Brief Communication: Women with More Feminine Digit Ratio (2D:4D) Have Higher Reproductive Success

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ABSTRACT

Objectives: Prenatal development has a long-lasting influence on biological condition and health. Second-to-fourth digit ratio (2D:4D) is suggested as an indicator of sex hormone exposure during fetal development, and it is likely that women with a more feminine digit ratio were exposed to higher prenatal estrogen levels. Therefore, we tested if 2D:4D was related to a woman's reproductive characteristics.

Methods: We studied 319 women aged 46–92, who went through a natural menopause and whose husbands were alive at least until their menopause were studied. Women were recruited at the Mogielica Human Ecology Study Site located in rural Poland.

Results: Women with more feminine 2D:4D had a higher number of children ($P = 0.002$), gave birth to their last child at a later age ($P = 0.02$), and had a longer reproductive lifespan ($P = 0.04$) than women with more masculine 2D:4D. Age and number of years of education were included as potential confounders in the analyses.

Conclusions: The results indicated that women with more feminine 2D:4D had higher reproductive success. While the exact mechanisms were not known, and the relationship between 2D:4D and adult sex hormone levels was questioned by previous studies, there might be other biological pathways explaining the observed results, that is, via behaviors that were indirectly related to fertility. Am J Phys Anthropol 000:000–000, 2016.

It is suggested in the literature that digit ratio (2D:4D) is a potential marker reflecting prenatal hormonal environment and thus having a life-long influence on physiology, behavior, and fertility (Manning, 2011; Manning et al., 2014). In animal models, hormone injections during fetal development lead to early ovarian stimulation and onset of puberty (Birch et al., 2003, but see: Ruuskanen et al., 2011). In humans, where such experiments cannot be conducted, the second-to-fourth digit ratio (2D:4D) has been proposed as a marker of prenatal sex hormone exposure (Lutchmaya et al., 2004). The 2D:4D is the ratio between the length of second (2D, index finger) and fourth finger (4D, ring finger) (Manning et al., 1998) and is a sexually dimorphic trait, present from the 14th week of pregnancy (Galis et al., 2010). It is suggested that a more masculine (low) 2D:4D is the result of greater prenatal testosterone exposure and is expressed by a ring finger longer than the index finger, while a more feminine (high) 2D:4D results from greater estrogen exposure (Manning et al., 1998). However, there is still some controversy regarding whether 2D:4D is actually a good marker of prenatal sex hormone exposure in humans. Current evidence is based mainly on clinical studies of subjects with disorders related to prenatal hormone levels like Congenital Adrenal Hyperplasia (CAH) or Klinefelter's syndrome (i.e., Brown et al., 2002; Manning et al., 2013). Studies where actual prenatal hormone levels are measured are limited; however, a non-clinical study performed by Lutchmaya et al. (2004) has shown that, among 2-year-old children, 2D:4D was positively associated with fetal estradiol, and negatively associated with fetal testosterone, measured during amniocentesis. These results suggest that 2D:4D is a plausible indicator of fetal exposure to the sex steroids.

This study aims to test a hypothesis suggesting that prenatal, hormonal environment (reflected in the 2D:4D ratio) does have a long-term influence on reproduction in women. In particular, we study the association between 2D:4D and reproductive history in post-menopausal women (by comparing groups of women with more masculine and more feminine 2D:4D), including several characteristics that were not previously studied, such as age at last birth and number of children of a given sex. Earlier studies have shown that women with more feminine 2D:4D have a higher number of children, a longer reproductive lifespan (Kalichman et al., 2013), have their first child at an earlier age, have earlier preferred age of having a first child, and possess higher sex drive and level of sexual excitement (Manning et al., 2000;

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Manning and Fink, 2008). However, other studies did not confirm these findings (for a review see: Putz et al., 2004). Thus, it is still not clear if the 2D:4D digit ratio can be used as a predictor of women's reproductive pattern.

