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

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Abstract

Objective

Digit ratio (2D:4D) is a negative correlate of sports performance, although this relationship may be weak in open-skill sports such as basketball. The primary aim was to quantify relationships between 2D:4D and game-related statistics in semi-professional female basketball players. The secondary aim was to quantify the differences in mean 2D:4Ds between players based on their position in the starting lineup.

Methods

Using a cross-sectional design, 64 female basketball players who competed in the South Australian Premier League were measured in-season for height, mass, and 2D:4D, with game-related statistics collected end-season. Partial correlations (adjusted for age and body mass index) were used to quantify relationships between right and left 2D:4Ds and game-related statistics. Unpaired *t*-tests were used to quantify differences in mean 2D:4Ds between starting and reserve players.

Results

2D:4D was a substantial negative correlate of blocks, rebounds, and field-goal percentage; meaning, females with lower 2D:4Ds were generally better defensively as they recorded more blocks and rebounds, and were more efficient scorers, irrespective of their age and body size. Mean 2D:4D differed by position in the starting lineup, as females with lower 2D:4Ds were more likely to be in the starting lineup.

Conclusions

This study found evidence that 2D:4D was a correlate of performance in an open-skill sport. Female players with lower digit ratios tended to perform better in several aspects of basketball, especially defensively, and were more likely to be starters, suggesting they are the best players on the team in their positions. These results probably reflect the organizational benefits of prenatal testosterone.

1 INTRODUCTION

Digit ratio, also known as 2D:4D, is the ratio of the length of the second digit (2D) to the length of the fourth digit (4D). This non-functional trait is thought to be established by birth, with evidence indicating that the 2D:4D is essentially fixed as early as the second trimester of pregnancy (Lutchmaya, Baron-Cohen, Raggat, Knickmeyer, & Manning, **2004**; Malas, Dogan, Evcil, & Desdicioglu, **2006**). 2D:4D is developmentally stable across the lifespan, which is why it is a commonly used proxy measure for prenatal testosterone and estrogen (Trivers, Manning, & Jacobson, **2006**). 2D:4D is sexually dimorphic, with males typically displaying lower 2D:4Ds than females. This sex difference likely reflects a balance between prenatal testosterone and estrogen, as the fetal fourth digit has large numbers of receptors for androgen (Manning, **2011**; Zheng & Cohn, **2011**).

2D:4D is considered a proxy of prenatal testosterone (Zheng & Cohn, **2011**). Prenatal testosterone has numerous long-term organizational effects on the body, including the regulation of numerous skeletogenic genes responsible for increased growth and development of the skeleton, brain, and several other physiological systems (e.g., cardiovascular and endocrine systems) (Kimura, **1996**; Mortlock & Innis, **1997**; Zheng & Cohn, **2011**). Individuals with lower 2D:4Ds have enhanced visual-spatial processing abilities, due to better right-hemisphere brain development, which are important for sports/athletic performance (Manning & Taylor, **2001**; Peters, Manning, & Reimers, **2007**; Tlauka, Williams, & Williamson, **2008**). Research has also suggested that 2D:4D may reflect the short-term activational effects of testosterone. For example, low 2D:4D has been correlated with marked spikes in testosterone in men during "challenge" situations, such as those experienced during competitive sport (Crewther, Cook, Kilduff, & Manning, **2015**), and with high sensitivity to circulating levels of testosterone in both men and women (Buskens, Raub, van Miltenburg, Montoya, & van Honk, **2016**; Carré et al., **2015**; Chen, Decety, Huang, Chen, & Cheng, **2016**).

Researchers have suggested that 2D:4D is negatively correlated with performance across a very wide range of sports, which was illustrated in a detailed study of professional soccer players from the English leagues (Manning & Taylor, **2001**). Subsequently, results from studies on the relationship between the 2D:4D and sports/athletic performance have generally reported weak negative correlations, but with considerable variability across different activities (e.g., Hönekopp & Schuster, **2010**; Moffit & Swanik, **2011**; Tester & Campbell, **2007**). The most comprehensive of these studies was a meta-analysis of 25 studies and 2527 participants across numerous sports/athletic events. The overall relationship between 2D:4D and sports/athletic performance was weak and negative, indicating that athletes with lower 2D:4Ds performed better (Hönekopp & Schuster, **2010**). While most of the studies analyzed by Hönekopp and Schuster (**2010**) considered individual disciplines, subsequent studies on team sports such as American football (Schorer, Rienhoff, Westphal, & Baker, **2013**), volleyball (Panda, Majumdar, Umesh, & Sudhakar, **2014**), and basketball (Frick, Hull, Manning, & Tomkinson **2017**), showed similar results. Relative to males, much less is known about the 2D:4D-performance relationship in females. While available research has indicated that the relationship is stronger in males than in females, meaningful relationships have been observed in females (Hönekopp & Schuster, **2010**; Hull, Schranz, Manning, & Tomkinson, **2015**), highlighting the need for further investigation to better understand true relationships.

