Published in final edited form as:

Pers Individ Dif. 2011 September ; 51(4): 402–405. doi:10.1016/j.paid.2010.07.024.

The 2nd to 4th digit ratio (2D:4D) and eating disorder diagnosis in women

Stephanie Jane Quinton^a, April Rose Smith^b, and Thomas Joiner^b

Stephanie Jane Quinton: squinton@csu.edu.au

^a School of Psychology, Charles Stuart University, Bathurst, NSW 2795, Australia, Phone: + 61 2 6338 6118, Fax: + 61 2 6338 4401

^b Florida State University, 1107 West Call Street, Tallahassee, FL, 32306 USA

Abstract

Eating disorders are more common in females than in males and are believed to be caused, in part, by biological and hormonal factors. Digit ratio or 2D:4D (the ratio of the 2nd to the 4th digit) is considered to be a proxy for prenatal testosterone (PT) and prenatal oestrogen (PE) exposure. However, how 2D:4D may be related to type of eating pathology is unknown. The relationship between 2D:4D and eating disorder diagnosis was investigated in recovered and currently eating disordered ($n=31$) and control ($n=99$) women. Mean 2D:4D ratio was significantly lower (indicating higher levels of PT and lower levels of PE) in anorexic (AN) compared to bulimic (BN) women, with controls intermediary. In eating disordered women, 2D:4D was positively and significantly related to current weight, lowest weight and current BMI, with strongest associations for right 2D:4D. Among women, low 2D:4D is related to AN and high 2D:4D to BN, suggesting a differential causal influence of prenatal sex hormones on later eating pathology.

Keywords

sex differences; prenatal testosterone; eating psychopathology

1. Introduction

Eating disorders (ED) are most common in adolescent and young adult women, although they also occur in males (American Psychiatric Association, [APA], 2000). This gender-dependent expression may be related to both biological and psychological factors (Keel et al., 1997; McCabe & Vincent, 2003). Biological influences may include the organising effects of prenatal sex steroids on the foetus. The frequency of ED may further be modulated by between-sex and within-sex variation in prenatal testosterone (PT) and prenatal oestrogen (PE). Females generally have lower PT and a higher frequency of ED compared to males.

There is now a wide body of research suggesting that the 2nd to 4th digit ratio (2D:4D) is a proxy of PT and PE (e.g., Manning et al., 1998; Manning, 2002). Specifically, 2D:4D is known to be sexually dimorphic, fixed in utero, and negatively related to PT (i.e., the more PT the lower the 2D:4D ratio; Manning, 2002). Mean right 2D:4D is often lower than left,

Correspondence to: Stephanie Jane Quinton, squinton@csu.edu.au.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

and associations between 2D:4D and sex hormones are often stronger for the right compared to the left hand (Lutchmaya et al., 2004). However, it should be noted that the appropriateness of 2D:4D as a proxy for prenatal hormone exposure has been called into question. Some researchers have suggested it is unclear whether digit ratio varies by ethnicity (Van Dongen, Wijnaedts, Ten Broek, & Galis, 2009); others have noted digit ratio can be affected by other factors, such as measurement technique (Manning, Fink, Neave, & Caswell, 2005) and postnatal developmental (Galis, Broek, Van Dongen, Wijnaedts, 2010).

Two studies have reported a positive association between digit ratio (2D:4D) and disordered eating (Klump et al., 2006; Smith et al., in press). Additionally, Culbert and colleagues (2008) found support for the influence of prenatal hormone exposure in a twin sample. It is believed that sharing a prenatal environment with a male co-twin leads to increased levels of PT in the prenatal environment. Consistent with this hypothesis, Culbert and colleagues (2008) found an association between twin pair type and disordered eating, such that disordered eating was greatest among women from female-female twin pairs (lowest PT in prenatal environment), lowest among men from male-male twin pairs (highest PT in prenatal environment), and men and women from female-male twin pairs evidenced intermediary levels of disordered eating. However, a limitation of these studies is that they did not distinguish between bulimic and restrictive pathologies, and were comprised of non-clinical samples. Whether and how 2D:4D may be related to ED type is unknown, although given that AN has a lower base rate than BN (APA, 2000), it may be that these studies were more likely to relate to bulimic rather than anorexic symptoms.

