Sexually dimorphic traits (digit ratio, body height, systemizing–empathizing scores) and gender segregation between occupations: Evidence from the BBC internet study

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1. Introduction

Some occupations have an excess of women and others an excess of men. Thus the proportion of women per occupation (PW) may vary considerably from male-typical occupations such as engineering to female-typical occupations such as homemaker. Gender segregation between occupations may have its roots in social factors that lead to discrimination or absence of female role models, and this may be one influence that leads to variation in PW (Petersen & Morgan, 1995).

In the last two decades there has been movement in the US and UK towards a more even sex ratio (PW = 0.5) in many occupations (Weeden, 1998; Wells, 1999), but in some such as the female-dominated caring professions and in male-dominated engineering there has been little change (Govier, 2003). This situation may in part arise because of the influences that determine women’s individual choices. For example many women are obliged to take time out to have children. Consequently they may choose an occupation that has little or no financial penalty for breaks in employment, that is flexible in the provision and accommodation of maternity leave, one in which the work is not so physically demanding as to affect pregnancy, or even one in which injury is unlikely to affect their role of caregiver to children. Such hypotheses have been tested, but with mixed results (DeLeire & Levy, 2004; England, 1982, 1985; Polachek, 1981, 1985).

In this present study we stress a biological explanation by arguing that the occupational sex segregation could arise because men and women differ biologically, even prenatally. Testosterone (T) is a sex steroid hormone and males produce twice as much as females, even in the womb. Prenatal T (PT) has been shown in animal research to cause organisational changes in the brain while adult T (AT) may have activational effects, such that high PT is associated with higher systemising (Auyeung et al., 2006) and lower empathizing ability (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004; Chapman et al., 2006). Both PT and AT influence an individual’s ‘brainsex’ and the resulting variation in brain masculinization/feminization could, at least in part, explain gender segregation across occupations (Baron-Cohen, 2003; Govier, 2003). Here we test this model by relating PW per occupation to (i) the ratio of the length of the 2nd and 4th digits (2D:4D), a putative correlate of PT, (ii) height, a possible correlate of AT, and (iii) a measure of the relative strength of systemizing and empathizing (systemizing–empathizing scores), a putative correlate of PT and AT.

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Digit ratio shows sex differences such that males have, on average, lower 2D:4D ratios than females. This sexual dimorphism is highly conserved and is found not only in humans but throughout the primates (Manning, 2002, 2008; Manning, Scott, Wilson, & Lewis-Jones, 1998; Nelson & Shultz, 2010). In humans it has been suggested that 2D:4D, and particularly right hand 2D:4D and the difference of right minus left hand 2D:4D (Dr-I), are negatively related to PT (Manning, 2002; Manning et al., 1998). Across populations both 2D:4D and Dr-I are sexually dimorphic (Manning, Churchill, & Peters, 2007; Manning, Stewart, Bundred, & Trivers, 2004). The sex difference is seen in young children (Manning et al., 2004), arises in utero as early as nine weeks (Galits, Ten Broek, Van Dongen, & Wijnjaendts, 2010; Malas, Dogan, Evcil, & Desdicoglu, 2006), and the strength of the sexual dimorphism in infants is strongly related to the sex difference in adults (McIntyre, Elliot, Lieberman, Demerath, and Towne, 2005; Trivers, Manning, & Jacobson, 2006). Children with congenital adrenal hyperplasia, a condition in which high PT is produced, have lower 2D:4D than typical controls (Brown, Hines, Fane, & Breedlove, 2002; Ciumas, Linden Hirschberg, & Savic, 2009; Okten, Kalyoncu, & Yaris, 2002; but see Buck, Williams, Hughes, & Acerini, 2003). Right hand 2D:4D and Dr-I are positively correlated with complete or partial T insensitivity as determined from the structure of the androgen receptor gene (Berenbaum, Bryk, Nowak, Quigley, & Moffat, 2009; Manning, Bundred, Newton, & Flanagan, 2003) and right hand 2D:4D was found to be negatively correlated with foetal testosterone:oestradiol ratios obtained from amniocentesis (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004).

