Sporting Achievement: What Is the Contribution of Digit Ratio?

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ABSTRACT Second-to-fourth digit ratio, a marker for prenatal testosterone levels, has been shown to be associated with sporting achievement in men. It is unclear, however, whether digit ratio makes a contribution over and above salient personality variables. The present study, which included female participants, measured four personality traits and one cognitive ability (mental rotation) that have been linked to both sports achievement and sex. The significant relationship between digit ratio and sporting achievement was nearly identical in women and men. A multiple regression showed that when significant correlates of sporting ability (weight, height, years playing, hours per week training, social potency, and mental rotation) were entered first, the contribution of digit ratio remained highly significant. We suggest that physiological as well as psychological factors may be an important avenue for future study.

Prenatal testosterone exposure has been shown to be associated with sporting achievement in men (Manning & Taylor, 2001). However, the route by which testosterone exerts this effect is not yet established. In the present article we examine the possibility that early androgenization may affect personality traits that are relevant to sports achievement.

The ratio of the lengths of the second to the fourth digit is sexually dimorphic, with males showing a lower digit ratio (i.e., the ring finger is longer relative to the index finger). The digit ratio is thought to reflect the exposure of the individual to prenatal testosterone. The differentiation of the foetal gonads is controlled by the Homobox or Hox genes. In particular, the posterior-most Hox-d and Hox-a genes are strongly expressed in the urinogenital system, including the

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gonads, and are also required for the growth and differentiation of digits and toes (Csatho et al., 2003). Deregulation of Hox-d expression in mice alters the relative lengths of digits and affects the growth of the genital bud (Kondo, Zakany, Kakany, Innis, & Duboule, 1997). In humans, the disorder *hand-foot-genital syndrome* causes anatomical defects in the digits and genitalia and results from a mutation of the Hox-a gene (Mortlock & Innis, 1997). The shared genetic basis of digit and gonad differentiation strongly suggests that patterns of digit formation reflect testis function and, therefore, prenatal sex hormone concentration. A lower 2D:4D ratio measured at age 2 is associated with higher levels of fetal testosterone relative to fetal estradiol in amniotic fluid (Lutchmaya, Baron-Cohen, Raggett, Knickmeyer, & Manning, 2004). (It should be noted that tissue sensitivity to testosterone depends upon the X-linked androgen receptor gene. Alleles of this gene with a low number of CAG triplets are more responsive to testosterone, and right-hand 2D:4D ratio is positively correlated with CAG numbers in men; see Manning, Bundred, Newton, & Flannigan, 2003.)

Digit ratio has been examined in relation to biological variables such as male reproductive function (e.g., germ cell failure, low sperm number, and testosterone concentrations; Manning, Scutt, Wilson, & Lewis-Jones, 1998) and health (e.g., immune dysfunction, myocardial infarction; Manning & Bundred, 2000). It is reported to be associated with a number of male-typed psychological traits, including numerical and spatial ability (Kempel et al., 2005); improved left-hand performance (Manning, Trivers, Thornhill, & Singh, 2000); autism (Manning, Baron-Cohen, Wheelwright, & Sanders, 2001); perceived dominance and masculinity (Neave, Laing, Fink, & Manning, 2003); masculine gender role (Csatho et al., 2003); and, among females, sensation seeking, psychoticism, and neuroticism (Austin, Manning, McInroy, & Mathews, 2002). There has, however, been methodological criticism: the use of multiple digit ratio measures (left, right, and both hands combined) within a single study increases the chances of Type 1 errors, and a number of null findings have been reported (Putz, Gaulin, Sporter, & McBurnley, 2004). This makes replication studies especially important.

In an early study, Manning and Taylor (2001) reported that, among men, 2D:4D ratio was negatively associated with sports attainment. Digit ratio remained significant when it was entered into a multiple regression along with age, sport experience, and sports discipline. In a further study of football players, digit ratio increased in line with attainment in the predicted order; internationals, coaches, premier club players, divisions I, II, and III, and club players. But *how* does prenatal testosterone impact sporting performance? In the present study we selected five personality traits for investigation. Our selection was guided principally by the fact that the variables have been shown to be associated with sporting excellence and, secondarily, by a consideration of the extent to which they have shown sex differences in past studies.

