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How well does second-to-fourth-digit ratio in hands correlate with other indications of masculinity in males?

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Low second-to-fourth-digit (2D : 4D) ratios in hands have previously been used as a proxy for prenatal testosterone levels. Moreover, it has recently been suggested that prenatal testosterone levels may direct future masculinization. If true, 2D : 4D ratios should negatively correlate with traits in males that are developed and maintained by testosterone at puberty such as facial and body masculinity and testes volume. We failed to find significant correlations between 2D : 4D ratios and these traits.

Keywords: second-to-fourth-digit ratios; masculinity; testosterone

1. INTRODUCTION

Numerous studies have found that the second-to-fourth-digit (2D : 4D) ratio in hands is lower in males (less than 1) than females (close to 1) (Manning *et al.* 1998; McFadden & Shubel 2002; Peters *et al.* 2002; Coolican & Peters 2003), a pattern that has been replicated across different cultures (Manning *et al.* 2000). 2D : 4D ratios are fixed early in development (Manning *et al.* 1998; for reviews see Manning & Bundred 2000; Manning 2002). By examining digit ratios in individuals with congential adrenal hyperplasia and control individuals, Brown *et al.* (2002) and Ökten *et al.* (2002) confirmed that 2D : 4D sex differences are as a result of differences in prenatal androgen levels, with those exposed to high levels developing low 2D : 4D ratios. Moreover, Manning *et al.* (2003) show that allelic variation at the androgen receptor gene is associated with variation in 2D : 4D ratios; alleles with greater numbers of CAG repeats associated with lower prenatal sensitivity to testosterone and higher 2D : 4D ratios.

Previous studies found a relationship between 2D : 4D ratios and traits that depend on pubertal and adult testosterone levels. For example, males with lower 2D : 4D ratios self-reported higher levels of competitive sport than males with higher 2D : 4D ratios (Manning & Taylor 2001). Many studies that found an association between 2D : 4D ratios and testosterone-dependent traits found such a relationship in the right but not the left hand (reviewed in Manning 2002). For example right, but not left, 2D : 4D ratios were significantly negatively associated with waist-to-hip ratios in a combined sample of English and Jamaican women (Manning *et al.* 2000) and positively associated with running speed in men (Manning 2002). Furthermore, right 2D : 4D ratio minus left 2D : 4D ratio (D_{r-l}) was also associated with running speed such that men with lower right than left 2D : 4D ratios achieved significantly faster running speeds than men with lower left than right 2D : 4D ratios (Manning 2002). However, some studies failed to find an association between 2D : 4D ratios and testosterone-dependent traits even when right and left hands were examined separately. For example, Firman *et al.* (2003) failed to find an association between semen quality and right or left 2D : 4D ratios in men, a relationship previously reported by Manning *et al.* (1998).

Recently, Neave *et al.* (2003) argued that prenatal testosterone levels may generally set the developmental pathway of an individual to higher or lower degrees of masculinization. On this view, if 2D : 4D ratios are an accurate reflection of prenatal testosterone, then they should be correlated with pubertal testosterone-dependent traits in males. Structural differences in male and female faces result from different amounts of the sex hormones. High testosterone levels result in the growth of the lower face, jaw, cheekbones, brow ridges and the protrusion of the face's centre between the brow and base of the nose, whereas oestrogen inhibits this growth (Swaddle & Reierson 2002; see also Dabbs (2000), Little *et al.* (2002), Thornhill & Gangestad (1996) and Zimmer (2001) for reviews). High oestrogen levels result in an increase in lip size (reviewed in Thornhill & Gangestad 1996). Testosterone in males causes muscles to increase in size and an increase in fat-free body mass (Bhasin *et al.* 1996). Oestrogen stimulates the accumulation of fat in the gluteofemoral region whereas testosterone inhibits this and stimulates the accumulation of fat in the abdominal region, thus giving male and female bodies a distinctive masculine and feminine appearance, respectively (reviewed in Barber 1995).