With regard to AT, body height is strongly sexually dimorphic across all human groups such that males are on average taller than females (Gray & Wolfe, 1980). The sexual dimorphism in height is not strongly developed until puberty and is largely dependent on growth of the long bones (Antoszewska & Wolainski, 1992). It is known that androgen receptors are present in osteoblasts and androgen is metabolised in bone (Lorentzontz, Swanson, Andersson, Mellström, & Ohlsson, 2005). Furthermore, observations in androgen-resistant animals show the sex differences in bone are dependent on functional androgen receptors (Vanderschuren & Bouillon, 1995).

Finally, men, on average, score higher than women in understanding and building systems, while women are better able to identify other people’s emotions than are men. Thus men score higher on the Systemizing Quotient (SQ) and women score higher on the Empathizing Quotient (EQ) (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003) and the same pattern of sex differences is seen on the child versions of these psychological measures (Auyeung et al., 2009). There is evidence that PT (as measured from amniotic fluid) is positively related to systemizing (Auyeung et al., 2006) and negatively related to empathizing (Chapman et al., 2006; Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006).

Based on the reported associations of PT, 2D:4D and SQ–EQ and AT and body height, we examined the relationship between these sexually dimorphic traits and PW across a number of occupations in participants in a large internet sample. Our prediction was that measures of PT and AT would be negatively correlated with PW. With regard to our correlates of T this would mean that right hand 2D:4D (but not left hand 2D:4D) and Dr-I would be positively correlated with PW, while body height and SQ–EQ would be negatively related to PW.

2. Methods

Participants were drawn from a large Internet survey (the BBC Internet study) of cognitive and behavioural sex differences, hosted by the BBC Science and Nature Website. Details of the study and patterns of 2D:4D within the study are given in Reimers (2007) and Manning et al. (2007), respectively. Data were collected between January and May 2005. Briefly, the study took 30–40 min to complete, and comprised questions about demographics, personality, sexuality and sexual behaviour, social attitudes and behaviours, along with cognitive tests and physical characteristics such as the 2D:4D ratio. There were six blocks, taking between 3 and 6 min each to complete. Participants completed the blocks in sequence and were able to stop and return to the study at any point later.

The first questions in the study were gender (male/female) and age (0–99) for which a value had to be entered in order to continue. Responses to all other questions were optional. Occupation and ethnicity appeared on the first page with gender and age, both with dropdown menus, from which participants could choose one of 25 categories for occupation and one of seven categories for ethnicity (Asian/Asian British, Black/Black British, Black other, Chinese, Middle/Near Eastern, Mixed ethnic, White).

In the second part participants provided self-measured finger lengths following the methodology of Manning et al. (1998); see also Caswell and Manning (2009). After viewing a diagram of the hand, they were given instructions as to how to measure their index finger and ring finger on the palm-side of the right and left hand. The participants were asked to measure finger lengths with a ruler and to report lengths to the nearest millimetre using drop-down menus, with values between 10 and 100 mm in 1 mm increments (Reimers, 2007). Participants were also asked to report their body height.

In the third part there were 10 questions selected from the full EQ and ten from the full SQ (Baron-Cohen et al., 2003). The selected questions had the highest sex difference in the control data reported in Wheelwright et al. (2006). The scoring options were from left to right: definitely agree (DA), slightly agree (SA), slightly disagree (SD), and definitely disagree (DD). This was scored positively or negatively (positively: DA and SA = 0, SD = 1, DD = 2). An SQ and EQ score was calculated by summing across the 10 questions. Full details of the items and the scoring were given in Manning, Baron-Cohen, Wheelwright, and Fink (2010).

