

Research article

Exploring the organizational effect of prenatal testosterone upon the sporting brain

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Abstract

The 2D:4D ratio is a putative marker for prenatal testosterone and has the potential to explain variations in sport performance. To date there has been little research into the association between sporting performance, digit ratio and psychological variables. This study examined the relationship between 2D:4D and mental toughness, optimism, goal orientations, aggression, coping style and their association with sporting achievement. A post facto design was adopted. Participants consisted of an opportunity sample of 122 sports people: male ($n = 60$) and female ($n = 62$) from a university in North East England. Following informed consent, a Vernier Caliper was used to measure digit ratio hand scans. Participants completed self-reports measures including, the Alternative Psychological Performance Inventory (Golby et al., 2008), Sport Mental Toughness Questionnaire (Sheard et al., 2009), Life Orientation Test-Revised (Scheier et al., 1994), Buss-Perry aggression (Buss-Perry, 1992) and 30 item coping style questionnaire (Joseph et al., 1995). MANOVA revealed significant gender differences in 2D:4D with males demonstrating lower ratios (Manning, 2002). The 2D:4D was found to differentiate eleven of the seventeen measured variables, including mental toughness scores ($p < 0.001$) and varying levels of sporting achievement i.e. international/national, regional and school levels ($p < 0.001$). Specifically, this difference was significant when comparing the highest (international/national) and lowest (leisure/school) groups. Perhaps there is a threshold for prenatal testosterone's influence upon sporting ability. Further research is necessary to examine the subtle differences between competitors involved in different achievement levels. It is proposed that high prenatal levels of testosterone may contribute to the development of increased mental toughness, optimism, ego/task goal orientations in individuals, and hence aptitude towards sport. Findings lend support for the tentative claim that mental toughness may be partially biologically predetermined. Theoretical and practical implications are considered, along with limitations of the current study.

Key words: Digit ratio, sport performance, mental toughness, coping style, aggression.

Introduction

Success in sport is proposed to be determined by marginal psycho-physiological differences. Adaptive psychological variables, such as optimism (Norlander and Archer, 2002) and mental toughness (Golby and Sheard, 2004; Kuan and Roy, 2007), are increasingly recognized as important prerequisites to sporting success (Fletcher and Wagstaff, 2009). Research has recently considered the influence of biological factors on developing psychological constructs, i.e. (Golby and Sheard, 2006).

Initial research exploring the biological basis of

behavior has identified the organizational effects of prenatal testosterone on various adult psycho-physiological parameters (Neave et al., 2003). A putative marker for exposure to prenatal testosterone is the 2D:4D ratio (Honekopp et al., 2006). Testosterone influences the growth of the ring finger (4D), whereas oestrogen exposure stimulates the growth of the index finger (2D) (Manning, 2002). The ratio of the index finger to the ring finger (2D:4D) has been shown to be a sexually dimorphic trait. Specifically, males demonstrated a lower ratio, arguably due to increased prenatal testosterone exposure (Manning, 2002). It is suggested that high levels of prenatal testosterone may have a permanent masculinizing effect on human behavior, (Manning, 2002) which could potentially explain the relationship between sporting performance and 2D:4D (Honekopp et al., 2006).

"Masculine" attributes arguably play an important role in sport performance, e.g., aggression. Sports performance has been found to negatively relate to 2D:4D in sports such as football, athletics, skiing, fencing, cross country running and general fitness (Manning, 2002; Honekopp et al., 2006). It appears that those exposed to increased levels of prenatal testosterone have greater sporting ability. However, the exclusively male samples included in these studies limit the ability to generalize findings. Only two studies focus on females, one identified a negative association between digit ratio and endurance running performance (Paul et al., 2006) and similarly, another study located a negative association between 2D:4D and fencing performance (Voracek et al., 2010).

This link between digit ratio and sport performance is thought to be multidimensional. Significant associations have been widely noted between physiological parameters (e.g., effective cardiovascular system, physical fitness and visuo-spatial ability) and 2D:4D. Behavioral differences such as increased exercise frequency have been identified in those with low 2D:4D in comparison with high digit ratio (Honekopp et al., 2006). Surprisingly, only one study considered psychological variables in relation to levels of prenatal testosterone exposure. Tester and Campbell (2007) assessed the relationship between 2D:4D, social potency and harm avoidance, although they reported no significant findings. As there is scarce research to guide the selection of relevant psychological constructs in relation to 2D:4D and sport, the current study rationalizes the inclusion of the selected variables with reference to their proposed importance in sport performance.

