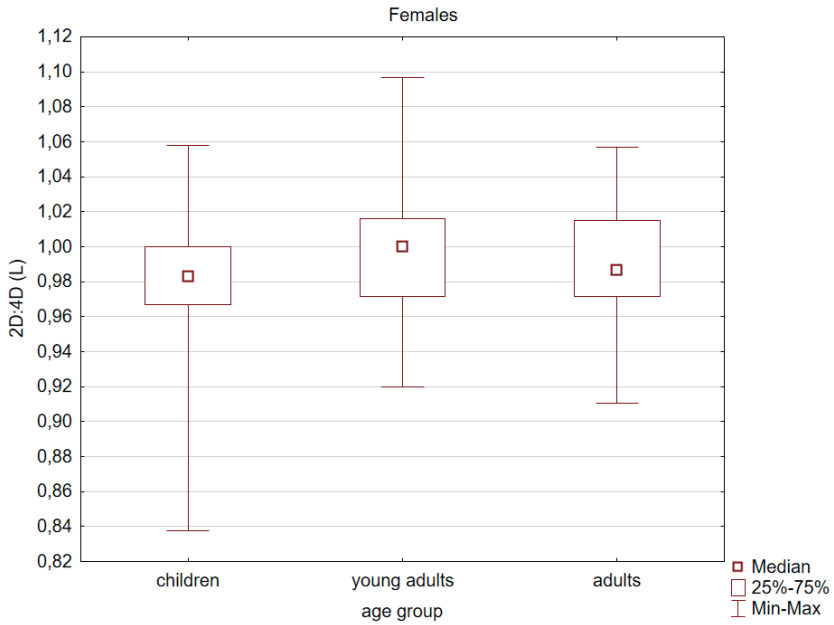
Fig. 3. Differentiation of 2D: 4D finger ratio of the left hand between the three age groups among females. Statistically significant effects: adults and children (*p*=0.005) and young adults and children (*p*<0.001)
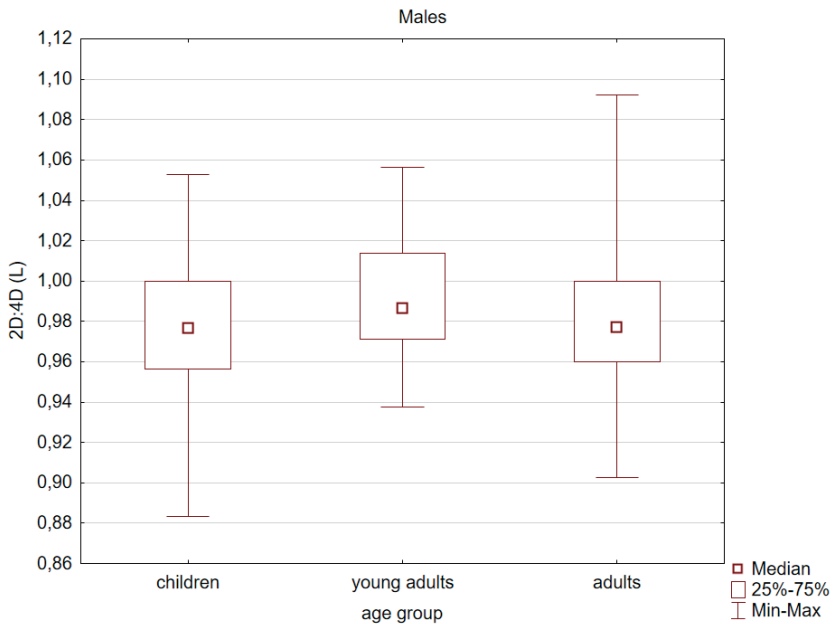

Fig. 4. Differentiation of 2D: 4D finger ratio of the left hand between the three age groups among males. Statistically significant effects: young adults and children (*p*=0.011)

Discussion

Although the relationship between the 2D:4D digit ratio and biology, behaviour and health has been widely investigated (Pruszkowska-Przybylska et al. 2008; Pruszkowska-Przybylska et al. 2021; Kasielska-Trojan et al. 2020; Sitek et al. 2018; Kobus et al. 2021) the association between 2D:4D and age is poorly understood mainly because studies have reported inconsistent results.

Regardless of the ethnic group, some changes in the 2D:4D digit ratio may occur during the prenatal period, the first two years after birth, and in later life (Butovskaya et al. 2021; Knickmeyer et al. 2011). The results of our study show that there are generation differences in the 2D:4D digit ratio for both hands between children and young adults. Older individuals seem to have higher digit ratios independently of sex possibly because there is an estrogen impact on digit development observed during late adolescence. In addition, Kyriakidis et al. (2021) reported that Greeks aged 38–63 years old had significantly higher 2D:4D ratio compared to a group aged <38 and ≥64 years old. In contrary, a study conducted by Kobus et al. (2021) showed no statistically significant correlation between 2D:4D observed across generations in a group of Poles aged 18–76 years. Similarly, Manning and Fink (2018) reported insignificant influence of age and no interaction effect of age and sex on 2D:4D in children or adults. The relationship between 2D:4D digit ratio and age has been also investigated in several longitudinal studies suggesting that 2D:4D digit ratio is not unstable in children and adolescents (Trivers et al. 2020; McIntyre et al. 2006; Trivers et al. 2006; Králík et al. 2017; Körner et al. 2020; Guo et al. 2021). One

study by Richards et al. (2017) showed that 2D:4D among adult males was negatively correlated with age. The results of this study also show a negative, although non-significant, trend among adult males regarding the association of 2D:4D (right hand) with age. It is possible that chondrocytes are regulated during adulthood by testosterone, which, compared to children, is at a higher and more stable level in adults.

The time of the hand morphogenesis corresponds to the prenatal sex hormone exposure although there is no evidence that proportion of second and fourth finger remains equal during the entire ontogenesis. Moreover, longitudinal cohort study by ethnicity is needed to determine possible fluctuating changes of 2D:4D ratio.

We underline that confirmation of the correlation between 2D:4D digit ratio and age does not exclude the 2D:4D value as a determinant of the influence of sex hormones in prenatal development. However, each analysis should always be started by checking the relationship of the finger index in a given studied group with age and, if there is such a relationship, control for the influence of age on the value of this indicator while examining other effects.

Developing research in this area is necessary to create universal correction tool for each investigated group for 2D:4D research.

Limitations

The limitation of the study might be not equal number of individuals from each stage of the ontogenesis.

Due to cross sectional nature of the study the effect that was observed could be a secular effect within age sections of a population.

Another limitation of the study might be a wide range of age that could also have biological implication. For instance, the pattern of relationship with age might have higher order differences between younger and older age groups. Thus, longitudinal studies that include the same individuals are needed to provide information to supplement our findings.

Conclusions

There might be a possible association between digit ratio and age, and direction of the correlation might be related to the phase of the ontogenesis. The results of our study suggest that controlling the influence of age on the 2D:4D digit ratio value while examining other effects is important.

Conflict of interests

The Authors declare no conflict of interests.

Authors' contribution

P.P.-P. designed the study, collected the material, analyzed the data, and prepared the draft and final version of the manuscript. M.K. collected the material and participated in preparing the draft of the manuscript. E.Ż. participated in preparing the manuscript and provided critical comments on the manuscript. I.R. and M.P. collected the material. W.K. participating in the study designing A.S. designed the study, collected the material, participated in preparing the manuscript and provided critical comments on the manuscript.

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