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Relationships between the digit ratio (2D:4D) and game-related statistics in professional and semi-professional male basketball players

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Abstract

Objectives

The primary aim of this study was to examine relationships between digit ratio (2D:4D) and game-related statistics in professional and semi-professional male basketball players. The secondary aim was to quantify differences in mean 2D:4Ds between starting and reserve players.

Methods

Using a cross-sectional design, 93 male basketball players from the professional Australian National Basketball League and the semi-professional South Australian Premier League were measured in-season for height, mass, and 2D:4D, with game-related statistics collected end-season. Linear relationships between right and left 2D:4Ds and game-related statistics were quantified using nonparametric partial correlations, and differences in mean 2D:4Ds between starting and reserve players were quantified using analysis of covariance (ANCOVA). All partial correlations and ANCOVAs were adjusted for playing experience, body size, and competitive standard.

Results

2D:4D was a weak to moderate negative correlate of points scored and assists-to-turnovers ratio, indicating that males with lower 2D:4Ds were generally better offensively as they recorded more points and assists relative to turnovers. The difference in mean 2D:4D between starting and reserve players was negligible.

Conclusions

2D:4D was favorably correlated with open-skill sports performance, as evidenced by the better offensive statistics of male basketball players with lower 2D:4Ds. These results probably reflect the organizational benefits of prenatal testosterone and indicate that 2D:4D may be a useful complement to traditional physical, physiological, skill, and behavioral predictors of basketball success.

1 INTRODUCTION

The digit ratio (2D:4D) is the ratio of the length of the second digit (2D; the index finger) and the fourth digit (4D; the ring finger). Evidence indicates that 2D:4D is developmentally stable and fixed as early as the second semester of pregnancy (Malas, Dogan, Evcil & Desdicioglu, 2006), which is why it has been used as a marker of prenatal testosterone and estrogen. Males typically have lower 2D:4Ds (ie, relatively longer 4Ds) than females (Manning, 2002a) probably as a result of a sex-related difference in prenatal testosterone and estrogen levels, as the fetal 4D has large numbers of receptors for androgen and estrogen (Manning, 2011; Zheng & Cohn, 2011).

Prenatal testosterone has long-term organizational effects on the structure and function of several bodily systems (eg, the cardiovascular and musculoskeletal systems) (Geschwind & Galaburda, 1987) that are important for physical activity and exercise. 2D:4D is also thought to be a marker of the short-term activational effects of adult testosterone. Men with lower 2D:4Ds tend to experience more marked spikes in testosterone during challenging situations (eg, in competitive sports) (Kilduff, Hopp, Cook, Crewther & Manning, 2013; Kilduff et al., 2013), and 2D:4D modulates the effects of exogenous testosterone application on empathy, moral judgments, cooperation, aggression, status, and para-hippocampal activity associated with mental rotation task scores in men (Carré et al., 2015; Wu, Zilioli, Eisenneger, Clark & Li, 2017) and women (van Honk, Montoya, Bos, van Vugt & Terburg, 2012; van Honk, 2011).

2D:4D has consistently been shown to be a negative correlate of sports performance, athletic performance and physical fitness; individuals with low 2D:4Ds are more likely to perform better than individuals with high 2D:4Ds (Dyer, Short, Short, Manning & Tomkinson, 2018; Frick, Hull, Manning & Tomkinson, 2017; Hönekopp & Schuster, 2010; Hull, Schranz, Manning & Tomkinson, 2015; Manning & Taylor, 2001; Tomkinson & Tomkinson, 2017). This relationship was first demonstrated in English professional football (soccer) players by Manning and Taylor (2001) and subsequently across a range of sports including (but not limited to) American football (gridiron) (Schorer, Rienhoff, Westphal & Baker, 2013), basketball (Dyer et al., 2018; Frick et al., 2017), cross-country running (Manning, Morris & Caswell, 2007), fencing (Voracek, Reimer & Dressler, 2010), handball (Baker et al., 2013), kabaddi (an Indian contact sport) (Sudhakar, Majumdar, Umesh & Panda, 2014), rowing (Hull et al., 2015), rugby (Bennett, Manning, Cook & Kilduff, 2010), sprinting (Manning & Hill, 2009), slalom skiing (Manning, 2002b), sumo wrestling (Tamiya, Lee & Ohtake, 2012), surfing (Kilduff, Cook & Manning, 2011), swimming (Perciavalle, Corrado, Scuto, Perciavalle, & Coco, 2014), tennis (Hsu et al., 2015), and volleyball (Panda, Majumdar, Umesh & Sudhakar, 2014).