One particular construct that may be deemed im-

portant in differentiating athletes' performance is mental toughness (Kuan and Roy, 2007; Golby and Sheard, 2004). The ability to regulate emotion and imagery effectively, display commitment and determination, possess an uncontrollable desire to succeed, and an unshakeable confidence, are all characteristic of mentally tough individuals (Crust and Clough, 2005). A further feature of mental toughness is the ability to adapt to stressful conditions. Dealing successfully with competitive stressors requires effective coping strategies. Individuals tend to have a preferred coping style that can be defined as the individual's tendency to respond and resolve problems with a particular style of action (Bolger, 1990). Three categories of response style: emotion (emotion regulation), task/approach (practical and logical solutions to eliminate or lessen the perceived stressor) and avoidance (avoiding consideration of the stressor) coping, were identified by Lazarus and Folkman (1984). In exploring the relationship between coping style, optimism and mental toughness, Nicholls et al. (2008) identified a relationship between mental toughness and utilization of more approach coping strategies and fewer avoidance tactics. Furthermore, an association between mental toughness and optimism was also reported.

Optimism is a disposition whereby individuals appraise potential outcomes positively (Burke et al., 2000). Optimism has been proposed to predict sporting achievement in sports such as cross country skiers and swimmers (Norlander and Archer, 2002). Several other psychological variables associated with sporting success have been related to optimism, including the direction of anxiety interpretation (Wilson et al., 2002). Specifically, athletes with a more optimistic disposition experienced increased facilitative anxiety perceptions (Wilson et al., 2002).

Ntoumanis (2001) proposed that an individual's motivation to compete and succeed in sport is important in determining subsequent levels of application. One existing motivation theory is the achievement motivation theory (Duda and Hall, 2001) which emphasizes the importance of goal orientation. The model proposes two distinct ego (out-performing peers) and task (intrinsic involvement) orientated goal categories. Duda and Treasure (2001) suggested that performers with adaptive, high task and ego goal orientations are better equipped to meet the demands of sport. However, research has suggested that task orientations are of greater benefit to sporting performance, since they promote self-control (Gano-Overway, 2008) and greater enjoyment (Spray et al., 1999).

Aggression serves as the final psychological factor included in this study, and may be positively associated with prenatal testosterone levels (Bailey and Hurd, 2005). In a sporting context, aggression is related to the athletes' tendency to "force action" (Kerr, 2004). Wilson (1983) found that women with low 2D:4D were more assertive and aggressive. Several studies have shown a negative correlation between aggression and 2D:4D (Bailey and Hurd, 2005). Further evidence is necessary to investigate this relationship.

This exploratory study was designed to examine the potential of varying levels of prenatal testosterone to differentiate individuals' levels of mental toughness,

preference of coping style, optimism, ego and task goal orientations and aggression, which are considered to be important prerequisites of sporting excellence.

Methods

Participants

The participants in this study were an opportunity sample of 122 (male = 60 and females = 62) sports people from a North Eastern university categorized as 18-25 years ($n = 90$) and 25+ years ($n = 32$), from all levels of sporting achievement: International/national ($n = 23$), Regional ($n = 43$), School/recreational ($n = 56$).

Participants included competitors from a range of sports, including swimming and climbing, and had between four and thirty years' experience of competition.

Measures

Mental toughness

The Alternative Psychological Performance Inventory (PPI-A, Golby et al., 2007) was used to measure mental toughness. The questionnaire obtains an overall toughness score, and 4 sub scale scores: self-belief, determination, positive cognition and visualization. Responses are given on a five point Likert scale, which ranges from 'almost always' to 'almost never'. Collectively satisfying absolute and incremental fit index benchmarks, the inventory possesses satisfactory psychometric properties, with adequate reliability and convergent and discriminant validity (Golby et al., 2007).