Web studies often attract a large sample. However, there are disadvantages. Participants in Web studies usually have higher levels of education than non-participants and this was the case for the Study with high proportions of participants reporting they had post-graduate degrees (13.5%) or had attended a University (35.5%) (Reimers, 2007). Inaccurate self-measurement may also be of concern. However in the case of the Study, tests of consistency of 2D:4D with that of experimenter-measured studies gave similar results (e.g., in the sex-dependent and ethnicity-dependent patterns of 2D:4D; Manning et al., 2007).

3. Results

There were 255,116 participants who completed the entire study of whom 47.3% were female. White participants made up the greatest proportion (84.3%), followed by Asian (6.3%), mixed ethnicity (3.9%), Chinese (2.2%), Middle/Near Eastern (1.2%), Black/Black British (0.8%), Black (0.8%). The analysis was restricted to respondents who were 18 years and older. Inspection of the 2D:4D data showed extreme values varying from 0 to 10. We excluded such outliers by considering a range from 0.80 to 1.20, as recommended from a comparison of self- and experimenter-measured 2D:4D (Caswell & Manning, 2009). There were a total of 199,021 participants (89,506 women) available with occupational choices. The occupations are arranged in ascending order of PW in Table 1. PW varied from 17% for male-dominated Engineering/
R&D to 94% for the female-dominated Homemaker category. Means for male and female digit ratios (for brevity we give Dr–l only), height and SQ–EQ are also given in Table 1.

A comparison of male/female means within occupations showed the expected sex differences (paired t-tests females \( [x] \) – males \( [y] \)). Considering 2D:4D, there were lower values in males compared to females (right hand 2D:4D \( x \sim y \sim 0.01 \), \( t = 19.98, p < 0.0001 \): left hand 2D:4D \( x \sim y \sim 0.007 \), \( t = 13.88, p < 0.0001 \): Dr–l \( x \sim y \sim 0.002 \), \( t = 7.18, p < 0.0001 \)). Considering body height, women were shorter than men \( x \sim y \sim -0.14 \), \( t = 180.09, p < 0.0001 \). Finally, considering SQ–EQ, this was higher for males \( x \sim y \sim -6.85 \), \( t = 63.81, p < 0.0001 \).

Three occupation categories were not informative ('Unemployed', 'Retired', and 'Student') since these contained individuals who might have worked in any occupation. We therefore removed these three categories from the analysis, and considered the participants in the remaining 22 occupations. With very large samples even very weak effects can be significant. Therefore, we used mean digit ratios, height and SQ–EQ scores per occupation and sex in the analyses. Thus the relationships had a sample size of 22 and significant correlations would have to have large effect sizes.

There were positive associations between digit ratios and PW, and negative associations between height or SQ–EQ and PW, and when we found these we used one-tailed significance tests. The correlations for digit ratios were stronger for women, with significant associations between right hand 2D:4D and Dr–l (but not left hand 2D:4D) and PW (Fig. 1a and b). There were no significant correlations between 2D:4D and PW for men. The relationships between body height and PW in men and women were negative and stronger than those for digit ratios (Fig. 2), and there were very strong negative correlations between SQ–EQ and PW in both sexes (Fig. 3; Table 2).

A multiple regression analysis for females only with PW as dependent variable and Dr–l, height, and SQ–EQ as independent variables showed that Dr–l remained positively related to PW (beta = 0.27, \( t = 2.39 \), \( p < 0.01 \)) and height (beta = 0.20, \( t = 1.83 \), \( p < 0.05 \)) and SQ–EQ (beta = 0.25, \( t = 5.93 \), \( p < 0.0001 \)) remained significantly negatively related to PW. A similar test for males gave no significant relationship for Dr–l (details not shown). There were ethnicity effects on 2D:4D in the Study (Manning et al., 2007).