While much of the available research examining the 2D:4D-performance relationship is available for closed-skill sports athletes (ie, those who perform in stable, predictable, self-paced environments where the athlete initiates the action; Wang et al., **2013**), future research should also consider open-skill sports athletes (ie, those who perform in unstable, unpredictable, externally paced environments where the athlete is required to react to a stimulus). Open-skill sports athletes perform better than closed-skill sports athletes in cognitively demanding tasks (Mann, Williams, Ward, & Janelle, **2007**; Voss, Kramer, Basak, Prakash, & Roberts, **2010**), the likely result of greater variability in visual attention, decision-making, and action execution (Taddei, Bultrini, Spinelli, & Di Russo, **2012**). Meaningful relationships between 2D:4D and open-skill sports performance have been observed in males (Frick et al., **2017**; Panda et al., **2014**; Schorer et al., **2013**), however, little is known about this relationship in females.

To date, only two studies have examined the relationship between 2D:4D and basketball performance (Frick et al., **2017**; Tester & Campbell **2007**). The first was a cross-sectional study of 12 teams (comprising both males and females) from three different sports (rugby, football [soccer], and basketball), where participants self-reported their highest competitive standard (Tester & Campbell, **2007**). Using pooled data across all three sports, Tester and Campbell (**2007**) reported a moderate negative correlation between 2D:4D and sporting competitive standard, with similar correlations observed for both males and females. Unfortunately, a separate correlation for basketball players was not reported. More recently, the relationship between 2D:4D and competitive basketball performance was examined in 221 Australian men who competed at different competitive standards (social, state, national, and international) (Frick et al., **2017**). Their results showed that the 2D:4D could discriminate between basketball players competing at different standards, but not within a competitive standard, as only negligible to weak correlations between 2D:4D and objective game-related statistics were observed. Unfortunately, the relationship between 2D:4D and basketball performance in females is unknown. The aim of this study therefore was to quantify relationships between 2D:4D and game-related statistics in semi-professional female basketball players. The secondary aim was to quantify differences in mean 2D:4Ds between female players based on their position in the starting lineup (ie, starters vs. reserves). We hypothesized that 2D:4D would be a weak negative correlate of basketball game-related statistics and that starters would exhibit lower mean 2D:4Ds.

2 METHODS

This study used a cross-sectional design.

2.1 Participants

Sixty-four Australian female basketball players from the Premier League (formerly the Central Australian Basketball League), a semi-professional basketball league in South Australia, Australia, volunteered for this study. This sample represented 70% (64/92) of all eligible players (ie, those who played in at least half of the regular season games) and 89% (8/9) of all teams. Players identified as playing the guard (44% or 28/64), forward (44% or 28/64), or center (12% or 8/64) positions, with approximately two-thirds identifying as starters (69% or 44/64). Players had an average of 5 years (range: 0–17) of Premier League experience and played an average of 15 (range: 10–20) regular season games. Means (SD) for the sample were as follows: age, 22 (4) years; height, 176 (7) cm; mass, 70 (8) kg; BMI, 23 (2) kg/m^2; right 2D:4D (2D:4DR), 0.979 (0.033); and left 2D:4D (2D:4DL), 0.975 (0.035). Signed informed consent was obtained from all participants, with only those of European descent included in the study 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 second digit (2D) or fourth digit (4D), or who did not play in at least half of the games within the regular Premier League season, were excluded. Participants were also excluded on the basis of poor photographic quality (see next section), when landmarks on the second or fourth digits could not be confidently identified. The Human Research Ethics Committee of the University of South Australia (P162-05) and the Institutional Review Board of the University of North Dakota approved this study.

2.2 Demographic information

Data on age, ethnicity, playing team, playing position (guard, forward, or center), and position in the starting lineup (starter or reserve), were gathered via a basic demographic and performance questionnaire. Standing height was measured to the nearest 0.1 cm using a stadiometer, and body weight was recorded to the nearest 0.1 kg using a digital weighing scale. Body mass index (BMI) was calculated from the measured height and weight values (kg/m^2).

