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2nd to 4th Digit Ratio and Offspring Sex Ratio

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There is evidence that the ratio of the length of the 2nd and 4th digit (2D : 4D) is negatively related to prenatal and adult concentrations of testosterone. It has also been reported that high levels of testosterone at conception in both fathers and mothers are associated with an increased sex ratio (proportion of males at birth). It follows from these observations that low values of 2D : 4D may be related to high sex ratio. We present evidence from three populations (English, Spanish and Jamaican) that 2D : 4D is negatively related to sex ratio, independent of the sex and ethnicity of the parents.

Introduction

It is likely that the ratio of the length of the 2nd digit (the index finger) to the 4th digit (the ring finger), or 2D : 4D, is negatively associated with prenatal and adult testosterone concentrations because: (a) males tend to have lower values of 2D : 4D (i.e. longer ring fingers relative to their index fingers) than females (Phelps, 1952; Manning *et al.*, 1998), (b) digit ratios may be determined as early as the 14 week of fetal life (Garn *et al.*, 1975), and 2D : 4D is sexually dimorphic as early as 2 years and appears to be unchanged at puberty (Manning *et al.*, 1998), (c) the ratio of waist-to-hip circumference (WHR) in women is positively correlated with serum levels of testosterone and negatively with women's 2D : 4D (Manning *et al.*, 2000), (d) the WHR of mothers is negatively related to the 2D : 4D of their children (Manning *et al.*, 1999) and (e) a negative association between adult male 2D : 4D and total serum testosterone has been reported (Manning *et al.*, 1998).

James (1996, 1997, 2000) has presented evidence that high testosterone, in both male and female parents, at conception is associated with an increased sex ratio (proportion of males at birth). If this is so, the 2D : 4D ratio of adults may be negatively related to the sex ratio of their children (James, 2001). We have tested this prediction in samples from English, Spanish and Jamaican populations.

Methods

Digit length of the right and the left hand was measured from the basal crease proximal to the palm to the tip of the finger using vernier callipers measuring to 0.01 mm (see Manning *et al.*, 1998). Participants who reported broken 2nd or 4th digits were excluded from the study,

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as were subjects with arthritis and similar conditions in the fingers. In two samples (English and Spanish), digits were measured directly from the hand, and in one sample (Jamaican), from photocopies of the hand. It has been shown that 2D : 4D ratios calculated from measurements of the digits and from measurements of photocopies do not show significant differences (Manning *et al.*, 2000). All subjects reported the number and sex of their putative biological children.

The English sample was recruited in the Liverpool area from adult education students and groups of elderly retired individuals. There were 225 participants (98 males and 127 females), all over the age of 30 years. Digit length was measured from the right and the left hand and the 2nd and 4th digits were measured twice for 100 hands from 100 subjects.

There were 85 subjects in the Spanish sample (40 males and 45 females) recruited from the Granada area. All participants were over 30 years of age. The 2nd and 4th digits were measured on both right and left hands and the digits of 85 hands were measured twice.

The Jamaican sample was recruited from the Southfield area in the parish of St Elizabeth and was part of the Jamaican Symmetry Project, a long-term study of developmental stability (Trivers *et al.*, 1999). There were 146 participants over the age of 30 years (54 males and 92 females). Digits were measured on both right and left hands and 30 hands were measured twice.

Results

Repeatabilities (r_1) or intra-class correlation coefficients of 2D : 4D were calculated using model II single-factor ANOVA (Zar, 1984):

$$r_1 = (\text{groups}\, MS - \text{error}\, MS)/(\text{groups}\, MS + \text{error}\, MS),$$

where MS is the mean squares. The values of r_1 were high (English sample 0.89, Spanish 0.98, Jamaican 0.90). Repeated measurements for ANOVA analyses showed that in all three samples, the ratio (F) of differences between subjects to measurement error was significant. This indicated that our measurement error was significantly lower than real between-subject differences in 2D : 4D (English sample $F = 18.27$, $p = 0.0001$; Spanish $F = 87.51$, $p = 0.0001$; Jamaican $F = 27.72$, $p = 0.0001$). We concluded that our measurements of 2D : 4D reflected real differences between subjects.