### Table 1

<table>
<thead>
<tr>
<th>Occupation</th>
<th>n</th>
<th>PW</th>
<th>Dr–l</th>
<th>Height</th>
<th>SQ–EQ</th>
<th>Dr–l</th>
<th>Height</th>
<th>SQ–EQ</th>
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<tr>
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<td>5141</td>
<td>0.94</td>
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<td>1.784</td>
<td>3.898</td>
<td>0.003</td>
<td>1.648</td>
<td>-3.497</td>
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<td>0.75</td>
<td>0.001</td>
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<td>3.738</td>
<td>0.003</td>
<td>1.651</td>
<td>-3.271</td>
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<td>Healthcare</td>
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<td>0.0002</td>
<td>1.789</td>
<td>3.237</td>
<td>0.002</td>
<td>1.650</td>
<td>-3.917</td>
</tr>
<tr>
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<td>0.001</td>
<td>1.790</td>
<td>3.553</td>
<td>0.003</td>
<td>1.652</td>
<td>-3.252</td>
</tr>
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<td>Education</td>
<td>12,500</td>
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<td>0.001</td>
<td>1.789</td>
<td>5.194</td>
<td>0.001</td>
<td>1.655</td>
<td>-1.827</td>
</tr>
<tr>
<td>Customer service</td>
<td>6071</td>
<td>0.56</td>
<td>0.001</td>
<td>1.798</td>
<td>5.960</td>
<td>0.002</td>
<td>1.657</td>
<td>-1.523</td>
</tr>
<tr>
<td>Medical/Science</td>
<td>7739</td>
<td>0.54</td>
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<td>1.798</td>
<td>5.960</td>
<td>0.002</td>
<td>1.657</td>
<td>-1.523</td>
</tr>
<tr>
<td>Legal</td>
<td>2604</td>
<td>0.53</td>
<td>0.0002</td>
<td>1.798</td>
<td>5.960</td>
<td>0.002</td>
<td>1.657</td>
<td>-1.523</td>
</tr>
<tr>
<td>Student</td>
<td>45,419</td>
<td>0.49</td>
<td>0.0002</td>
<td>1.794</td>
<td>5.039</td>
<td>0.002</td>
<td>1.654</td>
<td>-1.999</td>
</tr>
<tr>
<td>Accounting/finance</td>
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<td>0.49</td>
<td>0.0003</td>
<td>1.795</td>
<td>5.754</td>
<td>0.001</td>
<td>1.652</td>
<td>-1.450</td>
</tr>
<tr>
<td>Prof. services</td>
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<td>0.48</td>
<td>0.0004</td>
<td>1.796</td>
<td>3.361</td>
<td>0.001</td>
<td>1.666</td>
<td>-2.494</td>
</tr>
<tr>
<td>Sales/Market/advert</td>
<td>8430</td>
<td>0.46</td>
<td>0.0002</td>
<td>1.798</td>
<td>4.335</td>
<td>0.003</td>
<td>1.659</td>
<td>-2.615</td>
</tr>
<tr>
<td>Purchasing</td>
<td>640</td>
<td>0.44</td>
<td>0.0003</td>
<td>1.796</td>
<td>5.131</td>
<td>0.003</td>
<td>1.651</td>
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</tr>
<tr>
<td>Unemployed</td>
<td>5587</td>
<td>0.44</td>
<td>0.00005</td>
<td>1.786</td>
<td>3.841</td>
<td>0.0001</td>
<td>1.650</td>
<td>-2.013</td>
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<td>Business develop.</td>
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<td>0.38</td>
<td>0.002</td>
<td>1.794</td>
<td>5.158</td>
<td>0.002</td>
<td>1.653</td>
<td>-1.317</td>
</tr>
<tr>
<td>Government/military</td>
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<td>0.0002</td>
<td>1.793</td>
<td>5.430</td>
<td>0.002</td>
<td>1.654</td>
<td>-1.364</td>
</tr>
<tr>
<td>Gen. management</td>
<td>3326</td>
<td>0.36</td>
<td>0.001</td>
<td>1.798</td>
<td>5.140</td>
<td>0.001</td>
<td>1.658</td>
<td>-1.948</td>
</tr>
<tr>
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<td>3289</td>
<td>0.35</td>
<td>0.0003</td>
<td>1.797</td>
<td>4.893</td>
<td>0.002</td>
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<td>-1.536</td>
</tr>
<tr>
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<td>0.31</td>
<td>0.00002</td>
<td>1.797</td>
<td>5.771</td>
<td>0.001</td>
<td>1.660</td>
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<tr>
<td>Executive/snr manag</td>
<td>3326</td>
<td>0.27</td>
<td>0.001</td>
<td>1.797</td>
<td>5.740</td>
<td>0.001</td>
<td>1.656</td>
<td>-1.337</td>
</tr>
<tr>
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<td>0.23</td>
<td>0.003</td>
<td>1.789</td>
<td>5.270</td>
<td>0.003</td>
<td>1.654</td>
<td>-1.073</td>
</tr>
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<td>IT</td>
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<td>0.18</td>
<td>0.001</td>
<td>1.793</td>
<td>6.050</td>
<td>0.002</td>
<td>1.654</td>
<td>-0.396</td>
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<tr>
<td>Skilled labour</td>
<td>4477</td>
<td>0.17</td>
<td>0.002</td>
<td>1.793</td>
<td>4.845</td>
<td>0.001</td>
<td>1.655</td>
<td>-1.397</td>
</tr>
<tr>
<td>Engineering/R&amp;D</td>
<td>12,302</td>
<td>0.17</td>
<td>0.001</td>
<td>1.791</td>
<td>6.694</td>
<td>0.002</td>
<td>1.657</td>
<td>1.064</td>
</tr>
</tbody>
</table>

