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Second to fourth digit ratio in relation to age, BMI and life history in a population of young adults: a set of unexpected results

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There is a wealth of studies supporting a link between 2D:4D ratios and prenatal exposure to testosterone and oestrogen. Furthermore, 2D:4D ratios appear to relate to several aspects of human sexual behaviour, which suggests that these characteristics are determined in early embryological stages and not largely affected by factors later in life. However, not all studies have found associations as predicted, and we know relatively little about postnatal changes in 2D:4D ratios. This preliminary study in 100 young males and females explores associations between 2D:4D ratios on the one hand and age, life history and BMI on the other hand. In women, I found a decrease in 2D:4D ratios from typically feminine to typical masculine in the right hand of women; in men, I found a negative association between 2D:4D ratio and BMI. Both results were contrary to expectations. In spite of the relatively small sample size, these results might question the general validity of 2D:4D ratios as a predictor of human sexual behaviour that in turn could relate to prenatal exposure to sex hormones. It calls for further research focussing on factors that may disrupt expected associations between 2D:4D and aspects of human behaviour related to hormone levels.

Introduction

The ratio of the length of the second to fourth digit (2D:4D ratio) presumably reflects prenatal exposure to sex hormones. The 2D:4D ratio is sexually dimorphic, and males consistently have a slightly lower value (Manning *et al*. 1998). This dimorphism appears to emerge during early development, is consistent across different age classes and reflects foetal testosterone and oestrogen levels (Lutchmaya *et al*. 2004). 2D:4D ratios appear to correlate with a variety of covariates related to sex-dependent behaviour (Manning & Fink 2008). Although results are not always homogeneous, there are indications that 2D:4D ratios correlate with aggression, dominance, sporting ability, fertility problems, number of children, health status, sexual orientation and other variables related to reproductive success. These associations appear to be often stronger for the right hand 2D:4D (*see* Putz *et al*. 2004 and Manning & Fink 2008 for recent overviews). Putz *et al*. (2004) questioned the general usefulness of 2D:4D ratios that Manning and Fink (2008) accept, and argued that because levels of sex hormones fluctuate during growth and development, various sexually dimorphic traits differentiate at different ages, which obscures associations between 2D:4D ratios and traits affected by sex hormones.

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Surprisingly, we know relatively little about the individual changes in 2D:4D ratios throughout human life. The dimorphism in 2D:4D ratio between sexes emerges at the foetal stage and in young children, and increases with age (McIntyre *et al*. 2005, Malas *et al*. 2006, Trivers *et al*. 2006, Galis *et al*. 2009). Currently, it is not clear how stable the individual values of the 2D:4D ratios are, which could have important implications for its usefulness as an indicator at different ages. Only two longitudinal studies examine changes in 2D:4D ratios with age. Trivers *et al*. (2006) found that in children between 7 and 13 years old, variation in 2D:4D of the right hand explained about 60% of the variation in this digit ratio four years later. The associations were much weaker for the left hand. McIntyre *et al*. (2005) found relatively low correlations between 2D:4D ratios at age 17 and a multivariate measure of sex differences in the digital formulae at younger ages. Coefficients of determination were below 25% for all ages. These results are consistent with those of Trivers *et al*. (2006), since McIntyre *et al*. (2005) studied only left hands. Thus, changes in hand morphology with age are stronger in the left hand. In spite of these divergent patterns between right and left hands, high correlations in 2D:4D ratios between sides are often found. These results suggest that, in spite of the conclusion by McIntyre *et al*. (2005) that '... sex differences in fingers of children *are highly* correlated with adult finger length ratios', digit ratios have the potential to change during development and do not uniquely reflect foetal exposure to sex hormones. Indeed, Gillam *et al*. (2008) concluded on the basis of cross sectional data that age, lateral asymmetry and handedness can affect 2D:4D ratios. Furthermore, digit ratios may vary across the menstrual cycle (Mayhew *et al*. 2007). Some even conclude that adult hormone levels do not relate to 2D:4D (Hönekopp *et al*. 2007), which is in direct contradiction to Manning *et al*. (1998). The current prevailing assumption is that 2D:4D ratios mainly reflect prenatal exposure to sex hormones. The many results that appear to support this view (e.g., Fink *et al*. 2003, Manning & Fink 2008, but *see* Putz *et al*. 2004) call for further study of associations between 2D:4D ratios and human characteristics affected by hormone exposure.