The Sport Mental Toughness Questionnaire (SMTQ, Sheard et al., 2009) was used as a secondary measure of mental toughness. The questionnaire yields a total mental toughness figure, and 3 subscale scores: confidence, constancy and control. There is preliminary support for the factor structure, reliability and validity of the measure (Sheard et al., 2009).

Aggression

The Buss-Perry scale (Buss and Perry, 1992) provides an overall value of aggression and four sub-scale measures: Physical aggression (9 items), Verbal aggression (6 items), Anger (6 items) and Hostility (8 items). Statements are rated on a seven point Likert scale, ranging from 'extremely characteristic of me' to 'extremely uncharacteristic of me'. The measure has acceptable psychometric properties (Buss and Perry, 1992) and has been previously administered to sports persons (Lemieux et al., 2002).

Optimism scale

The Revised Life-Orientation Test (Scheier et al., 1994) comprises of three positive items, three negative items and four filler items. Statements are rated on a five point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. Scores range from 6-30, with a greater score representing higher optimism. Studies have shown the LOT-R to have acceptable validity and internal consistency (Smith, 2003). It is also appropriate in the assessment of athletes (Czech et al., 2002).

Coping strategies

Joseph et al. (1995) selected thirty coping style items, which were also used in this study. Style can be grouped into three categories: emotion (10 items), problem (10 items) and avoidance coping (10 items) (Endler and Parker, 1990). Statements are rated on a four point Likert scale, ranging from 'I do this a lot' to 'I never do this'. The score for each conceptual grouping can range from 10 to 40; overall scores ranging from 30 to 120. Psychometric properties of this measure are adequate (Joseph et al., 1995). Support is given to the utilization of this tool with competitive athletes (Nicholls et al., 2008).

Goal orientations

The Task and Ego Orientation in Sport Questionnaire (Duda and Nicholls, 1992) contains thirteen items: six indicating ego orientation and seven showing a task orientation. Items were rated on a five point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. Scores for ego orientation range from 6 to 30 and task orientation range from 7 to 35. The validity and internal reliability of this measure are deemed adequate (Ebbeck and Becker, 1994).

Digit ratio measurement

Digit ratio was measured using Vernier Calipers (Fink et al., 2006) accurate to 0.01 mm, which was grouped into low ($n = 61$) and high ($n = 61$) categories. Mean digit ratio for males is 0.96 (Manning, 2002), standard deviation is 0.04. The low group (0.90-0.96) is one and a half standard deviations below the mean. The high group (0.96-1.04) is two standard deviations above the mean.

Procedure

Following approval from the University Ethics Committee, requirements of the study were explained to participants before they gave signed consent to take part in the research. The confidentiality of results was explained to participants, who then completed the battery of questionnaires. They were finally required to provide a digital hand scan of both hands, which were computed using Vernier Calipers (Fink et al., 2006).

Data analyses

To explore the nature of the relationship between 2D:4D digit ratio and psychological variables, digit ratio was dichotomised using a mean split. Sport achievement level (international/national, regional, school and leisure) and digit ratio (high and low) group differences for each measured psychological characteristic were explored using a multivariate analysis of variance (MANOVA). Alpha was set at 0.05.

Recent studies have been criticized for including several measures of digit ratio within a single analysis (left/right hand) as it increases the probability of type I error (Voracek et al., 2006a; 2006b). Whilst the current research acknowledges this argument, Bonferroni correction compensates for this potential error. For the post-hoc tests, significance was set at $p < 0.025$.

Results

Means and standard deviations of all measured variables are presented in Table 1. There was a significant multivariate effect for right hand digit ratio, Wilks $\lambda = 0.581$, $F(1, 121) = 4.04$, $p < 0.001$, partial $\eta^2 = 0.419$, with significant differences observed in eleven of the seventeen dependant variables. This effect size is medium (Cohen, 1992) and is comparable to those reported by previous 2D:4D studies outside of sport (Grimbos et al., 2010).