In fact, it may be that 2D:4D (PT) has a complex relationship with disordered eating, such that increased 2D:4D (lower PT) is related to BN whereas decreased 2D:4D (higher PT) is associated with AN. Indirect evidence that AN may be associated with decreased 2D:4D comes from research which has found that decreased 2D:4D is significantly correlated with athletic achievement and physical fitness in women (Honekopp et al., 2006) as well as general athletic achievement (Manning et al., 2007; Honekopp & Schuster, 2010). Increased physical fitness as a result of lower 2D:4D (higher PT) may make it easier for a woman to succeed at sports, and female athletes are known to be at increased risk for developing an eating disorder as compared to non-athletes (Cobb, 2006; Sundgot-Borgen & Torstveit, 2004). Moreover, women with AN are more likely to engage in excessive exercise than are women with BN (Davis et al., 1997; Shroff et al., 2006), which may in part be related to their greater capacity for physical fitness due to lower 2D:4D or increased PT.

Further support for a potential relationship between AN and increased PT comes from research linking AN and autism, as individuals with autism have been found to have lower 2D:4D than unaffected individuals (Manning et al., 2001); this relationship has been found to be particularly strong in autistic females (De Bruin et al., 2009). Foetal testosterone levels have also been found to be positively associated with autistic traits (Auyeung et al., 2009). Zucker and colleagues (2007) conducted an extensive review of the literature and noted that individuals with AN and autism spectrum disorders (ASD) tend to have similar personality traits, such as behavioural rigidity and aloofness. Moreover, individuals with ASD and AN both experience deficits in social neurocognitive functioning (Zucker et al., 2007).

Therefore the association between 2D:4D (a proxy for prenatal sex steroids) and eating psychopathology was investigated in clinical (eating-disordered) and non-clinical control women. It was hypothesised that: 2D:4D would be associated with eating psychopathology, and that the direction of association would differ in AN and BN. Specifically, it was predicted that a diagnosis of AN would be related to lower 2D:4D (increased PT), whereas a diagnosis of BN would be related to higher 2D:4D (decreased PT). Moreover, it was hypothesized that any association would be stronger for right compared to left 2D:4D.

2. Method

2.1 Participants

Control women ($n=99$) were comprised of undergraduate students from a large UK University screened for current ED using the 26 item Eating Attitudes Test (EAT-26 score <20 ; Garner et al., 1982). The ED women ($n=31$) were recruited from the research database of the Eating Disorders Association - EDA, UK (response rate 23%). They self-reported whether their ED experience was ANr (restrictive, $n=16$), ANb/p (bingeing/purging, $n=9$), or BN ($n=6$), with ED type taken as their treating healthcare professional's original diagnosis. Participation was voluntary and without payment, with all participants giving informed consent. Approval was granted by the local University ethical committee and the EDA.

2.2 Measures

Ethnicity and age were self-reported, with height and weight measured objectively in control women. Demographics in clinical women were by self-report and also included lowest and highest adult weight, and whether they were currently ED or recovered. Digit ratio (2D:4D) was calculated by measuring the lengths of the 2nd (index) and 4th (finger) digits from photocopies of the ventral surface of the hands using digital vernier callipers recording to 0.01mm. Measurements were made from the mid- point of the finger crease proximal to the palm to the tip of the finger. These were made twice, blind and separated by at least one day. Although such indirect methods of measurement tend to result in lower ratios than direct measurements that use the same digit measurement landmarks (Manning et al., 2010), the current method was the most practicable given that it was not possible to measure the ED participants' fingers directly, and therefore considered appropriate (e.g., Manning et al., 2001).

3. Results

The first and second finger measurements showed high intra-class correlation coefficients (r_I) for all four fingers (i.e., 2D and 4D from right and left hands), varying from $r_I=0.990$ for 2D right to $r_I=0.996$ for 2D left. For all fingers the differences in finger length between individuals were much greater than the measurement error indicating high reliability of the measurements (2D right $F[1,129]=245.73$, $p=0.0001$; 4D right $F[1,129]=433.59$, $p=0.0001$; 2D left $F[1,129]=479.66$, $p=0.0001$; 4D left $F[1,129]=0.993$, $p=0.0001$). The 2D:4D ratios also had high r_I values which were highly significant (2D:4D right $r_I=0.976$, $F[1,129]=82.03$, $p=0.0001$; 2D:4D left $r_I=0.981$, $F[1,129]=104.93$, $p=0.0001$). The first and second ratings of 2D:4D values were averaged and the means used in all subsequent analyses.