This paper reports results of a study that examines the relationship between 2D:4D ratio, age, BMI and a few life history traits (age of first sexual contact and number of partners) in young adults between 18 and 30 years old. This age group is of particular interest because the 2D:4D ratio appears to reach the highest value at age 17 in the study by McIntyre *et al*. (2005). Furthermore, because sexual dimorphism in 2D:4D is often stronger for the right hand (Manning 2002), I compare patterns between the sides. If 2D:4D ratios are a biologically meaningful proxy of foetal hormone exposure, presumed associations with adult hormones and its possible effects on pubertal and adult development and behaviour, it can be predicted that 2D:4D (i) is lower in males; (ii) remains sexually dimorphic in different age groups; (iii) is positively correlated with the body mass index (BMI) (because high BMI levels reflect low testosterone levels, Fink *et al*. 2003). Furthermore, we can expect that high androgen (low 2D:4D ratio) in males and high oestrogen (high 2D:4D ratio) in females respectively relate to high mating success, which here are measured as number of partners and age of first sexual contact.

Material and methods

Levels of 2D:4D were obtained from scans of hands of 51 and 48 Caucasian heterosexual men and women with an average age of 22.6 (SD = 2.66) and 22.3 (SD = 1.87) years, respectively. For each participant I measured the length of the 2nd and 4th digits from both left and right hands 3 times independently and averaged these values. None of the participants reported any previous serious injuries on either hand. I performed all measurements in ImageJ (http://rsb.info.nih.gov/ij/). I took a second set of scans during a second visit from 20 study participants. The repeatability of 2D:4D ratio was estimated by random effects ANOVA with person as random effect. Repeatabilities of the 2D:4D measurements equalled 0.97 for the left hand and 0.98 for the right hand. All individuals completed a short series of questions, from which I retained gender, age, BMI (weight/height^2), number of sexual partners and the age of first sexual con-

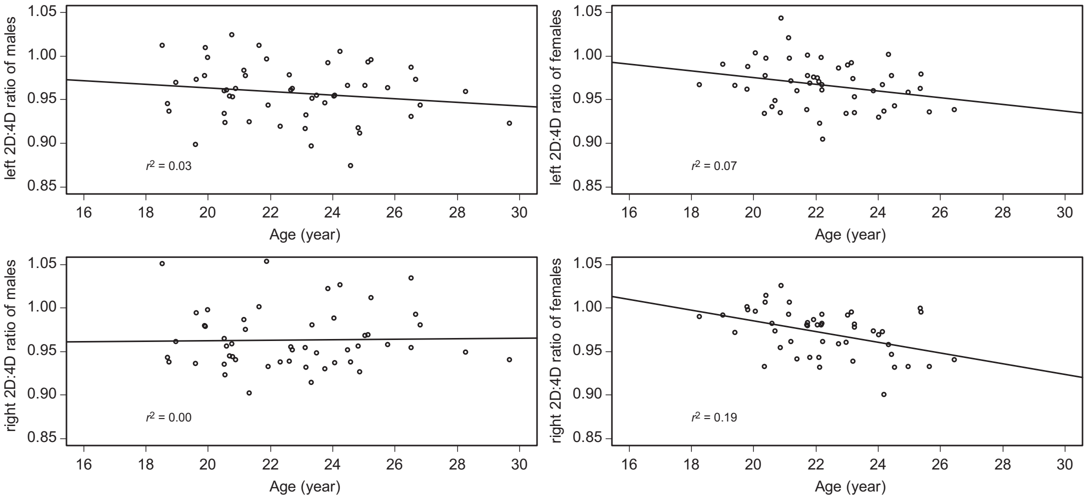

Fig. 1. Associations between age and 2D:4D ratio for the left (top graphs) and right (bottom graphs) hands and for males (left graphs) and females (right graphs).

tact. In addition to a relationship between BMI and 2D:4D ratio, I also tested for associations with weight and height (Barut *et al*. 2008). All statistical comparisons were based on linear (mixed models) performed in R (version 2.6.0). Details of model factors in the different analyses will be given in the results section.