Specifically, there were significant group differences in: *determination* $F(1, 121) = 23.22$, $p < 0.001$, partial $\eta^2 = 0.162$; *self-belief* $F(1, 121) = 20.75$, $p < 0.001$, partial $\eta^2 = 0.147$; *positive cognition* $F(1, 121) = 34.72$, $p < 0.001$, partial $\eta^2 = 0.224$; *visualization* $F(1, 121) = 44.55$, $p < 0.001$, partial $\eta^2 = 0.271$; *confidence* $F(1, 121) = 17.68$, $p < 0.001$, partial $\eta^2 = 0.128$; *constancy* $F(1, 121) = 7.604$, $p < 0.01$, partial $\eta^2 = 0.060$; *control* $F(1, 121) = 18.069$, $p < 0.001$, partial $\eta^2 = 0.131$; *optimism* $F(1, 121) = 9.989$, $p < 0.01$, partial $\eta^2 = 0.077$; *ego goal orientation* $F(1, 121) = 4.013$, $p < 0.05$, partial $\eta^2 = 0.032$; *task goal orientation* $F(1, 121) = 9.654$, $p < 0.01$, partial $\eta^2 = 0.074$ where those with a lower digit ratio scored higher than those with high 2D:4D. A significant group

Table 1. Means (\pm standard deviation) for all variables.

Variable	Mean (SD) low digit ratio (0.90-0.96)		Mean (SD) high digit ratio (0.97+)	
	Right hand	Left hand	Right hand	Left hand
PPI				
Determination	12.57 (1.89)	12.63 (1.92)	10.26 (2.80)	10.34 (2.72)
Self Belief	15.15 (2.85)	15.32 (2.79)	11.78 (3.34)	11.79 (3.27)
Positive Cognition	15.63 (2.33)	15.68 (2.37)	12.26 (2.88)	12.41 (2.84)
Visualisation	12.50 (2.9)	12.53 (2.96)	8.33 (3.16)	8.59 (3.19)
SMTQ				
Confidence	17.30 (3.72)	17.37 (3.76)	13.63 (2.87)	13.79 (2.85)
Constancy	13.05 (2.08)	13.13 (2.10)	11.48 (2.82)	11.48 (2.72)
Control	11.60 (2.37)	11.61 (2.43)	10.22 (2.74)	10.31 (2.66)
Optimism	22.30 (3.63)	22.29 (3.71)	19.89 (3.88)	20.07 (3.82)
Task coping	29.53 (3.97)	29.66 (4.03)	29.33 (4.91)	29.17 (4.77)
Emotion coping	25.70 (4.32)	25.84 (4.39)	27.04 (4.93)	26.76 (4.87)
Avoidance coping	22.55 (4.43)	22.55 (4.55)	22.74 (5.94)	22.72 (5.73)
Aggression				
Anger	19.11 (5.44)	18.86 (5.47)	20.67 (8.42)	20.88 (8.13)
Physical aggression	24.21 (9.25)	24.47 (9.42)	24.17 (11.34)	23.81 (10.97)
Hostility	15.13(5.81)	15.25 (5.83)	20.87 (11.27)	20.27 (11.11)
Verbal aggression	20.68 (6.64)	20.92 (6.75)	20.75 (8.70)	20.42 (8.43)
Task goal orientated	29.10 (3.23)	29.00 (3.27)	26.33 (4.56)	26.66 (4.56)
Ego goal orientated	17.65 (5.02)	17.70 (4.74)	15.15 (5.54)	15.03 (5.72)

Table 2. Mean (\pm standard deviation) of all variables displaying a significant difference in terms of sporting level of achievement.

Variable	Sporting level of achievement: Mean (SD)		
	1	2	3
Emotion coping	26.7 (2.58)	25.147 (4.81)	28.677 (4.37)
Task goal orientated	30.8 (3.49)	27.794 (3.80)	26.889 (4.35)
Ego goal orientated	20.3(4.06)	15.971 (4.80)	14.278 (5.45)
Determination	13.8 (1.40)	11.706 (2.26)	10.333 (3.05)
Self Belief	16.2 (2.15)	14.118 (3.80)	11.611 (2.66)
Positive Cognition	16.7 (2.0)	14.765 (2.13)	11.778 (3.41)
Visualisation	14.6 (1.96)	11.118 (3.03)	8.278 (3.74)
Confidence	19.7 (3.59)	15.853 (3.53)	13.333 (2.79)
Constancy	13.8 (1.30)	12.647 (2.50)	11.333 (2.60)
Optimism	22.43 (4.00)	21.40 (3.42)	18.51 (4.09)
Control	11.91 (2.04)	10.81 (2.59)	9.71 (2.77)
Hostility	14.04 (4.94)	20.35 (10.35)	22.67 (9.86)
Right hand digit ratio	.944(.02)	.961 (.03)	.979 (.03)
Left hand digit ratio	.945 (.14)	.959 (.03)	.981 (.25)