Available research has considered relationships between 2D:4D and both closed-skill and open-skill sports performance. Closed-skill sports require athletes to initiate the action and perform in stable, predictable, and self-paced environments (eg, golf, running, swimming), whereas open-skill sports require athletes to react to a stimulus and perform in unstable, unpredictable, and externally paced environments (eg, basketball, hockey, football) (Wang et al., 2013). Three studies have examined the relationship between 2D:4D and basketball performance (Dyer et al., 2018; Frick et al., 2017; Tester & Campbell, 2007). Tester and Campbell (2007) reported a moderate negative relationship between 2D:4D and the highest competitive standard attained in 155 university students who played basketball, football, and rugby. Unfortunately, the authors did not report a separate correlation for basketball players. Frick et al. (2017) reported differences in mean 2D:4Ds between male basketball players competing at four different competitive standards (club, state, national, and international), with players who attained a higher standard of play tending to have lower 2D:4Ds. They also reported that the 2D:4D was not meaningfully related to game-related statistics in professional players. More recently, Dyer et al. (2018) observed that semi-professional female players with low 2D:4D had better game-related statistics (specifically better defensive statistics, eg, higher rebound and block counts) and were more likely to be starting players. The aim of this study, therefore, was to expand the participant pool of Frick et al. (2017) and to re-examine relationships between 2D:4D and game-related statistics in both professional and semi-professional male basketball players. The secondary aim was to quantify differences in mean 2D:4Ds between starting and reserve players. It was hypothesized that in this more mixed group of male basketball players, 2D:4D will be a meaningful negative correlate of game-related statistics and that starters will exhibit lower mean 2D:4Ds.

2 METHOD

2.1 Subjects

This study is a secondary analysis of a cross-sectional dataset that was used to examine the relationship between 2D:4D and basketball performance in Australian men (Frick et al., 2017). Ninety-three Australian male basketball players from the Australian National Basketball League (NBL; a national professional basketball league) and the South Australian Premier League (PL; a state-based semi-professional basketball league) volunteered for this study. This sample represented 43% (93/215) of all eligible players (ie, those who played in at least half of the regular season games) and 86% (19/22) of all teams. Players identified as playing the guard (44% or 41/93), forward (42% or 39/93) or center (14% or 13/93) position, with approximately three-quarters identifying as starters (72% or 67/93). Players had an average of 6 years (range: 0–20) of experience at their respective competitive standard, played an average of 46% (range: 6%–83%) of game time and in an average of 89% (range: 50%–100%) of regular season games. Means±SD for the sample were as follows: age, 25 ± 5 years; height, 195 ± 9 cm; mass, 93 ± 12 kg; BMI, 24 ± 2 kg/m2; right 2D:4D (2D:4DR), 0.955 ± 0.038; and left 2D:4D (2D:4DL), 0.959 ± 0.040. All players (a) were informed of the benefits and risks of the study prior to providing signed informed consent, (b) must have played in at least half of the NBL and PL regular season games, and (c) were of European descent because of known ethnic differences in 2D:4Ds (Manning, Churchill & Peters, 2007). Participants who self-reported a major injury (eg, dislocation or break) to either the 2D or 4D were excluded. The Human Research Ethics Committee of the University of South Australia and the Institutional Review Board of the University of North Dakota approved this study.