Four of the variables were personality traits taken from the Multidimensional Personality Questionnaire (MPQ: Tellegen, 1982). Individuals scoring high on *social potency* are described as forceful and decisive: they are persuasive and like to influence others, enjoy leadership roles, and take charge and like to be noticed at social events. Social potency, therefore, shows conceptual overlap with assertiveness and dominance. Assertiveness is associated with sporting excellence (Eysenck, 1979). It is a desirable trait in competitive team sports, in terms of decision making and responsibility taking (Eysenck, Nias, & Cox, 1982). Athletes score higher on measures of dominance compared with nonathletes (Eysenck et al., 1982). Men are significantly higher on measures of dominance and assertiveness than women (Costa, Terracciano, & McCrae, 2001), including the MPQ social potency scale (Tellegen, 1982). Dominance forms a part of the masculinity scale of the Bem Sex Role Inventory (BSRI) (Bem, 1981) and the instrumental scale of the Personal Attributes Questionnaire (PAQ) (Spence & Helmreich, 1978) on which men score higher than women.

The *harm avoidance* scale assesses the tendency to avoid the excitement of adventure and danger and to prefer safer activities even if they are tedious and aggravating. Low scorers broadly correspond to what Zuckerman (1983) has termed sensation seekers. They enjoy risky stunts and adventures and the excitement of a dangerous emergency or disaster and are willing to expose themselves to possible attack or injury. Success in many sports, but particularly contact sports, is associated with a degree of risk taking and the ability to deal with potentially dangerous situations (Schroth, 1995). High-risk/contact-sport players score higher on sensation seeking than low-risk/noncontact-sport players (Zuckerman, 1983). A study comparing rugby players and marathon runners found rugby players to be higher on both the total score of the Sensation Seeking Scale and on the Thrill and Adventure Seeking subscale (Potgieter & Bisschoff, 1990). Men score higher than women on sensation seeking (Costa et al., 2001), and women score higher on harm avoidance (Driscoll, Zinkivskay, Evans, & Campbell, 2006; Tellegen, 1982).

Individuals who are high in *achievement* work hard, like long hours, enjoy demanding projects, persist where others give up, put work and accomplishments before many other things, and are perfectionists. Motivation to succeed is a prerequisite for good sport performance (Singer & Janelle, 1999). Career advancement is positively influenced by individual differences in motive to achieve, particularly among persons who work independently. This is often the case in sport where results are, to a great extent, attributable to the athletes' motivation to train independently. Specifically, Halvari and Thomassen (1997) present evidence from a variety of sporting domains that athletes with a strong motivation to succeed perform better than athletes with a strong motivation to avoid failure. Athletes score above average on need for achievement (Nias, 1979). Elite athletes (professional or international) reported significantly higher achievement motivation in comparison to other groups, with females, interestingly, scoring higher than males overall (Davis & Mogk, 1994). The lower value, resources, and funding for women's sport may require women in this domain to be especially highly motivated. Regarding sex differences, studies conducted in the 1950s and 1960s concluded that women had lower achievement motivation than men. However, women's scores have risen significantly since that time, and more recent studies show no gender differences (Costa et al., 2001). Specifically in sport, however, boys have higher perceived competence, and they value and enjoy sporting activities more than girls do (Fredericks & Eccles, 2005).

Research has confirmed that impulsivity and sensation seeking are two distinct traits (Whiteside & Lynam, 2001). The MPQ *control* scale captures a tendency to be reflective, cautious, plodding, and rational and to anticipate and plan events and activities. Lower scorers are described as impulsive, spontaneous, and reckless. Male and female university sports performers have significantly higher impulsivity scores than nonathletes, with soccer players and rowers having lower scores than rugby and lacrosse players (Schroth, 1995). McCutcheon (1980) also found contact sport participation (such as rugby and American football) to be related to elevated impulsiveness scores compared to noncontact sports participants and nonsport participant controls. With regard to sex differences in impulsivity in community samples, results appear to depend upon age and measurement. Developmental studies report lower impulsivity and a stronger ability to inhibit behavior among girls than boys (Kochanska, Coy, & Murray, 2001), and, at adolescence, girls show greater self-control (LaGrange & Silverman, 1999). Among adults, sex differences appear to be a function of the inventory used, and there are low correlations between the various measures. On CPI impulsivity, men score higher (Feingold, 1994), but the sex difference is reversed for NEO-PI (Costa et al., 2001). Women score higher on the Control scale of the MPQ (Driscoll et al., 2006) and on the higher-order MPQ Constraint factor of which it forms a part (Moffitt, Caspi, Rutter, & Silva, 2001).