Fig. 1. The associations between the proportion of women (PW) per occupation and mean right hand 2D:4D ± SE bars (a) and mean Dr–l ± SE bars (b) per occupation in a sample of 22 occupations and 89,506 women. The formula for the line in A is \( y = 48.304x - 47.546 \), \( r^2 = 0.26 \), and in B it is \( y = 72.95x + 0.342 \), \( r^2 = 0.34 \).
Whites were the most numerous ethnic group and unlike the other ethnicities they were represented in large numbers in all the occupations. Therefore, we considered Whites only in a multiple regression and found that Dr-I (beta = 0.26, t = 1.77, p < 0.05) and SQ–EQ (beta = −0.63, t = 4.41, p < 0.001) remained significantly related to PW but height did not (beta = −0.11, t = 0.82, p = 0.21).

4. Discussion

In women, two putative negative correlates of PT, right hand 2D:4D and Dr-I, were positively related to PW across 22 occupations. This suggests that women with high PT are more likely to work in occupations that are male-dominated, while women with low PT are more likely to work in occupations that are female-dominated. The mean Dr-I explains about 30% of the variance in PW in the overall data and in the White only sample. There were no significant links between 2D:4D, Dr-I and PW in men. This may be because of ceiling effects in 2D:4D in men.

The 2D:4D result supports the hypothesis that PT has an organising effect on the brain that in turn affects female choice of occupation. A number of studies have shown that gender dependent traits such as performance in dichotic listening tasks, synonym generation and spatial tests are correlated with some occupational choices. This applies within-sex such that male-typical scores have been reported among women in male-typical occupations and female-typical performance among women in female-typical occupations (Govier, 2003; Govier & Bobby, 1994; Govier & Feldman, 1999).

With regard to 2D:4D, there is evidence that low 2D:4D is linked to success in financial activities involving substantial risk. Coates, Gurnell, and Rustichini (2008) reported that high-frequency financial traders with low 2D:4D showed higher profits than traders with high 2D:4D. In addition, low 2D:4D and high circulating T levels are related to low levels of risk aversion and choice of risky careers in finance in women but not men (Sapienza, Zingales, & Maestripieri, 2009).