Non-clinical control women were Caucasian with a mean age of 19.82 years (SD=4.82), height 163.28 cm (SD=5.83), weight 62.98 kg (SD=11.92) and BMI of 23.63 (SD=4.35). Weight and BMI were within norms.

Clinical women were also Caucasian with a mean age of 36.25 years (SD=7.52), height 165.92 cm (SD=5.38), weight 52.13 kg (SD=8.89) and BMI of 18.86 (SD=3.03). Their lowest and highest adult weights were 41.23 (SD=8.69) and 64.84 kg (SD=15.13), respectively. As may be expected weight and BMI were towards the low normal range. BMI differed across type of ED, with ANr 17.91 (SD=2.86), ANb/p 18.72 (SD=2.59), and BN 20.78 (SD=2.14). The AN women's weight was higher than expected for a clinical sample and may reflect heterogeneity concerning illness and recovery status.

Due to non-significant differences between ANr and ANb/p women on BMI and right and left 2D:4D ($F[1,22]=1.424, P=0.246$; $F[1,25]=0.757, P=0.393$; $F[1,25]=0.282, P=0.60$, respectively), they were combined (AN, $n=25$) for all analyses. There was no association between 2D:4D and age for both non-clinical (right 2D:4D $r[97]=0.02, P=0.86$; left $r[97]=0.09, P=0.35$) and clinical women (right 2D:4D $r[29]=0.03, P=0.85$; left $r[29]=0.20, P=0.26$). Concordant with 2D:4D remaining stable across the lifespan (Manning, 2002), age was not a considered variable in subsequent analyses.

There were significant differences in mean 2D:4D between AN, BN, and control women, most clearly demonstrated with the right hand. AN displayed low masculinized 2D:4D, BN high feminized 2D:4D, with non-clinical controls intermediary. Right 2D:4D: AN 0.960 (SD=0.034), non-clinical 0.984 (SD=0.032), and BN 1.003 (SD=0.042), $F[1,158]=5.53, P=0.005$. Left 2D:4D: AN 0.960 (SD=0.033), non-clinical 0.957 (SD=0.032), and BN 0.998 (SD=0.052), $F[1,159]=5.19, P=0.007$. In ED women, right 2D:4D positively correlated with current weight ($r[30]=0.46, P=0.03$), lowest weight ($r[30]=0.40, P=0.03$) and current BMI ($r[30]=0.50, P=0.008$). That BMI was associated with both lowest and current weight for ED women was likely due to the inclusion of women who currently met diagnostic criteria for an eating disorder.

In non-clinical women, similar to the clinical ED sample, there was a trend for an association between 2D:4D and BMI (right $r[97]=0.15, P=0.15$, left $r[97]=0.17, P=0.06$).

4. Discussion

The association between 2D:4D (a proxy for PT) and eating psychopathology was investigated in clinical ED and non-clinical control women. Concerning right 2D:4D, AN women had a low mean 2D:4D and BN a high mean 2D:4D, whilst non-clinical controls were intermediary. In ED women, significant positive correlations occurred between right 2D:4D and current weight, BMI, and lowest weight. The association of 2D:4D with weight and BMI in clinical women (i.e., higher PT was associated with both lower weight and BMI) is in tandem with the results for digit ratio and differential ED type. That is, lower weight was associated with lower 2D:4D (higher PT) whereas higher weight was associated with higher 2D:4D (lower PT). This is in keeping with the diagnostic criteria for AN, as AN women are by definition severely underweight, whereas BN women's weight is typically in the normal range (APA, 2000).

These findings suggest that the aetiology of ED may be related to 2D:4D or the level of PT in utero, with AN having been exposed to high PT and BN low PT. The results for the BN women are supported by other studies which have found positive associations between disordered eating and digit ratio or PT exposure (Culbert, et al., 2008; Klump et al., 2006; Smith et al., in press). The finding that AN diagnosis had a negative relationship with digit ratio is novel.

Although this is the first study to report a relationship between lower 2D:4D (greater PT) and AN diagnosis, this association is in keeping with findings from other studies investigating disorders and conditions believed to be associated with AN. Specifically, both ASD and physical fitness have been linked to AN (Sundgot-Borgen & Torstveit, 2004; Zucker et al., 2007), and both individuals with ASD and greater physical fitness have been found to have more masculinised digit ratios (Honekopp et al., 2006; Manning et al., 2001).