2.2 Procedures

Participants self-reported age, ethnicity, playing team, playing position (guard, forward, or center), and whether they were a starter or a reserve. Standing height was measured to the nearest 0.1 cm using a stadiometer, body mass was recorded to the nearest 0.1 kg using a digital weighing scale, and body mass index (BMI) was subsequently derived.

2D and 4D lengths were measured from digital photographs of the palmar surface of each participant's outstretched right and left hands using the detailed procedures described by Hull et al. (2015). Cartesian coordinate geometry was used to determine 2D and 4D lengths, with 2D:4D calculated by dividing the 2D length by the 4D length. This method demonstrates very good repeatability and validity (vs direct caliper measurements) (Dyer et al., 2018; Frick et al., 2017; Hull et al., 2015). Prior to analyzing the study data, intra-tester and inter-tester repeatability and validity were assessed using a sample of 20 adults. Intra-tester repeatability was determined by comparing duplicate digital measurements of the lead author (KSK vs KSK) and inter-tester repeatability by comparing single measurements of the lead and senior authors (KSK vs GRT). The 2D:4Ds demonstrated very good intra- and inter-tester repeatability, with negligible systematic errors (change in means: intra-rater, <0.5%; inter-rater, <0.3%), small random errors (typical error: intra-rater, <1.0%; inter-rater, <1.0%), and nearly perfect test-retest correlations (intra-class correlation: intra-rater, >0.96; inter-rater, >0.97). The 2D:4Ds also demonstrated very good validity with small systematic errors (change in means: <0.9%), small random errors (typical error: <1.0%), and nearly perfect test-retest correlations (intra-class correlation: >0.92).

Game-related statistics for registered players were available from the official NBL (www.nbl.com.au) and PL websites (http://websites.sportstg.com/assoc_page.cgi?c=1-3656-0-0-0). These statistics were collected by NBL and PL statisticians and published as open access official game statistics, including: points, rebounds, assists, turnovers, steals, blocks, field goal percentage (FG%), three point percentage (3FG%), free throw percentage (FT%), and average minutes played. Game-related statistics (except the shooting efficiency statistics FG%, 3FG% and FT%), were standardized to the widely used metric of per 36 minutes (see below) to eliminate the influence of number of games played and playing time (Frick et al., 2017).

$$\left(\frac{\text{game–related statistic}}{\text{games played}}\right) \times \left(\frac{36}{\text{minutes per game}}\right)$$

2.3 Statistical analyses

Because playing experience and body size (operationalized as height and mass) were weak to strong correlates of game-related statistics, and because players competed at two different competitive standards, linear relationships between the 2D:4Ds and game-related statistics were quantified using partial correlations adjusted for playing experience, body size and competitive standard. Playing position was not used as a covariate because it was very strongly correlated with body size ($r > 0.7$) and was therefore considered to be statistically redundant. Nonparametric partial correlations and 95% confidence intervals were calculated for offensive (points, offensive rebounds, assists-to-turnovers ratio [assists: turnovers], FG%, 3FG%, and FT%) and defensive (defensive rebounds, steals, and blocks) game-related statistics separately (SPSS v24, IBM, Armonk, NY). To interpret the magnitude of correlation, effect sizes (ES) of 0.1, 0.3, and 0.5 were used as thresholds for weak, moderate, and strong respectively, with ES < 0.1 considered to be negligible and ES > 0.1 considered to be meaningful (Cohen, 1988). Negative correlations indicated that males with lower 2D:4Ds had better game-related statistics and positive correlations that males with lower 2D:4Ds had poorer game-related statistics.

Differences in mean 2D:4Ds between starting and reserve players were quantified using analysis of covariance (ANCOVA) adjusted for playing experience, body size, and competitive standard. Differences in means were expressed as absolute differences, with positive differences indicating higher 2D:4Ds for starters and negative differences indicating lower 2D:4Ds for starters. To interpret the magnitude of differences, ES (partial $\eta 2$) of 0.1, 0.6, and 1.4 were used as thresholds for small, moderate and large respectively, with ES < 0.1 considered to be negligible and ES > 0.1 considered to be meaningful (Cohen, 1988).

