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Association of second to fourth digit length ratio (2D:4D) with some anthropometric measurements: a comparison between Polish and Indian young adults aged 18-25 years

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ABSTRACT

Background: *The ratio of lengths of second to the fourth digit (2D:4D) is a proxy indicator of prenatal sex-hormone exposure. The male has lower 2D:4D than the female. The ratio and its sexual dimorphism vary across ethnicity. The relationships of 2D:4D with anthropometric dimensions are not consistent.* ***Objective:*** *To compare 2D:4D and its sexual dimorphism between the young Indian and Polish populations and to examine the relationship between 2D:4D and anthropometric measures.* ***Methods:*** *This cross-sectional study included 152 Indian (males: 71 females: 81) and 110 Polish (55 each sex) young adults aged between 18 and 25 years. Height, weight, waist and hip circumferences, second and fourth digit lengths were measured.* ***Results:*** *Males had significantly lower 2D:4D than the female in both hands in both the ethnic groups. All the anthropometric measurements were higher in Polish males, including the 2D:4D of both hands, than the Indians, except for BMI and WHR. Polish females had higher digit lengths, height, weight and HC than the Indian females. In Polish males, 2D:4D was negatively associated with height and WHR in both hands. No significant correlation was observed between any anthropometric measure (except for height) and 2D:4D among the Indians. However, the Indian Female had a nearly significant positive correlation between left 2D:4D and HC. In Indian Male correlation between left hand 2D:4D and Height is significant and similar to that of the Polish men.* ***Conclusion:*** *It was not possible to draw any conclusion regarding the nature of association between 2D:4D and anthropometric parameters. The findings indicate a link between fat patterning and digit ratio.*

Key words: *Digit ratio; 2D:4D; Anthropometry; Adiposity, Sexual dimorphism; ethnicity; Indian; Polish; adults*

INTRODUCTION

The ratio of lengths of the second (index finger) to the fourth digit (ring finger) is a negative correlate of prenatal i.e., intrauterine testosterone exposure and a positive correlate of estrogen exposure (Manning et al., 1998; Lutchmaya et al., 2004; Cohen-Bendahan et al., 2005, Keogh et al., 2007). Males tend to have longer fourth digits relative to second digits than females do and thus, the second-to-fourth digit ratio (2D:4D) is higher in women than men (Cohen-Bendahan et al., 2005; Manning, 2002). This digit ratio (DR) also has been shown to correlate with the level of testosterone in the amniotic fluid of foetus (Lutchmaya et al., 2004). Prenatal testosterone seems to lengthen the ring finger, whereas prenatal estrogen lengthens the index finger to result in the sex difference (Manning et al., 1998). 2D:4D was also reported to be fixed by about two years of age and remains almost unchanged for the rest of life (Manning et al., 1998).

2D:4D has been shown to be associated with several behavioral and morphological characters expressed in adults (Manning, 2002; 2009). This is probably because 2D:4D, as a biomarker, reflects the organizational effects of foetal testosterone and estrogen (Manning, 2002). However studies (Manning et al., 2004; Honekopp et al., 2007) concluded that in the general population 2D:4D is not strongly associated with adult sex hormone levels. In a recent study, testosterone as well as testosterone to estrogen ratio was significantly negatively related to right 2D:4D in men, but the association was very weak and absent in women (Muller et al., 2011).

Higher prenatal testosterone exposure corresponds to ‘masculine’ characteristics such as increased physical strength and endurance, pace, speed and also influence some personality traits, such as assertiveness and risk-taking behavior, typically more commonly found among the male (Manning, 2002; Manning & Taylor, 2001) and are very often exhibited later in life. Females exposed to excess testosterone or other androgens demonstrated behaviors typical of males even during their infancy (Hines, 2000). Athletic ability was shown to be negatively correlated with 2D:4D of each hand for both sexes. Performance in training for endurance running was associated with low 2D:4D in both men and women (Ho¨nekopp & Schuster, 2010). In a more recent study it was shown that low 2D:4D was associated with endurance-linked running, and this association was more pronounced in females (Trivers et al., 2013).