Results

Sexual dimorphism in 2D:4D ratio and relationship with age

Although non significant, men tended to have a slightly lower 2D:4D ratio as compared with that of females [right hand: 0.954 *vs*. 0.964 (t_{97} = 1.31, p = 0.19); left hand: 0.949 *vs*. 0.959 (t_{97} = 1.48, p = 0.14); average of both hands: 0.951 *vs*. 0.962 (t_{97} = 1.53, p = 0.13)]. In order to explore associations with age and differences between sides and sexes, 2D:4D of left and right was used as dependent variable. Sex, age, hand side and all two- and three-way interactions were treated as fixed effects. Because data from both hands within individuals are not independent, individual was added as a random effect to the model. Tests of fixed effects were based on likelihood ratio tests, which compare the log-likelihoods of nested models using chi-square distributions. Although not commonly used in this area of research, this type of analysis can test for interactions and objectively compare associations between hands and sexes. There was a statistically significant three-way interaction between age, side and sex (χ^2_1 = 4.18, p = 0.04). Thus, differences in 2D:4D between males and females differed between sides and were associated differently with age. In females, 2D:4D decreased with age and this decrease was more pronounced in the right hand (r = –0.43, df = 46, p = 0.002; Fig. 1). 2D:4D ratios did not decrease with age in any other group (female: left hand: r = –0.26, df = 46, p = 0.07; male: right hand: r = 0.02, df = 49, p = 0.88; left hand: r = –0.17, df = 49, p = 0.23). For the female right hand, model predictions for the youngest person of 18 years corresponded to a 2D:4D ratio which is often found in females (0.995, 95% CI: 0.979–1.013), while for the oldest person of 26 years, the 2D:4D reflected that of a male (0.946, 95% CI: 0.928–0.963). In spite of these different patterns between left and right hand, there was still a relatively strong association between the 2D:4D ratio of both hands (Fig. 2).

Associations between 2D:4D and life history traits

A summary of associations between 2D:4D ratios and age, BMI, number of sexual partners

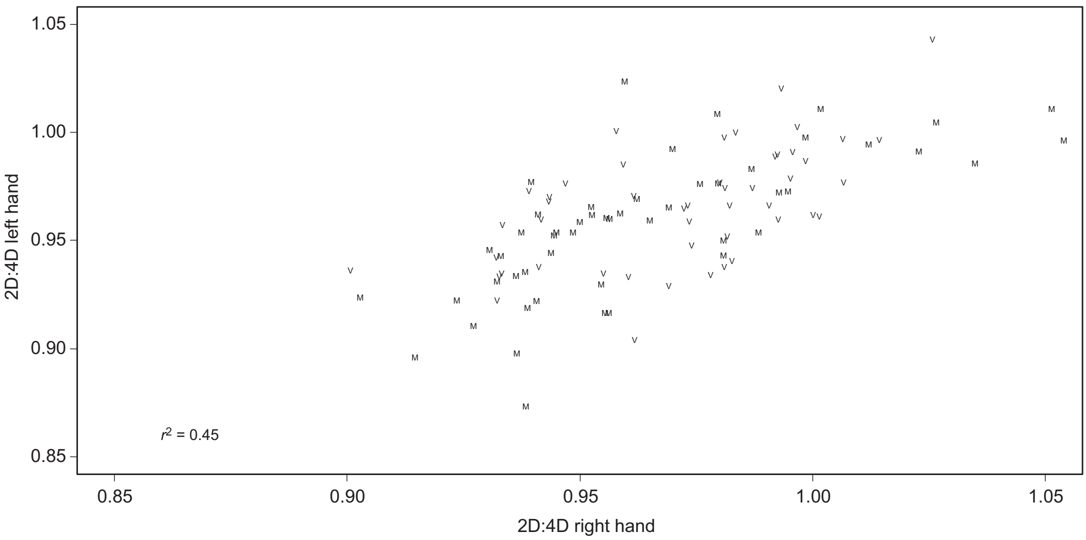

Fig. 2. Relationship between digit ratio in right and left hand for males (M) and females (F).

and age of first sexual contact are given in Table 1. The 2D:4D ratio was only significantly associated with BMI in males and this association was stronger for the right hand (Table 1). Surprisingly, the association was negative (Fig. 3): males with a higher BMI had a more masculine 2D:4D. Indeed, in a linear ANCOVA model with right hand 2D:4D ratio as dependent variable, and BMI, sex and the two way interaction as fixed effects, this interaction was statistically significant ($F_{1,95} = 7.51$, $p = 0.007$), which confirms that the association differed between males and females. This two-way interaction remained significant after adding height and height × sex to the model ($F_{1,93} = 8.30$, $p = 0.005$), suggesting that weight was mainly driving these associations with BMI, and not height as proposed in a previous study (Barut *et al.* 2008). Indeed, 2D:4D showed correlations with weight that were similar to BMI, but not with