Neave *et al.* (2003) examined the relationship between 2D : 4D ratios in 48 adult males and opposite-sex rated facial masculinity, facial dominance and facial attractiveness. They found weak but significant negative correlations between 2D : 4D ratios and both masculinity and dominance, supporting their argument that high prenatal testosterone levels serve to 'organize' male facial features to subsequently reflect dominance and masculine characteristics at puberty. Neave *et al.* predicted that if masculinity and dominance are associated with attractiveness then 2D : 4D ratios should also negatively correlate with attractiveness, but this was not found. They did find correlations between dominance and masculinity.

Our aim was to replicate the relationship between 2D : 4D ratios and masculine traits using objective measures of facial masculinity and face ratings, as well as body masculinity ratings and combined testes volume. Additionally, we used a larger sample size than Neave *et al.* (2003) and, unlike Neave *et al.*, we also collected 2D and 4D measures in females to confirm that 2D : 4D ratios were sexually dimorphic in our sample. If 2D : 4D ratios can be used as a proxy for prenatal testosterone levels that organize masculine development as claimed by Neave *et al.* (2003), then 2D : 4D should negatively correlate with measured and rated facial masculinity, rated body masculinity and combined testes volume.

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Table 1. Correlations between average 2D : 4D ratios, and rated body masculinity, rated facial masculinity, a masculinity factor score (from Koehler *et al.* 2004) and combined testes volume.
(Figures in bold show correlations with $p \leqslant 0.05$. * Significant after Bonferroni corrections for multiple comparisons ($N = 13$, critical $p = 0.0038$).)

	average right D2 : D4	body masculinity rated by males	body masculinity rated by females	face masculinity rated by males	face masculinity rated by females	factor score	combined testes volume
average left D2 : D4	**0.34*** **$p \leqslant 0.001$** **($N = 94$)**	−0.06 $p \leqslant 0.563$ ($N = 93$)	0.01 $p \leqslant 0.933$ ($N = 93$)	0.19 $p \leqslant 0.081$ ($N = 88$)	0.15 $p \leqslant 0.168$ ($N = 88$)	0.12 $p \leqslant 0.248$ ($N = 88$)	−0.12 $p \leqslant 0.427$ ($N = 43$)
average right D2 : D4		−0.03 $p \leqslant 0.749$ ($N = 93$)	0.11 $p \leqslant 0.312$ ($N = 93$)	0.11 $p \leqslant 0.301$ ($N = 88$)	0.03 $p \leqslant 0.766$ ($N = 88$)	−0.01 $p \leqslant 0.912$ ($N = 88$)	−0.10 $p \leqslant 0.527$ ($N = 43$)

2. VARIABLES

(a) *Second-to-fourth-digit ratio*

Digital callipers were used to measure the distance between the tip of the finger and the ventral proximal crease of the second digit and the fourth digit on two photocopies of left and right hands for 94 males with a mean age of 23.7 years (s.d. = 5.8, range of 18–46 years) and 100 females with a mean age of 25.3 years (s.d. = 6.3, range of 17–51 years) recruited from the University of Western Australia. All were heterosexual. A second experimenter measured the length of the second digit and the fourth digit on replicate 1 left hands for a subset of 98 posers (48 males) to assess measurement reliability.

(b) *Face and body ratings*

Opposite-sex masculinity ratings were available from Koehler *et al.* (2004) for 88 (clean shaven) of the male faces. The ratings were made from photographs of the males displaying neutral expressions. We obtained same-sex masculinity ratings for these faces from 17 males, five of whom rated only 47 male faces, five of whom rated the remaining 41 faces, and seven of whom rated all male faces, using the same procedure as Koehler *et al.* (2004).

Body masculinity ratings were obtained for 93 males. All ratings were made from frontal view photographs (without head), showing posers wearing black shorts and a T-shirt standing in a relaxed pose with feet together and arms by their sides. The same raters that rated posers' faces also rated posers' bodies. Half the female and male raters rated all the faces followed by all the bodies whereas the remaining participants received the reverse order with each rater receiving a randomized order of stimuli. Inter-rater reliability was good (opposite-sex rating for faces: $\alpha = 0.83$–0.83; same-sex rating for faces: $\alpha = 0.62$–0.75; opposite-sex rating for bodies: $\alpha = 0.88$–0.90; same-sex rating for bodies: $\alpha = 0.73$–0.76).

(c) *Face measurements*

Area measurements of the chin and face (below the pupils) and linear measurements of mean eyebrow height, cheekbone width, nostril width and lower face length were available from Koehler *et al.* (2004). These measures were used to create a masculinity factor score (see Koehler *et al.* 2004).