3 RESULTS

Partial correlations (adjusted for playing experience, body size, and competitive standard) between 2D:4D and game-related statistics ranged from moderate negative to negligible positive. Both 2D:4DR and 2D:4DL were weak to moderate negative correlates of points and assists: turnovers, indicating that males with lower 2D:4Ds scored more points and recorded more assists relative to turnovers (Figure 1). Somewhat stronger relationships were observed between 2D:4D and per 36-minute offensive statistics (mean partial r [range]: −0.20 [−0.28 to −0.11]) than between 2D:4D and per 36-minute defensive statistics (mean partial r [range]: −0.09 [−0.14 to −0.03]) (Figure 1). Both 2D:4DR and 2D:4DL were negligible to weak negative correlates of shooting efficiency (data not shown).

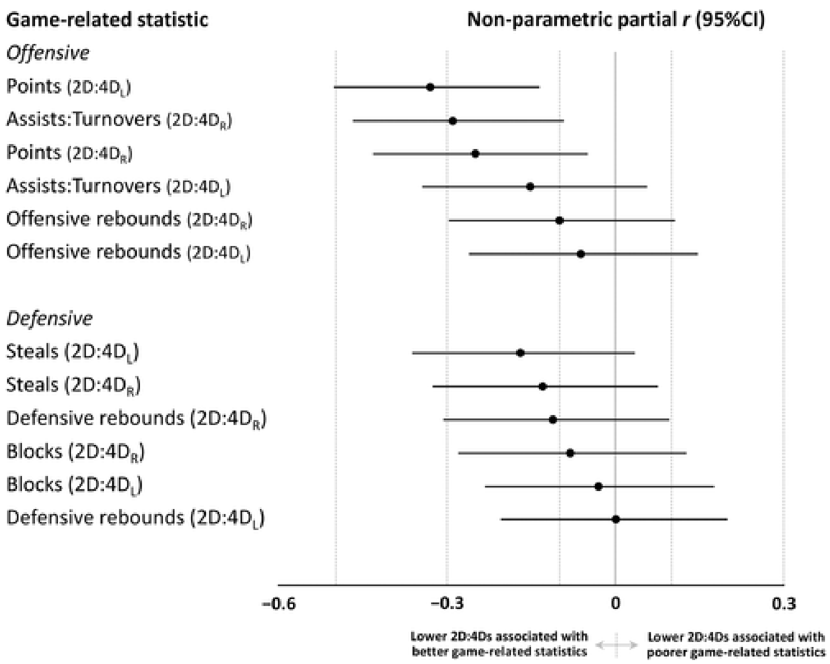

Figure 1

Forest plot of the nonparametric partial correlations (95% CIs) (adjusted for playing experience, body size, and competitive standard) between 2D:4D and per 36-minute game-related statistics. The black dots represent the correlations between 2D:4D and game-related statistics and the solid horizontal lines represent the corresponding 95% CIs. Negative correlations indicate that men with lower 2D:4Ds had better game-related statistics and positive correlations indicated that men with lower 2D:4Ds had poorer game-related statistics. The dashed vertical lines represent Cohen's standardized thresholds for weak, moderate, and strong correlations. Note: 2D:4DR = right 2D:4D; 2D:4DL = left 2D:4D; 95% CI = 95% confidence interval

Mean 2D:4D did not differ between starting and reserve players (difference in means [95%CI]: 2D:4DR, 0.005 [−0.012, 0.022], ES = negligible; 2D:4DL, −0.008 [−0.026, 0.010], ES = negligible) following adjustment for playing experience, body size and competitive standard. There were no statistically significant ($P < .05$) interaction effects between starters/reserves and the covariates (ES = negligible to small).