MATERIALS AND METHODS

This study was conducted amongst a rural Polish population at the Mogielica Human Ecology Study Site, currently undergoing a fertility transition (Colleran et al., 2014), but until recently characterized by natural fertility (Jasienska and Ellison, 2004; Jasienska, 2013). The participants were 319 women, aged 46–92 (mean = 65.5, SD = 9.57) who went through a natural menopause (mean age = 51.2, SD = 3.21), and whose husbands were alive at least until their menopause. Data on reproductive history and lifestyle characteristics (Table 1) was collected via questionnaire. The measurements of second and fourth finger length, from proximal finger crease to the distal tip of the finger on both hands, were taken by trained study assistants according to a previously published procedure (Klimek et al., 2014). Participants ($n = 24$) with arthritis were excluded from the study during recruitment and are not included in the analysis. Moreover, 27 women (8.5% of total sample) had their 2D:4D value calculated only for one hand due to finger injury in the second hand.

In the studied group there were 136 women with more masculine 2D:4D in both hands (42.6% of total sample), 52 women with more masculine 2D:4D in the left hand and more feminine 2D:4D in the right hand (16.3% of total sample), 53 women had more feminine 2D:4D in both hands (16.6% of total sample), and 51 women had more feminine 2D:4D in the left hand but more masculine 2D:4D in the right hand (15.9% of total sample).

Statistical analysis

Women were divided into two groups based on their 2D:4D value: more feminine ($2D:4D \geq 1$) and more masculine ($2D:4D < 1$) in both hands, following previously published methods (e.g., Tamiya et al., 2012; Hussain et al., 2014; Klimek et al., 2014). We decided to perform the analysis separately for the right and left hand, since it is documented in literature that early developmental masculinization influences delay in development of left-sided body traits (Geschwind and Galaburda, 1985). This may lead to a stronger expression of sexually dimorphic traits on the right side of the body (Tanner, 1990) and cause different 2D:4D values between hands. Moreover, a meta-analysis of 116 studies suggests that right-hand digit ratio might be a more suitable marker of pre-natal sex hormone exposure than left-hand (Honeköpp and Watson, 2010), while another meta-analysis did not find a better predicting power of either of the hands and suggested that 2D:4D of both hands should be analyzed separately (Honeköpp and Schuster, 2010). Therefore, performing analysis on both hands is a rational choice.

The 2D:4D ratios were examined as the categorical variable, as has been done in many previous studies (e.g., Fink et al., 2007; Kalichman et al., 2013; Hussain et al., 2014; Klimek et al., 2014) since it is simpler to interpret than 2D:4D derived from linear models. However, dichotomizing might result in loss of statistical power (Cohen, 1983; Fitzsimons, 2008). Differences between the groups with low and high 2D:4D (in right and left hand) in reproductive characteristics (such as: number of children, number of children of a given sex, woman's age at first and last birth, and reproductive lifespan) were tested by analysis of covariance (ANCOVA), with age and years of education (in all analysis), and number of sons and daughters (depending on the type of analysis) as potential covariates. Number of children, number of sons and number of daughters, were analyzed in models with Poisson distribution. Analysis of mean interbirth intervals and reproductive lifespan (time between the first and the last birth) were performed among women with at least two children. Moreover, eight women with mean interbirth intervals longer than 100 months were excluded from analysis of differences in interbirth intervals as outliers, based on Cook's distance value. Statistica software version 10 was used to perform statistical analysis.

TABLE 1. Characteristics of the study group (number of participants, mean, and standard deviation)

	N	Mean	SD
Age	319	65.5	9.57
Number of years of education	273	8.3	2.78
Number of children	317	4.5	2.40
Number of daughters	316	2.1	1.53
Number of sons	316	2.4	1.69
Age at first birth (years)	291	24.1	4.03
Age at last birth (years)	292	34.6	5.80
Reproductive lifespan (years)	287	10.4	5.83
Mean interbirth interval (months)	274	37.6	15.55
Right hand 2D:4D	298	0.9	0.04
Left hand 2D:4D	301	0.9	0.05

RESULTS

Women with more feminine right hand 2D:4D, in comparison to women with more masculine right hand 2D:4D, had a higher number of children (5.3 and 4.3, respectively, $\chi^2_1 = 10.1$; $P = 0.002$) and were reproductively active for longer (11.8 and 10.1 years, respectively, $F_{(1,227)} = 4.30$; $P = 0.04$). In addition, they had a higher number of daughters (2.5 and 2.0, respectively, $\chi^2_1 = 5.08$; $P = 0.02$), when controlled for number of sons, and a higher number of sons (2.8 and 2.3, respectively, $\chi^2_1 = 6.06$; $P = 0.01$), when controlled for number of daughters. Moreover, women with more feminine left hand 2D:4D gave birth to their last child at a later age (35.0 and 33.4, respectively, $F_{(1,263)} = 3.38$; $P = 0.02$), than women with more masculine left hand 2D:4D. No statistically significant differences were found for age at first birth and mean interbirth intervals between women with more feminine and more masculine 2D:4D in both hands (Table 2).