However, any exact causal mechanism between 2D:4D (or PT) and type of ED is still unknown. It is possible that disordered eating, which often manifests during adolescence and puberty, is linked to hormonal changes (Klump et al., 2006), with the type of pathology expressed dependent upon the level of PT. If low 2D:4D (high PT) is causal in AN, this may

link with the association between 2D:4D and autism (Manning et al., 2001) and anorexia and autism (Gillberg et al., 1996). Although both autism and low 2D:4D are more common in males, this hormonal effect may be sex-dependent with high PT having differential effects on females compared to males. The association between high 2D:4D (low PT) and bulimia is more readily explainable as both are more common in females.

Despite support for distal and proximal biological hormonal influences on eating pathology (e.g., Crisp, 1983; Culbert, et al., 2008; Klump et al., 2006; Smith, et al., in press), the aetiology of AN and BN is multi-factorial (Jansen, 2001). How early hormonal influences mesh with other biological risk factors (Striegel-Moore & Bulik, 2007) and developmental and psychological models (Smolak & Levine, 1996; McManus & Waller, 1995) needs addressing. Moreover, future research should examine whether high 2D:4D (low PT) is associated with both bingeing and purging behaviours.

A few limitations of the current study are important to note. First, the sample was entirely Caucasian. As such, it is unclear whether these results generalise to other racial groups. Second, our ED sample was small, and their response rate was low, thus this ED sample may not be representative. However, despite the small sample size we were able to obtain significant results. Given these limitations, further work is necessary to establish the relationship between 2D:4D and disordered eating in more pure clinical samples, and whether it is predictive of long-term outcome in ED. Although future research is needed to replicate these findings, to our knowledge this is the first study to examine 2D:4D (PT) by eating disorder type, and thus adds to the growing body of research on biological factors which may differentially contribute to the development of AN and BN.

Acknowledgments

This research was supported, in part, by a grant from the National Institute of Mental Health to April R. Smith and Thomas E. Joiner (1 F31 MH083382-01A2). The NIMH had no further role in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

References

- American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4. American Psychiatric Association; Washington, D.C: 2000. text revision
- Auyeung B, Baron-Cohen S, Ashwin E, Knickmeyer R, Taylor K, Hackett G. Fetal testosterone and autistic traits. *British Journal of Psychology*. 2009; 100:1–22. [PubMed: 18547459]
- Cobb, KL. Eating disorders in athletes: A review of the literature. In: Swain, P., editor. *Eating Disorders: New Research*. Nova Science Publishers; Hauppauge, NY: 2006. p. 65–98.
- Crisp AH. Anorexia Nervosa. *British Medical Journal*. 1983; 287:855–858. [PubMed: 6412858]
- Culbert KM, Breedlove SM, Burt A, Klump KL. Prenatal hormone exposure and risk for eating disorders: A comparison of opposite-sex and same-sex twins. *Archives of General Psychology*. 2008; 65:329–336.
- Davis C, Katzman DK, Kaptein S, Kirsch C, Brewer H, Kalmbach K, Olmstead MP, Woodside DB, Kaplan AS. The prevalence of high-level exercise in the eating disorders: Etiological implications. *Comprehensive Psychiatry*. 1997; 38:321–326. [PubMed: 9406737]
- De Bruin EI, De Nijs PFA, Verheij F, Verhagen DH, Ferdinand RF. Autistic features in girls from a psychiatric sample are strongly associated with low 2D:4D ratio. *Autism*. 2009; 13(5):511–521. [PubMed: 19759064]
- Galis F, Ten Broek CMA, Van Dongen S, Wijnaendts LCD. Sexual dimorphism in the prenatal digit ratio (2D:4D). *Archives of Sexual Behavior*. 2010; 39:57–62. [PubMed: 19301112]
- Garner DM, Olmsted MP, Bohr Y, Garfinkel PE. The Eating Attitudes Test: psychometric features and clinical correlates. *Psychological Medicine*. 1982; 12:871–878. [PubMed: 6961471]