Hormone related diseases, such as breast and prostate cancers in adulthood were also related to digit ratio in some studies (Manning & Leinster, 2001; Muller et al., 2011). Subjective pain feeling was associated with lower 2D:4D ratio in both sexes (Koziel et al., 2013). Studies on the association of androgen exposure or digit ratio with adult anthropometric measures are scanty. The distribution of body fat is thought to signal the ratio of pubertal/adult estrogen to testosterone, since the predominance of estrogen at puberty produces a typical female body shape, while the predominance of testosterone produces a typical male body shape (Bjorntrop, 1997). There were a few studies which showed some relationship of adiposity with prenatal androgen exposure (Abbot et al., 2002) and 2D:4D (McIntyre et al., 2003; Fink et al., 2003; 2006; Wallen, 2009). Adult adiposity pattern is responsible for many complex chronic diseases including some hormone-related cancers. Therefore the relationship of these disease risks with 2D:4D was assumed to be mediated by anthropometric features with particular reference to adiposity (Muller et al., 2013). Nevertheless, studies on the association of anthropometric parameters with digit ratio were inconsistent (Van Dangen, 2009; Muller et al., 2013). It seems that there is need to conduct studies to document the variation of this relationship across ethnic groups. For instance, as the body composition of Asian Indians is different from the Caucasoid (Yajnik, 2001; WHO, 2004), the relationship of adiposity measures to digit ratios may be different in these two populations. The ethnic difference in 2D:4D was also reported in children (Manning et al., 2004).

In this study, we compared Indian and Polish students as the representatives of two great racial groups of Caucasoid and Asian-Indians as ethnic contrasts. We have selected the young college and university students aged 18-25 years with an understanding that this age group is devoid of either pubertal effect on growth or have not yet experienced long adult life exposures to environment. Again, the 2D:4D ratio appears to reach the highest value at age 17 (McIntyre et al., 2005). Only one such study among this age group was evident online (Barut et al., 2008). The objectives of the present study wear to compare 2D:4D and its sexual dimorphism between the young Indian and Polish populations. It also aimed to examine the relationship between digit ratio, which is determined in-utero, and three sexually dimorphic anthropometric dimensions, which are largely determined at puberty.

MATERIALS AND METHODS

Subjects and settings

This cross-sectional study included 152 Indian (males: 71 females: 81) and 110 Polish (55 each sex) young adults aged between 18 and 25 years. The study protocol followed the ethical standards and guidelines as laid down in Helsinki Declaration (Goodyear et al., 2007). In Poland, the researcher (SK) had a written consent of the Chancellor of University, and in India, the study was approved by the Departmental Committee of the Department of Anthropology, Vidyasagar University, West Bengal. Informed consent was also obtained from all the participants in each country.

Measurements

The measurement protocols were standardized between researchers of two countries beforehand and performed by specifically trained physical anthropologists in Poland and by two of the authors (SJ and TM) in India. The female participants were measured by female investigators. Height was measured to the nearest 1 mm with anthropometer. Weight was recorded to the nearest 500 g with standard weight scales. Waist and hip circumferences were measured by non-stretchable plastic tapes following standard procedures (Lohman et al., 1988).The lengths of the second and fourth digits of each hand were measured to the nearest 0.01 mm using vernier calipers. The finger lengths were recorded on the ventral surface of the hand, from the mid-point of the basal crease (most proximal to palm) to the tip of the digit. This procedure maintains good reliability (Manning, 2002) and low measurement error (Keogh et al., 2007). Digit ratios (2D:4D) were then calculated as the length of the 2D divided by the length of the 4D for each hand.

Statistical analyses

Means and standard deviations, separately for male and female students of two ethnicities were calculated for all anthropometric measurements, indices and 2D:4D for each hand and for the average values of two hands. Students' T-tests were performed to observe the significance of difference in all measurements between sexes and ethnicities. Receiver operating characteristic (ROC) curves compare sensitivity versus specificity across a range of values for the ability to predict a dichotomous outcome. Area under (ROC) curve (AUC) is another measure of test performance of the test to discriminate cases (here, the males) from the normal/control (here, the females) (See Florkowski, 2008). In this study, ROC curve analyses were undertaken, separately

for the Indian and the Polish samples, to see the ability of DR to predict sex and the appropriate cut off of 2D:4D to differentiate female (coded 1) from male (coded 0). All the statistical analyses were carried out through Statistica 10 (StatSoft, 2010) and MedCalc software.