Visual-spatial skills are essential to field and team sports: "Striking a moving opponent or ball requires fine judgement of distance. Determining the exact point of impact demands an accurate perception of the surface of the target as it moves through space, in addition to an awareness of the relative movement of one's own hand, foot, head, and so forth" (Manning, 2002, p. 128). *Mental rotation* tasks indicate superior male performance in terms of accuracy and speed (Blough & Slavin, 1987), and a male advantage has been reported by about 10 years of age (Johnson & Meade, 1987). The sexual dimorphism in mental rotation ability is thought to be due to differences in brain development and function, caused at least in part by prenatal sex hormones. Geschwind and Galaburda (1985) report evidence that prenatal testosterone enhances, while prenatal estrogen inhibits, the growth of the right hemisphere of the brain responsible for good spatial abilities. Although Manning and Taylor found an association between digit ratio and mental rotation ability (Study 2), their study did not directly examine whether mental rotation explained the relationship between digit ratio and sporting prowess.

Sporting achievement is of course related to a number of factors beyond personality. These include physique (height and weight), training intensity (hours per week), and experience (years playing the sport). These are measured in the present study in order to examine whether digit ratio predicts sports achievement when these factors are controlled. We also include women in our sample in order to assess the underresearched relationship between digit ratio and sports achievement for females as well as males. (A recent study reported that elite female athletes have a lower left-hand digit ratio than controls but not lower than subelite athletes; Pokrywka, Rachon, Sucheka-Rachon & Bitel, 2006.) Beyond these somatic, effort, and gender control variables, our aim is to examine the extent to which psychological traits and competencies (social potency, harm avoidance, achievement, control, and mental rotation), when entered first into a regression equation, attenuate the relationship between digit ratio and sports achievement.

METHOD

Participants

Participants were current students at universities in the northeast of England. They were selected on the basis of being regular members (training or competing a minimum of once per week) of university or college sports teams. The sample of 155 was drawn from 12 teams representing three sports; rugby (league and union), football, and basketball. The sample was composed of 52 rugby players (27 men and 25 women), 54 football players (23 men and 31 women), and 49 basketball players (23 men and 26 women). The mean age was 20.38 years ($SD = 1.32$).

Instruments

Sports rank and personal information. The sports achievement rank scale was used (Manning & Pickup, 1998). This scale has been shown to correlate with best times for 800-m running (Manning & Pickup, 1998) and replicates associations between rank and digit ratio found when professional football players are ranked by the division in which they play (Manning & Taylor, 2001). Participants indicated their highest level of sporting achievement from no participation through social, organized, county, and national competition to national representation. The scale is scored from (1) *no involvement in sport* to (10) *national representation*. Because of the nature of participant recruitment, all scores were higher than 1. Information was sought on gender, age, height, weight, hours spent training per week, and years playing the sport.

Mental rotation test (Philips & Rawles, 1979). This is a timed test based on the mental rotation test described by Shepard and Metzler (1971).

Participants have 2 minutes to examine 20 pairs of stimuli and decide if they are the same (i.e., if the spatial rotation of one image would make it identical to the other) or different. Participants are instructed to complete as many of the 20 items as possible in the timed period.

Multidimensional Personality Questionnaire Brief Form (Patrick, Curtin, & Tellegen, 2002). Items from the following four scales were given: Social Potency (e.g., ''I enjoy being in the spotlight''), Achievement (e.g., ''I push myself to the limits''), Control (e.g. ''I almost never do anything reckless''), and Harm Avoidance (e.g. ''I would like least like (A) Being chosen as the 'target' for a knife-throwing act or (B) Being sick to my stomach for 24 hours''). All items have dichotomous responses. These 12-item scales correlate greater than .93 with the original MPQ scales, and the internal consistencies are respectively .80, .80, .74, .76 (Patrick et al., 2002). The 48 items representing the different scales were interspersed.

Digit ratio measurement. A standard photocopier was used to make copies of the palms of the participants' right hands (rings removed). Electronic digital callipers (with a resolution of 0.01 mm, an accuracy of 0.03 mm, and a repeatability of 0.01 mm) were used after the testing, to measure the participants' digit lengths from the photocopies taken from their hands. Measures were made from the central point of the tip of the second finger to the central point of the basal crease of the second finger and divided by the same measure from the fourth finger. Values lower then 1 indicate that the ring finger is longer than the index finger.

Procedure

Participants were tested prior to one of their normal training sessions. They were given a verbal briefing that explained the nature of the investigation and testing, the confidentiality of participants' data, and the participants' right to withdraw at any time. The participants completed the Mental Rotation Test in a group setting. After being shown two example questions, they were instructed to perform the task as ''quickly and as accurately as possible'' in the 2-minute period. The participant information sheet and the items from the Multidimensional Personality Questionnaire were then completed without any time limitation. After this, the participants were taken to a photocopier, where they had the palm of their right hands photocopied.