4 DISCUSSION

In this study, 2D:4D was a weak to moderate negative correlate of several offensive game-related statistics, even when adjusted for playing experience, body size, and competitive standard. These results indicate that male basketball players with low 2D:4Ds tend to perform better in professional and semi-professional games, especially offensively by scoring more points and recording more assists relative to turnovers. Mean 2D:4D did not differ meaningfully between starting and reserve players.

The results of this study probably reflect the long-term organizational benefits of prenatal testosterone, which has powerful long-term benefits to the developing human. Prenatal testosterone influences the growth and development of the heart, muscles, bones and brain (Geschwind & Galaburda, 1987), all of which are important for sporting success. Physical fitness is an important determinant of success in basketball, with upper body strength, lower body explosive strength, running speed/agility, and cardiorespiratory endurance all favorably correlated with game-related statistics, especially offensive statistics (Castagna, Chaouachi, Rampinini, Chamari & Impellizzeri, 2009; McGill, Andersen & Horne, 2012). For example, upper body strength is required for dribbling, passing and shooting; lower body explosive strength is required to jump for scoring; speed/agility is required for dribbling the ball up the court quickly and for scoring; and cardiorespiratory endurance is required for rapid recovery from repeated short bursts. 2D:4D has been favorably correlated with cardiorespiratory endurance, for example, maximal oxygen uptake (urn:x-wiley:10420533:media:ajhb23182:ajhb23182-math-0002O2max), running speed at urn:x-wiley:10420533:media:ajhb23182:ajhb23182-math-0003O2max, and peak blood lactate concentration (Hill, Simpson, Millet, Manning & Kilduff, 2012), muscular strength, for example, upper body strength (Fink, Thanzami, Seydel & Manning, 2006; Tomkinson & Tomkinson, 2017), and lower body explosive strength (Hsu et al., 2018) and speed, for example, both short- and long-distance running speed (Manning & Hill, 2009; Manning et al., 2007) in males.

Mental toughness also plays an important role in sporting success. Mentally tough athletes are highly motivated, resilient, confident, and adapt well to stress (Crust, 2007). Mental toughness has been favorably linked with cognition, physical fitness, and basketball performance (Crust, 2007; Newland, Newton, Finch, Harbke & Podlog, 2013). In a study of 122 British athletes, Golby and Meggs (2011) found that those with low 2D:4Ds were mentally tougher, more determined, more confident and more optimistic.

It is also possible that the results of this study reflect the short-term activational benefits of testosterone. Low 2D:4D has been favorably correlated with marked spikes in testosterone in men during challenging situations, such as when exposed to aggressive stimuli and/or intense exercise (Kilduff et al., 2013; Kilduff et al., 2013). This suggests that men with low 2D:4D will be more aggressive and will take more risks when they are challenged, such as in competitive sports like basketball. There is certainly some evidence for this in male sport. For example, elite football players with low 2D:4D tend to be more aggressive and commit more fouls per game (punished by the referee as a caution [yellow card] or as an expulsion [red card]) than players with high 2D:4D (Mailhos, Buunk, Del Arca & Tutte, 2016; Perciavalle, Di Corrado, Petralia, Gurrisi, Massimino & Coco, 2013).

The results of this study are theory-consistent, showing that 2D:4D is meaningfully linked with sports, athletic, and fitness test performance (Dyer et al., 2018; Frick et al., 2017; Hönekopp &