RESULTS

Table 1. Descriptive statistics of age and anthropometric variables among the Polish and Indian university students by sex.

Variable	Polish Female N= 55	Polish Male N= 55	t (Polish male vs female)	Indian Female N=71	Indian Male N=81	t Indian male vs female)	t (Polish vs Indian female)	t (Polish vs Indian male)
Age (year)	21.7 (1.89)	21.6 (1.62)	0.16	21.4 (1.05)	21.2 (1.90)	1.07	1.022	1.572
Left 2D (cm)	6.994 (0.346)	7.322 (0.428)	-4.425**	6.593 (0.386)	6.894 (0.407)	-4.662***	6.050***	5.898***
Right 2D (cm)	6.990 (0.361)	7.319 (0.415)	-4.435**	6.593 (0.376)	6.874 (0.397)	-4.454***	5.973***	6.297***
Left 4D (cm)	6.838 (0.353)	7.414 (0.506)	-6.925**	6.444 (0.332)	7.110 (0.439)	-10.628***	6.429***	3.718***
Right 4D (cm)	6.850 (0.360)	7.409 (0.536)	-6.415**	6.406 (0.347)	7.079 (0.434)	-10.454***	7.020***	3.949***
Left 2D:4D	1.023 (0.028)	0.989 (0.035)	5.647**	1.024 (0.048)	0.970 (0.036)	7.624***	.082	2.934**
Right 2D:4D	1.021 (0.030)	0.989 (0.035)	5.074**	1.031 (0.057)	0.972 (0.038)	7.339***	1.236	2.725**
Height (cm)	168.1 (5.75)	177.1 (7.95)	-6.818**	154.9 (6.21)	167.3 (5.15)	-13.394***	12.116***	8.037***
Weight (kg)	62.9 (8.7)	73.5 (13.5)	-4.895**	54.1 (12.3)	63.3 (9.6)	-5.082***	4.692**	5.158***
BMI (kg/m^2)	22.2 (2.5)	23.3 (3.4)	-1.951*	22.4 (4.6)	22.6 (3.1)	-.230	.324	1.350
WC (cm)	74.7 (7.3)	83.4 (9.9)	-5.204**	72.7 (10.2)	74.8 (8.5)	-1.329	1.230	5.385***
HC (cm)	98.9 (7.2)	101.1 (7.1)	-1.623	93.8 (12.5)	90.2 (6.9)	2.117*	2.906*	8.924***
WHR	0.75 (0.04)	0.82 (0.07)	-6.497**	0.78 (0.12)	0.83 (0.05)	-3.035**	1.683	.404

*p<0.05; **p<0.01; ***p<0.001;

Table 1 demonstrates the descriptive statistics of age and anthropometric variables among the Polish and Indian university students by sex. There is no significant difference in age either between sexes within each ethnic group or between the ethnic groups within each sex. Therefore we could assume that all groups are of similar age. All measurements except 2D:4D were higher in Polish men than in Polish women. The DRs of both hands were significantly higher in Polish females. The HC is unexpectedly higher by about 2 cm in Polish males, although not significant. The differences between sexes in Indian subjects were similar to the Polish sample except for

BMI, WC and HC. The BMI and WC were not significantly different between Indian males and females. The HC was significantly larger by about 3.6 cm in Indian females than the males. All the anthropometric measurements were higher in Polish males, including the 2D:4D of both hands, than the Indians, except for BMI and WHR, which were not significantly different between males of the two ethnic groups. Similarly, the Polish females had higher digit lengths, height, weight and HC than the Indian females. However, there was no significant difference in DRs, BMI, WC and WHR between them.

Table 2. Correlation-coefficients of anthropometric variables with right and left 2D:4D among the Polish university students of Wroclaw.