NB: National and above = 1, Regional = 2, Leisure/school = 3

difference was located in relation to *hostility* $F(1, 121) = 15.095$, $p < 0.001$, partial $\eta^2 = 0.112$, where those with high 2D:4D reported significantly greater levels.

All effect sizes are small to moderate in size, with positive cognition and visualization demonstrating the largest effect sizes of all measured variables. Despite the small effect sizes located in this study, this knowledge is arguably valuable due to the subtlety of the psychological differences considered in this research (Cohen, 1992). There was a larger significant multivariate effect for left hand digit ratio, Wilks $\lambda = 0.522$, $F(1, 121) = 3.98$, $P < 0.001$, partial $\eta^2 = 0.388$. All significant effects shown for right hand are identical for left hand ratio.

There was a significant medium multivariate effect for sporting level achievement, Wilks $\lambda = 0.00$, $F(1, 121) = 3.505$, $p < 0.001$, partial $\eta^2 = 0.366$, with significant differences observed in 14 of the dependant variables (digit ratio was utilised as a dependant variable also). Means and standard deviations of all variables displaying significant findings are contained in Table 2, and post-hoc analysis results are presented in Table 3.

Discussion

This paper aimed to explore the relationship between 2D:4D and several psychological variables, selected for their relevance to sporting success. It is the first study,

within 2D:4D literature, to focus on this particular combination of variables and to utilize a sample of mixed gender. Sexual dimorphism was observed in digit ratio, as expected (Manning, 2002), with males demonstrating lower values.

The main findings substantiate previous research; those exposed to high prenatal testosterone possess greater aptitude within sport (Honekopp et al., 2006; Manning, 2002; Manning and Taylor, 2001; Voracek et al., 2010). This difference was significant when comparing the highest (international/national) and lowest (leisure/school) groups; perhaps there is a threshold for prenatal testosterone's influence upon sporting ability. This finding extends previous research which merely identified a negative relationship between highest sport achievement level and digit ratio (Honekopp et al., 2006). Future research may wish to explore the variances in digit ratio between differing competitive levels further. The psychological differences identified among performers, competing at different sporting levels in this study, may illuminate the nature of this relationship.

Significant differences were identified in relation to all measured mental toughness subcomponents. Specifically, those competing at higher levels (international/national), and with low 2D:4D, scored higher on the subscales of self-belief (SMTQ), visualisation (SMTQ), confidence (PPI-A), control (PPI-A), constancy

Table 3. Summarises the results of the post-hoc ANOVA analysis.

Variable	National – Regional	National – Leisure	Regional – Leisure
	(presence of significant effect)	(presence of significant effect)	(presence of significant effect)
Emotion focused coping	No	No	Yes
Task goal orientation	No	Yes	No
Ego goal orientation	Yes	Yes	No
Determination	Yes	Yes	No
Visualisation	Yes	Yes	No
Self belief	No	Yes	Yes
Positive cognition	No	Yes	Yes
Constancy	No	Yes	No
Optimism	No	Yes	Yes
Control	No	Yes	No
Hostility	Yes	Yes	No
Right hand digit ratio	No	Yes	No
Left hand digit ratio	No	Yes	No
Confidence	Yes	Yes	Yes

(PPI-A), determination (SMTQ) and positive cognition (SMTQ) than those with high 2D:4D and competing at lower levels (leisure/school). This provides further support for the claim that these characteristics are important in sport performance (Crust, 2008; Golby and Sheard, 2004; Gucciardi et al., 2008), and also highlights the potential of prenatal testosterone in partially explaining their development. However, it is important to consider the possibility that the present results could be due to a remarkable coincidence, and further evidence is necessary before firm conclusions can be drawn.