Schuster, 2010; Hull et al., 2015; Manning & Taylor, 2001; Tomkinson & Tomkinson, 2017). They also support the results of of Dyer et al. (2018) who found that semi-professional female players with low 2D:4D recorded better game-related statistics, especially better defensive statistics. It is therefore probable that prenatal testosterone benefits numerous bodily systems and behaviors that are important for basketball performance, which seemingly manifest in different ways for males (offensively) and females (defensively). Unlike Frick et al. (2017), who found that 2D:4D was not meaningfully related to game-related statistics in professional male players, this study found that 2D:4D was, in fact, meaningfully related to game-related statistics in a more mixed group of male basketball players that included both professional and semi-professional players. This between-study difference is likely due to differences in sample heterogeneity. Professional basketball players have almost certainly been selected by a stricter set of physical, physiological, skill, and behavioral criteria than semi-professional players, resulting in reduced performance variability and therefore weaker 2D:4D-performance correlations. Furthermore, unlike in closed-skill sports, single measures (such as the 2D:4D) are not typically favorably related to performance in open-skill sports such as basketball. This is because numerous factors resulting from the collective actions of all players, rather than a single player, are required for success in open-skill sports (Burgess & Naughton, 2010). This may help explain why the magnitude of the relationships between 2D:4D and basketball performance found in this study are somewhat smaller than those found in some closed-skill sports, for example, cross-country running (Manning et al., 2007), rowing (Hull et al., 2015), slalom skiing (Manning, 2002b), and swimming (Perciavalle et al., 2014).

This study adds to a growing body of literature examining the relationship between 2D:4D and sports/athletic performance, specifically the literature examining the relationships between 2D:4D and open-skill sports performance. It has several strengths. First, the sample consisted of only regular-team professional and semi-professional male basketball players, resulting in more reliable per 36-minute statistics. Second, it controlled for ethnicity, which contributes to variability in 2D:4D (Manning et al., 2007). Third, it used a validated photographic technique and Cartesian coordinate geometry to measure digit lengths, thus avoiding the potential confound of placing fingers downwards onto a glass surface, which may distort the fat pads of the finger tips and impact 2D:4D estimates (Ribeiro, Neave, Morais & Manning, 2016). Fourth, it adjusted relationships and differences in means for playing experience, body size and competitive standard, which were meaningful correlates of game-related statistics. Fifth, it related 2D:4D to game-related statistics that were collected by professional statisticians.

This study is, however, not without its limitations. Because the basketball players were in competition at the time of testing, it was impossible to measure all NBL and PL players, resulting in a smaller than expected sample. However, while small samples unfortunately reduce statistical confidence, they do not systematically bias the correlational estimates. Unfortunately, this study did not control for handedness, which has been shown to be meaningfully related to 2D:4D (Manning & Peters, 2009). Despite excluding individuals who self-reported major injuries to either the 2D or 4D, it is possible that minor injuries (eg, sprains, strains) also affected the 2D:4Ds. While this study improves our understanding of the relationships between 2D:4D and basketball performance, future studies should examine these relationships in athletes across a range of open-skill sports (including both field and court sports), across a range of competitive standards (in order to better understand the within-standard relationships and between-standard differences in 2D:4D) and across different ethnicities. Future studies may also wish to examine relationships between 2D:4D and overall quality of play measures (eg, composite statistics such as the player efficiency rating [https://en.wikipedia.org/wiki/Player_efficiency_rating] or the performance index rating [https://en.wikipedia.org/wiki/Performance_Index_Rating]), which unfortunately could not be examined in this study, or relationships between 2D:4D and team performance (eg, league ladder position).

Consistent with theory, this study found that 2D:4D was a meaningful negative correlate of game-related statistics in professional and semi-professional male basketball players. Males with lower 2D:4Ds were more likely to be better offensive players irrespective of their playing experience, body size, and competitive standard. These results are probably due to the underlying organizational benefits of prenatal testosterone. This study encourages additional research into the relationships between 2D:4D and open-skill sports performance in order to more confidently understand true relationships.

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CONFLICT OF INTEREST

We declare no conflicts of interest.

AUTHOR CONTRIBUTORS

KLK and GRT developed the research questions and designed the study; had full access to all the data in the study and take responsibility for the integrity of the data; led the statistical analysis, synthesis of results, and wrote the report. All authors contributed to the interpretation of results, and edited, critically reviewed and approved the final report.

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