RESULTS

Internal consistencies for the four psychometric scales (each with 12 items) were satisfactory; Social potency ($\alpha = .83$), Achievement ($\alpha = .81$), Control ($\alpha = .84$), and Harm avoidance ($\alpha = .71$).

Sex differences. Table 1 presents the means and standard deviations by sex for all variables. The sex differences that appeared were fairly predictable. Compared to women, men were significantly taller, $t(1{,}153) = 12.21$, $p < .001$, $d = 1.40$; heavier, $t(1{,}153) = 7.37$, $p < .001$, $d = 1.02$; had spent more years playing the sport, $t(1{,}153) = 7.62$, $p < .001$, $d = 1.05$, and had lower digit ratios, $t(1{,}153) = -3.12$, $p < .01$, $d = -0.49$. The only personality scale to reveal a significant sex difference was social potency on which men were higher than women, $t(1{,}150) = 2.28$, $p < .05$, $d = 0.36$). No sex differences were found for sports rank, mental rotation, achievement, harm avoidance, or control.

Correlations. All pairwise correlations were computed. Sports rank was significantly correlated with height, $r = 0.20$, $p < .01$; weight, $r = .24$, $p < .01$; hours per week training, $r = .42$, $p < .001$; years

Table 1
Means and Standard Deviations of Men and Women on All Variables

	Women ($N = 82$)	Men ($N = 73$)
Height (cms)***	168.02 (7.47)	181.81 (6.46)
Weight (kgs)***	64.93 (9.86)	77.59 (11.51)
Years playing***	4.85 (4.15)	10.14 (4.49)
Hours per week training	2.54 (1.04)	2.42 (1.22)
Sports rank	4.98 (1.78)	5.47 (1.66)
Mental rotation	11.16 (3.70)	12.18 (3.60)
Digit ratio**	0.97 (0.03)	0.95 (0.02)
Social potency*	7.23 (4.30)	8.63 (3.31)
Achievement	7.55 (3.00)	6.93 (3.19)
Harm avoidance	5.63 (3.07)	5.74 (2.91)
Control	7.57 (3.82)	6.77 (3.78)

*$p < .05$. **$p < .01$. ***$p < .001$.

playing, $r = .35$, $p < .001$ and social potency, $r = .23$, $p < .01$. Unexpectedly, mental rotation ability was negatively correlated with rank, $r = -.16$, $p < .01$. Digit ratio showed a very significant correlation with rank, $r = .35$, $p < .001$, equal in magnitude to years playing the sport. Digit ratio was also associated with height, $r = -.25$, $p < .01$; years playing, $r = -.22$, $p > 01$, and social potency, $r = -.17$, $p < .05$, each of which was also a correlate of rank. (Correlations were similar for men and women.[1]) These results indicate the need for a multiple regression analysis to isolate the unique contribution of digit ratio.

Multiple regression. A hierarchical model was specified as follows: Block 1 included physical factors (height, weight, gender). Block 2 included effort variables (years playing, hours training), Block 3 included personality/cognitive variables (mental rotation, social potency), and Block 4 entered digit ratio. In Block 5 two interactions (between gender and digit ratio and gender and social potency) were included, but they failed to contribute to the model. If the effect of digit ratio on sports rank is due to the previously entered variables, digit ratio should become nonsignificant and the semipartial correlation between digit ratio and rank will be extremely small relative to the zero-order correlation. The final model (see Table 2) explains one-third of the variance associated with rank. After weight, years playing the sport, and hours training per week had been entered, digit ratio continued to make a significant contribution. The zero-order correlation between digit ratio and rank, $r = -.35$, $p < .001$ was reduced to a semipartial correlation of $r = -.24$, $p < .001$ indicating that the major portion of the effect of digit ratio on rank remained unexplained by the previously entered variables. Note that neither of the psychological variables (social potency, $t = 0.90$, $p = .37$ and mental rotation, $t = -1.36$, $p = .17$) entered the regression equation.

1. Of 55 correlations compared across gender, only 2 were significantly different. The correlation between weight and hours training was $r = .41$ for men and $r = .08$ for women, $z = 2.23$, $p < .05$. The correlation between mental rotation and control was $r = -.11$ for men and $r = .28$ for women, $z = 2.43$, $p < .05$. Crucially, the correlation between digit ratio and sports rank was virtually identical for men ($r = -.34$) and for women ($r = -.33$).