Table 1. Correlations (*p*) between 2D:4D and aspects of human sexual behaviour (age of first sexual contact (age_first), number of partners (partners), relative number of partners per year after first sexual contact (rel_partners), body mass index (BMI), height and weight) for males and females separately. Statistically significant associations are set in boldface. Correlations significant after Bonferonni correction are indicated with an asterisk '*'.

	age_first	partners	rel_partners	BMI	height	weight
Males (*N* = 51)						
Right 2D:4D	0.14 (0.31)	–0.17 (0.23)	0.09 (0.52)	**–0.40 (0.004)***	–0.04 (0.79)	**–0.39 (0.005)***
Left 2D:4D	0.00 (0.94)	–0.20 (0.15)	0.02 (0.92)	**–0.27 (0.05)**	–0.04 (0.79)	**–0.29 (0.04)**
Age_first	–	–	0.15 (0.27)	–	–	–
Partners	**–0.62 (< 0.0001)***	–	**–0.35 (0.02)**	–	–	–
BMI	**–0.45 (0.001)***	**0.39 (0.004)***	0.02 (0.90)	–	–	–
Height	0.20 (0.16)	**–0.37 (0.008)**	**–0.35 (0.01)**	–0.21 (0.13)	–	–
Weight	–0.07 (0.62)	0.01 (0.95)	–0.02 (0.90)	**0.83 (< 0.0001)***	**0.36 (0.01)**	–
Females (*N* = 48)						
Right 2D:4D	–0.02 (0.89)	0.00 (0.95)	–0.25 (0.09)	0.13 (0.39)	0.14 (0.33)	0.12 (0.43)
Left 2D:4D	0.10 (0.48)	–0.03 (0.84)	–0.15 (0.33)	–0.07 (0.65)	0.11 (0.44)	–0.10 (0.52)
Age_first	–	–	0.21 (0.15)	–	–	–
Partners	**–0.61 (< 0.0001)***	–	**–0.60 (< 0.0001)***	–	–	–
BMI	–0.21 (0.15)	0.12 (0.42)	0.16 (0.26)	–	–	–
Height	–0.18 (0.19)	0.27 (0.06)	0.28 (0.06)	–0.03 (0.87)	–	–
Weight	–0.15 (0.30)	0.20 (0.17)	0.18 (0.21)	**0.95 (< 0.0001)***	0.28 (0.06)	–

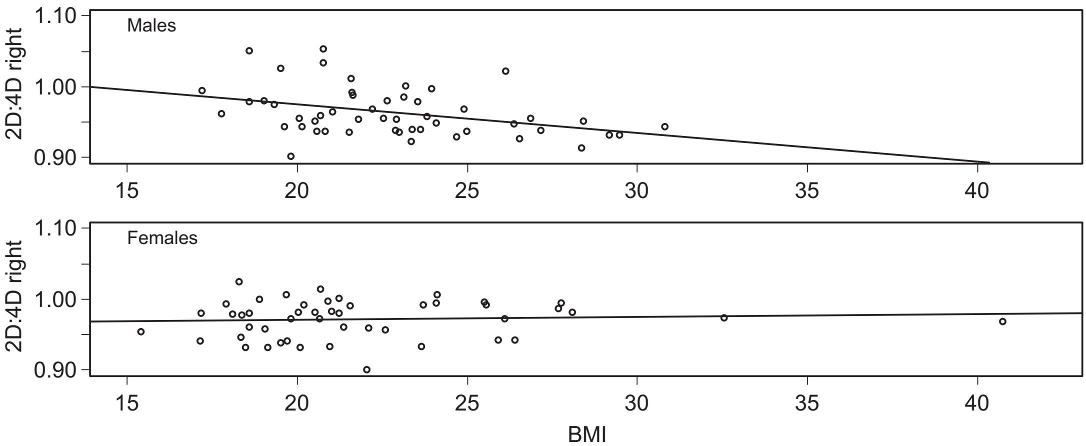

Fig. 3. Relationships between Body Mass Index and digit ratio of the right hand for males and females. The association differed significantly between both sexes (see text for details).

height (Table 1). Correlations between weight and 2D:4D also differed significantly between males and females (weight × sex interaction: $F_{1,95} = 8.26, p = 0.005$). Males with a higher BMI also appeared to engage in a sexual relationship earlier (Table 1). The association between BMI and number of partners in males appeared to be driven by the fact that men with higher BMI had their first sexual relationship at a younger age because the relative number of partners per year since the first sexual contact (number of partners divided by the number of years since the first sexual contact) did not correlate with BMI (Table 1).