- Gillberg IC, Gillberg C, Rastam M, Johansson M. The cognitive profile of anorexia nervosa: a comparative study including a community-based sample. *Comprehensive Psychiatry*. 1996; 37:23–30. [PubMed: 8770522]
- Honekopp J, Manning JT, Muller C. Digit ratio (2D:4D) and physical fitness in males and females: Evidence for effects of prenatal androgens on sexually selected traits. *Hormones and Behavior*. 2006; 49:545–549. [PubMed: 16403410]
- Honekopp J, Schuster M. A meta-analysis on 2D:4D and athletic prowess: substantial relationships but neither hand out-predicts the other. *Personality and Individual Differences*. 2010; 48:4–10.
- Jansen A. Towards effective treatment of eating disorders: nothing is as practical as a good theory. *Behaviour, Research and Therapy*. 2001; 39:1007–1022. [PubMed: 11520008]
- Joiner, TE. Why people die by suicide. Harvard University Press; Cambridge, MA: 2005.
- Keel PK, Dorer DJ, Eddy KT, Franko D, Charatan DA, Herzog DB. Predictors of mortality in eating disorders. *Archives of General Psychiatry*. 2003; 60:179–183. [PubMed: 12578435]
- Keel PK, Fulkerson JA, Leon GR. Disordered eating precursors in pre- and early adolescent girls and boys. *Journal of Youth and Adolescence*. 1997; 26:203–216.
- Klump KL, Gobrogge KL, Perkins PS, Thorne D, Sisk C, Breedlove SM. Preliminary evidence that gonadal hormones organize and activate disordered eating. *Psychological Medicine*. 2006; 36:539–546. [PubMed: 16336745]
- Lutchmaya S, Baron-Cohen S, Raggatt P, Knickmeyer R, Manning JT. 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Human Development*. 2004; 77:23–28. [PubMed: 15113628]
- Manning, JT. Digit ratio: a pointer to fertility, behavior, and health. Rutgers University Press; New Jersey: 2002.
- Manning JT, Baron-Cohen S, Wheelwright S, Fink B. Is digit ratio (2D:4D) related to systematizing and empathizing? Evidence from direct finger measurements reported in the BBC internet survey. *Personality and Individual Differences*. 2010; 48:767–771.
- Manning JT, Baron-Cohen S, Wheelwright S, Sanders G. The 2nd to 4th digit ratio and autism. *Developmental Medicine and Child Neurology*. 2001; 43:160–164. [PubMed: 11263685]
- Manning JT, Fink B, Neave N, Caswell N. Photocopies yield lower digit ratios (2D:4D) than direct finger measurements. *Archives of Sexual Behavior*. 2005; 34:329–333. [PubMed: 15971015]
- Manning JT, Morris L, Caswell N. Endurance running and digit ratio (2D:4D): implications for fetal testosterone effects on running speed and vascular health. *American Journal of Human Biology*. 2007; 19:416–421. [PubMed: 17420996]
- Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: a predictor of sperm numbers and concentration of testosterone, luteinizing hormone and oestrogen. *Human Reproduction*. 1998; 13(11):3000–3004. [PubMed: 9853845]
- McCabe M, Vincent MA. The role of biodevelopmental and psychological factors in disordered eating among adolescent males and females. *European Eating Disorders Review*. 2003; 11:315–328.
- McManus F, Waller G. A functional analysis of binge eating. *Clinical Psychology Review*. 1995; 15:845–863.
- Shroff H, Reba L, Thornton LM, Tozzi F, Klump KL, Berrettini WH. Features associated with excessive exercise in women with eating disorders. *International Journal of Eating Disorders*. 2006; 39:454–461. [PubMed: 16637047]
- Smith A, Hawkeswood S, Joiner TE. The measure of a man: Associations between digit ratios and disordered eating in males. *International Journal of Eating Disorders*. (in press).
- Smolak, L.; Levine, MP. Adolescent transitions and the development of eating problems. In: Smolak, L.; Levine, MP.; Striegel-Moore, R., editors. *The developmental psychopathology of eating disorders*. Lawrence Erlbaum Associates; Mahwah, New Jersey: 1996. p. 207-235.
- Striegel-Moore RH, Bulik CM. Risk factors for eating disorders. *American Psychologist*. 2007; 62:181–198. [PubMed: 17469897]
- Sundgot-Borgen J, Torstveit MK. Prevalence of eating disorders in elite athletes is higher than in the general population. *Journal of Sports Medicine*. 2004; 14:25–32.

- Van Dongen S, Wijnaendts LC, Ten Broek CM, Galis F. Fluctuating asymmetry does not consistently reflect severe developmental disorders in human fetuses. *Evolution*. 2009; 63:1832–44. [PubMed: 19245674]
- Zucker NL, Losh M, Bulik CM, LaBar KS, Piven J, Pelphrey KA. Anorexia nervosa and autism spectrum disorders: Guided investigation of social cognitive endophenotypes. *Psychological Bulletin*. 2007; 133:976–1006. [PubMed: 17967091]