Table 2
Summary of Hierarchical Regression Analysis for Variables Predicting Sports Rank ($N = 155$)

	Model 1			Model 2			Model 3			Model 4		
Variable	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE(B)*	β
Weight	0.03	0.01	0.24	0.02	0.01	0.17	0.01	0.01	0.08	0.01	0.01	0.06
Hours training				0.60	0.11	0.39	0.58	0.11	0.37	0.54	0.11	0.35
Years playing							0.10	0.03	0.28	0.08	0.03	0.24
Digit ratio										– 17.80	5.02	– 0.25
R^2		.06			.21			.27			.33	
F change in R^2		9.68**			27.76***			14.49***			12.55***	

**$p < .01$. ***$p < .001$.

DISCUSSION

Our data replicate the work of Manning and Taylor (2001) in finding an association between sports achievement and digit ratio and extend their findings by demonstrating that the relationship is of equal magnitude for women as for men. More elusive, however, is the route by which prenatal testosterone is exerting its effect. Digit ratio is associated with somatic factors, specifically height and weight, but these are not sufficient to statistically explain its effect. Both are associated with number of years playing sport, suggestive of the likelihood that a certain physique may act as a gating threshold for sporting involvement. Effort variables (years playing and hours per week training) were strongly associated with higher sports achievement, and, indeed, any other result would have been surprising and disheartening. But, again, their contribution did not eliminate the digit ratio effect.

Personality variables failed to enter the regression equation at all. We examined four traits that appeared to be good prima facie candidates for an association with both sporting achievement and prenatal testosterone. None was associated with digit ratio. Previous findings have been equivocal concerning associations between digit ratio and personality traits. Dominance, conceptually allied to social potency, was found by Putz et al. (2004) to be unrelated to digit ratio, but this was based on a single-item measure. Sensation seeking, the conceptual inverse of harm avoidance, has been linked to low digit ratio in women but not in men (Austin et al. 2002). No data have been published on achievement and control. While information is available on personality and circulating testosterone, extrapolations to prenatal effects would be premature because the link between digit ratio and adult circulating testosterone is not yet established in healthy men (Manning et al., 1998; Neave et al., 2003). Digit ratio is a useful but indirect proxy measure for prenatal testosterone. Future studies might consider a more direct assessment within a longitudinal design: Testosterone can be extracted from amniotic fluid during gestation (Lutchmaya et al., 2004) and from the umbilical cord blood at birth (Tan & Tan, 2001). Together with genetic information on androgen receptors, a more precise assessment could be made.

Given that the both personality traits and sports achievement were obtained by self-report methods, it might be suggested that they would share variance as a result of common measurement. However, only social potency correlated with sports rank, and this variable failed to enter the regression equation, adding weight to the importance of digit ratio as a strong predictor of sporting ability. With regard to personality measurement, it might be argued that sport-specific inventories would have been more appropriate, but we consciously selected general trait measures because organized sport has been a relatively recent cultural development. There is no reason to suppose evolutionary selection pressures for sporting personalities per se but rather for traits relevant to male reproductive success (e.g., dominance, risk taking) that have subsequently been co-opted for sport. Furthermore, the MPQ is a widely used instrument demonstrating considerable convergent validity with other inventories and with ratings by parents and friends (Patrick et al., 2002).

Unlike Manning and Taylor, we failed to find any association between mental rotation and digit ratio. However, other studies have similarly produced null findings (e.g. Austin et al., 2002; Putz et al., 2004). It is more difficult to explain the negative relationship between sports rank and mental rotation in light of previous positive results (Manning & Taylor, 2001), although null results have also been reported (Scali, Brownlow, & Hicks, 2000). It may be that the essentially sedentary, cognitive, and reflective nature of the mental rotation task is less well suited to detecting sports ability than a measure more clearly geared to relevant variables such as trajectory prediction and the speed and accuracy of motor response.

While there are other candidate psychological variables that still require examination, Manning and Taylor (2001) have suggested that physiological variables, specifically cardiovascular efficiency, might be profitably examined. Recent work suggests that low testosterone levels are associated with cardiovascular events such as acute myocardial infarction and stroke (Rosano, 2000). Androgen replacement therapy enhances coronary blood flow and vasomotion, and acute administration of testosterone increases exercise tolerance in men with coronary artery disease (Rosano et al., 1999). Manning and Bundred (2000) have suggested that formation of the cardiovascular system is sensitive to prenatal testosterone. In support of this, Honekopp, Manning, and Muller (2006) recently reported a significant relationship between digit ratio and physical fitness as assessed by performance on a series of gym-based tests. Among men, this relationship was statistically mediated by exercise frequency, and they suggest that prenatal androgenization may increase motivation to train. These results, taken together, suggest that low 2D:4D individuals may experience reduced energetic demands of exercise and, in consequence, a greater enjoyment of training. The sporting benefits of a low digit ratio may be as much in the body as in the mind.

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