Variable	Polish Female		Polish Male	
	Left 2D:4D	Right 2D:4D	Left 2D:4D	Right 2D:4D
Age (year)	0.079	-0.008	0.302*	0.212
Height (cm)	-0.121	-0.089	-0.287**	-0.452**
Weight (kg)	-0.051	0.152	-0.057	-0.086
BMI (kg/m^2)	0.003	0.226	0.103	0.167
WC (cm)	-0.072	0.183	-0.287*	-0.238
HC (cm)	-0.022	0.135	0.202	0.267*
WHR$	-0.096	0.170	-0.606**	-0.577**

*p<0.05; **p<0.001; $controlled for age.

Table 2 shows the results of correlation analyses between digit ratios of both hands and anthropometry in Polish youths. Both WHR and digit ratio were correlated with age in Polish males. Thus age was controlled for to reveal correlation between WHR and DRs.In Polish males, 2D:4D was negatively associated with height and WHR (masculine pattern) in both hands. No significant correlation was observed between any anthropometric measure (except for height) and 2D:4D among the Indian students. But the Indian Female had a nearly significant positive correlation of 0.23 (p=0.055) between left 2D:4D and HC. In Indian Male correlation between left hand DR and Height is significant and similar to that of the Polish men (r = -0.272 (p<0.05).

Table 3 demonstrates the results of receiver operating characteristics curves (ROC) of digit ratios between Polish and Indian young adults, separately for each hand. For each analysis, the males were coded as '0' against the females coded '1'. For left hand 2D:4D, a cut-off value of 1.00 was found to be the best to distinguish females from males in both Polish and Indian youths. For right hand 2D:4D, the cut-off value of 1.00 among the Indians and 0.99 in the Polish youths

were found to be the best to distinguish females from males. For the Polish sample the Youden index for both hand's 2D:4D was 0.49. For Indians it was 0.62 for the left hand and 0.52 for the right 2D:4D. The values of areas under curves and Youden indices indicated that the model were better for the Indians than for the Polish sample. **Figures1** to **4** shows the ROC curves for each hand's 2D:4D in each of the ethnic groups, respectively.

Table 3. Comparison of the results of receiver operating characteristics curves (ROC) analyses of digit ratios between Polish and Indian young adults.

Variable	Left 2D:4D		Right 2D:4D	
	Polish	**Indian**	**Polish**	**Indian**
Cut-off value[$]	1.00	1.00	0.99	1.00
Area under curve	0.77[*]	0.83[*]	0.76[*]	0.80[*]
Sensitivity (95% CI)	72.73 (63.0 - 86.8)	81.69 (70.7-89.9)	89.09 (77.8-95.9)	71.83 (59.9-81.9)
Specificity (95% CI)	76.36 (59.0 - 83.9)	79.01 (68.5-87.3)	60.0 (45.9-73.0)	80.25 (69.9-88.3)
Positive predictive value	75.5 (61.1-86.3)	77.3 (66.2-86.2)	69.0 (56.9-79.5)	76.1 (64.1-85.7)
Negative predictive value	73.7 (60.2-84.5)	83.1 (72.8-90.7)	84.6 (69.5-94.1)	76.5 (66.0-85.0)
Youden Index	0.49	0.62	0.49	0.52

[*] $p < 0.0001$; [$] values greater than these distinguishes female from male.

DISCUSSION

In present study, males had significantly lower 2D:4D than the female in both hands in both the ethnic groups as expected (Cohen-Bendahan et al., 2005; Manning, 2002). However there were many studies arguing for a greater sexual dimorphism in DR in the right rather than in left hand (Manning et al., 1998; 2002; Fink et al., 2003, Honekopp and Watson, 2010). In a very recent study among the Hani in China, the mean 2D:4D in females was higher than that in males for each hand. However, females showed significantly higher 2D:4D than males in the right hand rather than in the left hand (Zhao et al., 2013). In both our Indian and Polish youth samples, the sexual dimorphism was similar in both hands.