DISCUSSION

Digit ratio values and their power to predict reproductive capacity vary across populations and ethnic groups (Manning et al., 2007). We have shown that among Polish women from a rural population, women with more feminine 2D:4D had more efficient reproduction and, thus, higher reproductive success (indicated by the number of children). These women had, on average, one child more than women with more masculine 2D:4D. The higher parity of women with more feminine 2D:4D was possibly due to a later age of last birth and a longer reproductive lifespan. These results suggest that 2D:4D might be a predictor of women's reproductive pattern.

TABLE 2. Differences between groups with low and high, right- and left-hand 2D:4D and women's reproductive characteristics

	Right 2D:4D				Left 2D:4D			
	High 2D:4D $n = 106$ Mean (SE)	Low 2D:4D $n = 192$ Mean (SE)	F/χ^2 [a]	P	High 2D:4D $n = 194$ Mean (SE)	Low 2D:4D $n = 107$ Mean (SE)	F/χ^2 [a]	P
Number of children[b]	5.3 (0.27)	4.3 (0.17)	13.1	0.003	4.7 (0.24)	4.6 (0.19)	1.63	0.20
Number of daughters[c]	2.5 (0.16)	2.0 (0.11)	5.08	0.02	2.1 (0.17)	2.1 (0.11)	0.04	0.85
Number of sons[d]	2.8 (0.20)	2.3 (0.12)	6.06	0.01	2.7 (0.17)	2.4 (0.14)	2.13	0.14
Age at first birth (years)[a]	24.2 (0.44)	23.7 (0.33)	1.52	0.22	24.2 (0.44)	23.9 (0.33)	0.20	0.65
Age at last birth (years)[a]	35.3 (0.59)	34.5 (0.43)	1.22	0.27	35.0 (0.68)	33.4 (0.50)	5.28	0.02
Reproductive lifespan (years)[a]	11.8 (0.63)	10.1 (0.46)	4.30	0.04	11.1 (0.62)	10.2 (0.46)	2.00	0.15
Mean interbirth intervals (months)[a]	38.1 (2.46)	40.7 (1.84)	0.75	0.38	39.6 (2.43)	39.5 (1.82)	0.00	0.98

P-values were derived from analysis of covariance (ANCOVA).
[a] Depending on the type of analysis [with (χ^2) or without (F) Poisson distribution].
[b] Controlled for age and years of education.
[c] Controlled for age, years of education, and number of sons.
[d] Controlled for age, years of education, and number of daughters. Groups of low and high 2D:4D in each hand are not always include the same women (i.e., when a woman had more masculine 2D:4D in the right hand and more feminine 2D:4D in the left hand she was classified to two different groups of 2D:4D).

In our study, we did not find a difference in mean age at first birth between groups of more feminine and more masculine 2D:4D women, contrary to, for example, Manning and Fink (2008). This is interesting because other studies have reported that women with more feminine 2D:4D tend to marry at an earlier age (Manning and Fink, 2008; but see: Sorokowski et al., 2012), prefer marriage at an earlier age (Manning and Fink, 2008) and have earlier menarche (Matchock, 2008, but see: Helle, 2010a), what might indicate that these women could start their reproduction earlier. Further, similarly to Helle (2010b), we did not find differences in mean interbirth intervals between groups of more masculine and more feminine 2D:4D women, but we did find a difference between these groups in age at last birth and reproductive lifespan. This might indicate that women with more feminine and more masculine 2D:4D do not differ in their ability to conceive from one pregnancy to the next, but that women with more feminine 2D:4D have a longer lasting ability to conceive when they get older. Additionally, reproduction in natural fertility populations depends on many biological and cultural factors, for example, age at menarche (Komlos, 1989), age at marriage (Wood, 1994), nutritional status (Nenko and Jasienska, 2013), breastfeeding, and resumption of ovarian function post-partum (Howie and McNeilly, 1982).