Our data are the first to show that in a range of occupations among women, male-typical 2D:4D is linked to male-typical occupations and female-typical 2D:4D to female-typical occupations. In common with Sapienza et al. (2009) we did not find the same effect in men. This may be because male PT is in general high and there could be a threshold over which additional increases in PT do not give further effects on ‘brainsex’ or on occupational choices. With regard to the female 2D:4D and PW correlations we think the most obvious explanation of our results is that PT influences women’s preference for aspects of particular jobs. It is already known that amniotic PT influences gender-typical play (see for review Hines, 2008) and gender-typical interests (Auyeung et al., 2009). However, we wish to underline that the effect of PT could be amplified by social factors, such as employers’ perceptions of applicants’ suitability for a job or the effects of being absent from the labour market due to having children. It is of note that there have been recent changes in PW in some occupations but not in others. This may be because preferences for the former are less strongly influenced by PT than for the latter.

We found sexually dimorphic measures other than digit ratios were significantly related to PW. Women in male-typical jobs tended to be taller than women in female-typical jobs. This is likely to reflect height being a positive correlate of AT (Deady & Law-Smith, 2006), Ability/interest in systemizing is associated with high PT (Auyeung et al., 2006) and high empathizing scores is associated with low PT (Chapman et al., 2006). We found that high SQ–EQ scores were negatively associated with PW. Among females the correlations between Dr-I, height, SQ–EQ and PW were independent of one another. However, considering the most common ethnic group only (Whites) in a multiple regression (independent variables Dr-I, height, SQ–EQ and dependent variable PW) Dr-I and SQ–EQ remained significantly linked to PW but body height did not. This suggests that height is not a strong predictor of PW whereas PT measures are.

There are limitations to our study. Self-reports of finger length and height may contain inaccuracies. However, the sex and ethnic differences in 2D:4D found in the Study are similar to those reported elsewhere (Manning et al., 2007), and self-reported height correlates strongly with experimenter-measured stature (Himes & Roche, 1982). In addition some occupation categories may have been too broad (military and civil service occupations could have

![Fig. 2.](image-url) The relationship between PW and height in a sample of 89,506 women from 22 occupations. The formula for the line is $y = -4.764x + 0.173$, $r^2 = 0.20$.

![Fig. 3.](image-url) The relationship between PW and SQ–EQ in a sample of 89,506 women from 22 occupations. The formula for the line is $y = -4.764x + 0.173$, $r^2 = 0.70$.
been split) and could have included further information such as first occupation. These issues with regard to occupation should be addressed in future studies.

In conclusion, our data support the hypothesis that, over and above any other social factors, biological markers are associated with the type of occupation that women end up in. That is, right hand 2D:4D and Dr-I, are related to PW across a wide range of occupations. Scores on the EQ and SQ have previously been found to be better predictors than an individual’s sex or whether a student studies sciences or humanities (Billington, Baron-Cohen, & Wheelwright, 2007), leading to the conclusion that one should not focus on whether an individual is male or female (which would be potentially sexist) but rather on their individual make-up (their hormone levels or their cognitive profile). There is accumulating evidence that 2D:4D and Dr-I are correlates of androgen sensitivity (Berenbaum et al., 2009; Manning et al., 2003, 2004) and levels of PT. This leads to the conclusion that high PT in women is related to potentially sexist) but rather on their individual make-up (their hormone levels or their cognitive profile). There is accumulating evidence that 2D:4D and Dr-I are correlates of androgen sensitivity (Berenbaum et al., 2009; Manning et al., 2003, 2004) and levels of PT. This leads to the conclusion that high PT in women is related to their choice of male-dominated careers. In addition height and SQ–EQ scores are negatively related to PW, supporting the view that high PT and AT combine to influence the choice of occupations with low PW.

References