Discussion

The 2D:4D ratio tended to be smaller on average in males as compared with that in females. However, associations with individual covariates were not consistent with *a priori* expectations under the assumption that 2D:4D ratios reflect foetal hormone exposure as well as serve as a proxy for hormone levels later in life and/or their effects on development, behaviour and life history. Firstly, there was a significant decrease in 2D:4D ratios on the right hand of females. This association was strong since this right hand 2D:4D ratio varied from a typically high 'feminine' one for the younger females, to a typically low 'masculine' one in the somewhat older women. Strikingly, the age range in these females was very narrow (18-26 years). Because this is a cross-sectional study, it cannot be ruled out that other variables co-varied with age and act as a confounding factor. However, no indications of associations between 2D:4D ratio and life history traits were found, although statistical power was probably low. Consistent with Putz *et al*.'s (2004) findings, I did not detect associations between digit ratios and number of partners. This result is also similar to the findings of Manning and Fink (2008), who used a sociosexual inventory which in turn is likely to be associated with number of partners. The decrease in 2D:4D ratios with increasing age in females is unlikely to be due to differences in menstrual cycle or use of oral contraception, as changes within the menstrual cycle or effects of oral contraception are much smaller than the changes with age reported here (Mayhew *et al*. 2007). Thus, the lower digit ratios in females of somewhat older ages are among the strongest differences with age ever reported.

In males, there appeared to be a negative association between 2D:4D and both BMI and weight in both hands. Thus, heavier men with a higher BMI and some with an overweight BMI of > 25, had a lower, more 'masculine', 2D:4D ratio. As indicated above, this is also contrary to expectations if lower 2D:4D ratios indicate higher pubertal or adult testosterone levels as well. Indeed, because high BMI reflects low testosterone levels, it has been hypothesised to relate positively to 2D:4D ratios. Later sexual maturity with a higher BMI suggests lower testosterone levels in these men (Wang 2002). A negative association between BMI and testosterone levels may also explain fertility problems in overweight men (e.g. Jensen *et al*. 2004). However, the younger age of first sexual contact for males with high BMI in this study is not in agreement with the idea that higher BMI would be associated with lower testosterone in these men. It is important to note that I did not measure body fat. Thus, the high BMI that I found in males might be attributed to overall muscle mass. This would invalidate the *a priori* expectations because a high BMI would not reflect low testosterone levels.

The use of scans or photocopies has been suggested as being a possible problem in measuring digit ratios because it may bias estimates. Some studies (e.g., Manning & Fink 2008) advocate the use of direct measurements because they are unbiased. In this study, the use of scans may have resulted in somewhat lower average 2D:4D ratios as compared with those reported in other studies (e.g., Manning *et al*. 1998). However, it seems unlikely that distortions due to the use of scans would artificially have caused the significant interactions observed in this study. For example, the significant three-way interaction between age, side and sex on 2D:4D ratios could only emerge artificially due to the use of scans if women of different age showed different distortions between left and right hand scans. In sum, it is unlikely that the statistically significant interactions reported here would have emerged as a by-product of our use of scans (*see* also Gillam *et al*. 2008 for similar arguments).

In conclusion, this preliminary study presents some patterns that were in contrast to *a priori* expectations. Although the numbers in this study are too small to explain why this may be the case, this study indicates that 2D:4D ratios might not ubiquitously relate to all adult characteristics that have been influenced by prenatal hormone exposure. Thus, the use of 2D:4D as predictor of particular life history traits appears to require further study. Negative or unexpected results as presented here cannot refute the vast amount of data that support the link between 2D:4D ratio and other aspects of human sexual behaviour and life history that are presumably related to (foetal) hormone levels (e.g., Manning & Fink 2008). However, larger studies are necessary to test the stability of 2D:4D ratios across different ages, and to confirm the unexpected associations with, for example, BMI in males. Patterns like the ones shown here could suggest that simple morphological features like the ratio of the length of two digits do not necessarily capture all aspects of individual developmental history and its effects on components sexual behaviour in any situation. More research will be required to gain insights into which other factors may affect human sexual behaviour as well and how these could potentially interfere with expected associations with 2D:4D ratios.

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