Furthermore, athletes participating in the lower level of sporting achievement (school/leisure), selected emotion focused coping as the preferred style, significantly more than regional level individuals. Research has provided strong evidence for the claim that greater self-confidence is associated with an increased perception of influence over one's life outcomes (Moritz et al., 2000). This sense of empowerment, coupled with increased positive cognition, could relate to higher levels of emotional stability (Gucciardi et al., 2008). This would indicate less use of emotion focused strategies, which is characteristic of the mentally tough person (Nicholls et al., 2008). However, no differences were identified in individuals' use of avoidance and approach coping strategies. It is speculated that individuals performing at a high level have the ability to select coping strategies according to the stressor presented at that time. Future research may wish to address this claim.

Findings of the present study also show that those people who compete at an international/national standard and with low 2D:4D scored significantly higher on the subcomponents of determination (SMTQ) and visualization (SMTQ) than those competing at all lower levels and with high 2D:4D. Perhaps those competing at an elite level are likely to be exposed to visualization and imagery techniques more frequently than their non-elite counterparts (MacIntyre and Moran, 2007). They may possess greater determination, because of the enhanced work ethic necessary to succeed (Holland et al., 2010). Furthermore, the competitive nature of sport and constant performance comparison among athletes is likely to increase the use of ego goals (Stornes and Ommundsen, 2004).

Results found that individuals with a low 2D:4D reported high scores of optimistic disposition than those with high 2D:4D. Significant differences on the dispositional optimism scale were observed in relation to sporting level of achievement. Specifically, those competing at higher levels reported a greater optimistic disposition. This finding appears to support previous research, which suggests that optimism level may be an important factor in determining the level of effort invested to achieve goals (Nicholls et al., 2008) and is a significant predictor of success (Norlander and Archer, 2002).

Interestingly, this study's findings in relation to self-reported aggression scores appear incongruent with previous 2D:4D research. Several studies had noted a negative relationship between all subscales of aggression and 2D:4D, which was most recently replicated by Bailey and Hurd (2005). Whereas, the present study found that individuals with low 2D:4D, and currently competing in

higher levels of sport, reported significantly lower hostility. However, this finding is consistent with evidence from sport psychology: hostility was shown to be positively related to risk of injury (Galambos et al., 2005) and negatively associated with the number of training hours undertaken in martial arts (Daniels and Thornton, 1992). Further research may wish to explore the exact mechanisms underlying this relationship.

The current study serves as preliminary research into the associations between 2D:4D and several psychological characteristics thought to be related to successful sporting achievement. Present findings highlight the scope for future research in this area, along with the tentative proposal that prenatal testosterone exposure may partially explain adult sporting success. The prospect of developing objective biological measures, such as 2D:4D ratio, to support self-reported measures of assessment, could significantly advance issues with measurement validity and reliability. Additionally, the potential for fabricated or bias responses on self-report measures could be reduced with the addition of biological indices (Chalabaev et al., 2009). Limitations of the present research include its heterogeneous sample; addressing similar research questions within specific sports and levels may provide a more detailed insight. However, it should be noted that the psychological measurements selected for use in the present study may require further assessment and development i.e. mental toughness questionnaires (Crust, 2008) and the Task and Ego Goal Orientation in Sport Questionnaire (Lane et al., 2005). Until such issues are addressed, perhaps future research may wish to employ other sound psychometric measurements in the consideration of 2D:4D and psychological variables relevant to sport. Notwithstanding, the present study shows a clear link between sporting ability and 2D:4D ratio which is worthy of further research.

Conclusion

The current paper provides initial support for an association between prenatal testosterone levels and mental toughness, optimism, goal orientations, coping strategies and hostility. Findings tentatively suggest that the mentioned psychological characteristics may be partially biologically predetermined.

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Key points

- Increased prenatal testosterone exposure was associated with successful sport performance. There is a need to further consider psychological aspects related to sport performance and their potential relationship with 2D:4D.
- Mental toughness variables, optimism, goal orientation, hostility and coping style are related to levels of 2:4D.
- Perhaps with further substantiation, 2D:4D could provide a supporting objective measure, to complement existing psychometric instruments.

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