The mean 2D : 4D ratios by country and by sex are given in Table 1. By considering the total sample, we found, as in earlier studies, that there were lower mean 2D : 4D ratios in male hands compared to females but the difference was not significant (right hand: males $= 0.97 \pm 0.04$, females $= 0.98 \pm 0.04$, $t = 1.75$, $p = 0.08$; left hand: males $= 0.97 \pm 0.04$, females $= 0.97 \pm 0.04$, $t = 0.75$, $p = 0.46$). There were significant ethnic differences in mean 2D : 4D with the English (right $= 0.98 \pm 0.04$, left $= 0.99$) and Spanish (right $= 0.99 \pm 0.04$, left $= 0.98 \pm 0.04$) subjects showing higher 2D : 4D values than the Jamaican participants (right $= 0.95 \pm 0.03$, left $= 0.95 \pm 0.04$; ANOVA, right hand $F_{2,454} = 51.40$, $p = 0.0001$, left $F_{2,454} = 48.29$, $p = 0.0001$). A two-factor ANOVA showed significant sex and ethnicity differences in 2D : 4D in the right hand (sex (A) $F_{1,451} = 3.97$, $p = 0.047$; ethnicity (B) $F_{2,451} = 52.07$, $p = 0.0001$, AB $F_{2,451} = 1.32$, $p = 0.27$), and significant ethnicity differences in the left (sex (A) $F_{1,451} = 1.55$, $p = 0.21$; ethnicity (B) $F_{2,451} = 46.43$, $p = 0.0001$, AB $F_{2,451} = 0.11$, $p = 0.90$). An inspection of Table 1 shows that the sex differences in the 2D : 4D ratio are in the English and Jamaican samples.

TABLE 1

	Mean 2D : 4D right	Mean 2D : 4D left
England		
Males	0.98 ± 0.04	0.98 ± 0.04
Females	0.99 ± 0.04	0.99 ± 0.04
Spain		
Males	0.99 ± 0.04	0.98 ± 0.04
Females	0.99 ± 0.04	0.98 ± 0.03
Jamaica		
Males	0.94 ± 0.03	0.94 ± 0.04
Females	0.95 ± 0.03	0.95 ± 0.04

In the total sample, the mean number of children was 2.64 ± 1.45. There were significant between-sample differences in the mean number of offspring with lowest numbers in the English sample (2.28 ± 1.10), intermediate in the Spanish sample (2.61 ± 1.51) and highest in the Jamaican participants (3.22 ± 1.79, ANOVA $F_{2,459} = 19.12$, $p = 0.0001$). We calculated the sex ratio (number of sons/total number of children). Proportions or percentages form a binomial rather than a normal distribution. This means that deviations from normality are greatest for small (0–30%) and large values (70–100%). The distribution will become near normal if the square root of each proportion is transformed to its arcsine (Zar, 1984). We therefore arcsine transformed the sex ratio.

As predicted there was a negative relationship between 2D : 4D and arcsine-transformed sex ratio. This relationship was significant with one-tailed tests (regression analysis: right hand $b = -63.40$, $F = 3.27$, $p = 0.035$; left hand $b = -57.07$, $F = 2.82$, $p = 0.045$). After controlling for multiple tests the associations were non-significant (Bonferroni adjustment, right hand $p = 0.07$, left hand $p = 0.09$)

Sex and ethnicity were associated with 2D : 4D. We therefore controlled for their influence using simultaneous multiple regression tests with independent variables 2D : 4D, sex (dummy-coded male = 1, female = 2) and ethnicity (we constructed two dummy-coded variables: English = 1, all others = 2; Spanish = 1, all others = 2) and dependent variable arcsine transformed 2D : 4D. The relationship between 2D : 4D and sex ratio remained negative and significant (right hand $b = -87.72$, $t = 2.23$, $p = 0.01$, one-tailed; left hand $b = -74.41$, $t = 1.98$, $p = 0.02$, one-tailed). The relationships remained significant after Bonferroni adjustment (right hand $p = 0.02$, left hand $p = 0.04$).

Discussion

We have found negative relationships between sex ratio (proportion of males) and 2D : 4D ratio. The effect was independent of the sex and the ethnicity of the parent. This means that low 2D : 4D individuals are more likely to have male offspring than subjects with high 2D : 4D.

Our finding is consistent with the models of James (1996, 1997, 2000) who has pointed out that (a) men who are exposed to chemicals which lower testosterone, e.g. borates and dioxins, have low sex ratio in their children and (b) *HLA* genes may code for gonadal size and therefore androgen concentrations. Subjects with *HLA*-related conditions correlated with low testosterone (e.g. rheumatoid arthritis, RA) tend to have low sex ratios in their families. Reiter's syndrome (RS) and ankylosing spondylitis (AS) on the other hand are associated with *HLA* B27, high androgens and high sex ratios. It may be expected that 2D : 4D ratios in subjects who had been exposed to borates and dioxins in utero will be high. In patients with *HLA*-related conditions, RA should be associated with high 2D : 4D, and RS and AS with low 2D : 4D ratios.

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