(d) *Combined testes volume*

All males were supplied with callipers and asked to return a measure of testes length and width. Forty-three males returned these measures. Testis volume was estimated as the volume of an ovoid, and left and right volumes summed to provide a combined testes volume (cm^3). Self-reported measures of testis size are highly repeatable and their magnitude and variance are consistent with medically assessed values (left: $R = 0.980$; right: $R = 0.972$; Simmons *et al.* 2004).

Descriptive statistics for all variables can be found in table 2 in electronic Appendix A.

3. RESULTS AND DISCUSSION

A very high reliability of measuring digits was obtained between experimenters (males' 2D: $r = 0.97$, $p \leqslant 0.001$; males' 4D: $r = 0.98$, $p \leqslant 0.001$; females' 2D: $r = 0.91$, $p \leqslant 0.001$; females' 4D: $r = 0.94$, $p \leqslant 0.001$). All 2D : 4D ratio measurements had significant repeatabilities (males' left: $F_{1,93} = 3.27$, $p \leqslant 0.0001$, $R = 0.694$; males' right: $F_{1,93} = 5.05$, $p \leqslant 0.0001$, $R = 0.802$; females' left: $F_{1,99} = 8.70$, $p \leqslant 0.0001$, $R = 0.885$; females' right: $F_{1,99} = 6.89$, $p \leqslant 0.0001$, $R = 0.855$). An average 2D : 4D ratio of replicate 1 and replicate 2 was calculated separately for each poser's hand. Consistent with previous studies, males had significantly lower average 2D : 4D ratios than females for both the left (males: mean (M) = 0.96, s.d. = 0.03; females: $M = 0.97$, s.d. = 0.03, $t_{192} = 3.47$, $p \leqslant 0.001$), and right hands (males: $M = 0.96$, s.d. = 0.03; females: $M = 0.98$, s.d. = 0.04, $t_{192} = 3.29$, $p \leqslant 0.001$). These values were in the range of those reported previously (e.g. Manning *et al.* 1998; Peters *et al.* 2002; Coolican & Peters 2003).

Pearson product-moment correlations were used to examine the relationships between 2D : 4D ratios (calculated separately for the left and right hand) and rated body masculinity (separate for male and female raters), rated facial masculinity (separate for male and female raters), the masculinity factor score and combined testes volume to determine how well 2D : 4D ratios correlate with other masculine traits in males.

Left and right 2D : 4D ratios were significantly correlated even after Bonferroni correction for multiple comparisons. However, the 2D : 4D ratios did not correlate significantly with any of our measures of masculinity (see table 1).

We further explored the relationships between 2D : 4D and rated facial masculinity by examining how well D_{r-l} correlated with ratings of facial masculinity because previous research has shown that some testosterone-dependent traits correlated significantly with right 2D : 4D and D_{r-l}, but not left 2D : 4D ratios (Manning 2002). However, using D_{r-l} we still failed to find an association between 2D : 4D ratios and opposite-sex rated facial masculinity, $r = 0.09$, $p \leqslant 0.384$, and same-sex rated facial masculinity, $r = 0.05$, $p \leqslant 0.609$, (see figures 1 and 2 in electronic Appendix B).

We were therefore unable to replicate Neave *et al.*'s (2003) finding of a relationship between 2D : 4D ratios and rated facial masculinity in males. Nor did we find a relationship between 2D : 4D ratios and measured facial masculinity or rated body masculinity. We can draw two possible conclusions from our results. First, it may be true that prenatal testosterone levels are important in determining future masculinization, but the 2D : 4D ratio is not a reliable indicator of these testosterone levels. Alternatively, prenatal testosterone levels may indeed determine the 2D : 4D ratio but the levels of testosterone experienced prenatally are not well correlated with those experienced during puberty when secondary sexual features develop. In this regard it is worth noting that adult testosterone levels show circadian and circannual variations (Reinberg & Lagoguey 1978; Andersson *et al.* 2003) and that Neave *et al.* found no relationship between 2D : 4D ratios and levels of circulating testosterone. These conflicting findings emphasis the importance of replication in studies of evolution and ecology (Palmer 2000).

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