There might be several explanations of the existing results. One is a potential relationship between 2D:4D and an adult's reproductive hormone levels. Some studies have indeed suggested such a relationship, but they were based on insufficient hormonal sampling or small sample sizes (Manning et al., 1998; McIntyre et al., 2007). Our previous study, based on a reliably assessed ovarian hormone levels (Jasienska and Jasienski, 2008) in a group of 186 women collecting daily saliva samples during one complete menstrual cycle, did not confirm that women with more feminine 2D:4D had higher levels of ovarian hormones (Klimek et al., 2015). This finding is in line with the fact that we did not observe differences in interbirth intervals in groups of women with low and high 2D:4D. Such differences would be expected if these women would vary in levels of hormones, because higher levels of progesterone and estradiol are related to higher chance of conception (Lipson and Ellison, 1996) and thus may lead to shorter interbirth intervals. This raises a question about other mechanisms that could be responsible for an association between 2D:4D and women's reproductive traits.

Firstly, among women more feminine 2D:4D is related to sexual behavior, including greater sex drive and higher levels of sexual excitement (Manning et al., 2000; Manning and Fink, 2008) which may lead to greater sexual activity and longer period of being sexually active and thus a higher chance of having a last child at later age among women with more feminine 2D:4D. Secondly, more feminine 2D:4D was also found to be related to lower levels of facial fluctuating asymmetry (Fink et al., 2004), which, in turn, is related to developmental stability (Grammer and Thornhill, 1994), levels of attractiveness, health status, and reproductive success (Fink et al., 2004). Thirdly, other factors like waist-to-hip ratio (WHR) that are simultaneously related to 2D:4D and reproductive characteristics (Singh and Zambarano 1997; Manning et al., 2000) might also have possible indirect effects on the connection between prenatal sex hormone balance and reproductive parameters. It has been shown that women with more feminine 2D:4D have lower WHR and are perceived as more attractive by their partners (Singh and Randall, 2007), which may contribute to their higher reproductive success.

It should be noted that analysis of age at last birth in groups of women with more masculine and more feminine 2D:4D was statistically significant only for left hand. Although right hand 2D:4D is proposed as more accurate marker of prenatal hormone exposure (Manning, 2002), female-typical variables are suggested to be strongly expressed on the left side of the body (Tanner, 1990). Moreover, a meta-analytic review on the relationship between 2D:4D and athletic prowess reviled that neither hand had better predicting power than the other (Honeköpp and Schuster, 2010), and 2D:4D for both hands should be analyzed in studies separately. There are also studies based only on left-hand 2D:4D among women (Peeters and Claessens, 2012). This might indicate, that the left-hand 2D:4D among women is also a valuable predictor of various characteristics and analyzing 2D:4D in both hands is biologically justified.

It is also worth mentioning, that majority of our participants had more masculine 2D:4D. This pattern might be typical for European women, as it was suggested by Manning et al. (2007) who found that European women

frequently have more masculine 2D:4D (below "1") in both hands.

The main limitations of the study should be taken into account. Finger length measurements were performed only once, and directly from the palm. According to Allaway et al. (2009), the most accurate measurements of finger length are obtained using computer-related methods. Since our study was based on home visits to our participants, we could not performed a hand scans or multiple measurements to calculate inter- or intra-observer errors. Although, our measurements were performed by trained assistants, contrary to less reliable methods like self-fingers measurement (i.e., Manning and Fink, 2008). Another limitation could also be recall bias since our study included older women. However, study assistants were trained to cross-check data collected via questionnaire.

In conclusion, our results suggest that 2D:4D digit ratio (a possible proxy for the prenatal hormonal environment) might have a life-long connection to women's reproduction, with an impact on both duration of reproductive lifespan and, ultimately, the reproductive success. Our results add to the accumulating evidence pointing to the importance of the prenatal hormonal environment as an important factor influencing reproductive patterns.

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