In this study another interesting observation was also made regarding sexual dimorphism from ROC curve analyses. First, the values of areas under curves and Youden indices indicated that the model were better for the Indians than for the Polish sample. Secondly, the cut off value of 0.99 for right hand 2D:4D in Polish males to distinguish between sexes was lower than those in left hand in them and both hand in Indian males and females. It might be indicative of a lower threshold for sexual dimorphism in right hand among the Polish men. In another word, the right hand digit ratio might be relatively more sensitive as regards sexual dimorphism in Polish males. Manning et al. (1998) reported that in humans right 2D:4D showed stronger relationships with target traits (such as testosterone, oestrogen and sperm numbers) than did left 2D:4D, suggesting that right 2D:4D is more sensitive to prenatal sex steroids than left 2D:4D (Manning et al., 1998; 2002). Hönekopp and Watson (2010) also reported that the sex difference in right 2D:4D was greater than that of left 2D:4D.

In our present study, higher 2D:4D (feminine) was related to lower height and WHR (feminine pattern) in both hands in Polish males. But in Indian males, similar significant association with height was found for left hands only. Weaker correlations with WC (negative) in left hand and HC (positive) in right hand were also found in Polish men. No significant correlation was observed between any other anthropometric measure and 2D:4D among the Indian males and females.However, the Indian females had a nearly significant positive correlation ($r = 0.23$, $p=0.055$) between left 2D:4D and HC. In Polish men also there was a positive correlation of 2D:4D with HC. It indicated that higher HC in Indian females as well as in Polish men was associated with higher 2D:4D. Relatively higher HC and lower WHR is indicative of feminine fat patterning and so is the higher 2D:4D. Therefore in Polish men as well as in Indian females a positive association between feminine adiposity pattern and 2D:4D was indicated. Higher 2D:4D is associated with both femininity and lower prenatal testosterone exposure. Therefore the latter might be associated with gynoid (female) fat patterning in Indian females and the Polish males. In this context it may be mentioned that high BMI levels was showed to reflect low testosterone levels (Fink et al., 2003). Besides, it was also hypothesized that prenatal androgen exposure might also be related to adult anthropometric measures, especially abdominal adiposity (Abbott et al., 2002), and that finger fat might be responsible for sex differences in 2D:4D (Wallen,

2009). However the absence of this phenomenon in Polish females and Indian males seemed to be due to ethnic variation.

McIntyre et al. (2003) found a weak inverse association between right hand 2D:4D and waist circumference in a sample of 42 men. But in another study (Fink et al., 2003) moderately strong inverse associations were found between waist circumference, hip circumference and waist-to-chest ratio and both right and left 2D:4D for women. This study also found that BMI was strongly positively correlated with left 2D:4D for men. Fink et al. (2006) demonstrated that right 2D:4D was inversely associated with hip circumference and positively correlated with waist-to-hip ratio for men, but found no associations between 2D:4D and any anthropometric measure for women. In a recent study, Muller et al. (2013) examined fat and lean body mass and waist and hip circumference as well as their weight and height in 8840 women and 6076 men and observed no strong association between 2D:4D and height, weight, BMI, waist circumference, hip circumference, waist-to-hip ratio, fat mass, fat-free mass or percentage fat mass. In a more recent study, higher (feminine) 2D:4D in both hands of men and in the right hand for women were corresponded to feminine body fat pattern. But there was no relationship between total fatness and 2D:4D for either sex (Ertuğrul, 2013). Muller (2013) found no substantial association between any assessed anthropometric measures, including those of adiposity and 2D:4D among the Australians. Also among the young Nigerian male and female, 2D:4D failed to show significant correlation with BMI, chest, waist and hip circumferences (Danborno et al., 2007).

In view of the findings of the above mentioned studies it is not possible to draw any final conclusion regarding the nature of association between digit ratio and anthropometric parameters. But our findings in combination with these findings indicate a link between fat patterning and digit ratio. This is also expected in view of the link between 2D:4D and intrauterine hormone exposure and the possible association of the latter with sex specific body fat patterning. But these relationships also seem to be mediated by gender and ethnicity. More studies are needed with larger multiethnic samples and meta-analyses to confirm this gender specific pattern of associations.

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