2.3 2D:4D measurement

2D:4D was measured using the photographic method described by Hull et al. (**2015**). This method required participants to place their hands on a flat surface directly underneath a tripod mounted digital camera, with palmar surfaces facing up, fingers outstretched, and the basal creases and tips of the second and fourth digits visible. All photographs were imported into the image-editing program Adobe Photoshop CC 2017 (Adobe Systems, San Jose, CA) prior to identification and extraction of the *XY* coordinates corresponding to the basal creases and tips of the second and fourth digits of each hand. *XY* coordinate data were then manually entered into Microsoft Excel (Microsoft, Redmond, WA) in order to calculate digit lengths using Cartesian coordinate geometry, with 2D:4Ds of both the right and left hands calculated as the second digit length divided by the fourth digit length.

Unlike with other indirect methods (eg, photocopies or scans) of capturing images of digits, this method does not require that the digits be placed downward onto a glass surface, which may distort digit tips and influence 2D:4Ds (Ribeiro, Neave, Morais, & Manning, 2016). This method demonstrates very good repeatability and validity (vs. manual measurements) (Allaway, Bloski, Pierson, & Lujan, **2009**; Hull et al., **2015**; Ranson, Taylor, & Stratton, **2013**). Prior to analyzing the study data, intra-tester and inter-tester repeatability were assessed using a sample of 20 adults. Intra-tester repeatability was determined by comparing duplicate digital measurements of the lead author (MD vs. MD), and inter-tester repeatability by comparing single measurements of the lead author and the senior author (MD vs. GT). The 2D:4Ds demonstrated very good intra- and inter-tester repeatability, with negligible-to-small systematic errors (change in means: intra-rater, <0.8%; inter-rater, <1.5%), small random errors (typical error: intra-rater, <1.3%; inter-rater, <2.1%), and very good test-retest correlations (intra-class correlation: intra-rater, >0.95; inter-rater, >0.86).

2.4 Performance statistics

Game-related statistics were available from the official Premier League website (**http://websites.sportstg.com/assoc_page.cgi?c=1-3656-0-0-0**) for all registered Premier League players for a single season. These game-related statistics were collected by Premier League statisticians and published as public access official game statistics, which included: points, rebounds, assists, field goal percentage (FG%), 3-point percentage (3FG%), free throw percentage (FT%), steals, blocks, turnovers, and average minutes played. In order to remove the influence of playing time and number of games played, all game-related statistics were standardized to the widely used metric of per 36 minutes:

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

2.5 Statistical analysis

Descriptive characteristics for all variables were calculated as means and standard deviations. Because both age and body size (operationalized as the BMI) were negligible to moderate correlates of basketball game-related statistics, linear relationships between the 2D:4Ds and basketball game-related statistics were quantified using partial correlations adjusted for age and body size. Partial correlations and 95% confidence intervals (95% CIs) were calculated for offensive (points, assists, turnovers, FG%, 3FG%, and FT%) and defensive (blocks, rebounds, and steals) basketball game-related statistics. For interpretation, negative correlations indicated that females with lower 2D:4Ds had better game-related statistics and positive correlations indicated that they had poorer game-related statistics. Correlations of 0.1, 0.3, and 0.5 were used as thresholds for weak, moderate, and strong, with correlations <0.1 considered to be negligible and correlations ≥0.1 considered to be substantial (Cohen, **1988**).

Difference in mean 2D:4Ds between females based on their position in the starting lineup (starter or reserve) were examined using unpaired *t*-tests for groups with equal variances (quantified using Levene's test of equality of variance) or the Aspin–Welch *t*-tests used for groups with unequal variances. Differences in means were expressed as absolute and standardized differences with the latter calculated by dividing the absolute difference in means (mean for starters minus mean for reserves) by the pooled between-subjects standard deviation. Negative differences indicated lower 2D:4Ds for starters and positive differences indicated higher 2D:4Ds for starters. Standardized differences of 0.2, 0.5, and 0.8 were used as thresholds for small, moderate, and large respectively, with differences <0.2 considered to be negligible and differences ≥0.2 considered to be substantial (Cohen, **1988**).

3 RESULTS

Age- and BMI-adjusted partial correlations between 2D:4D and basketball game-related statistics ranged from a moderate negative correlation to a weak positive correlation (Figure **1**). Both 2D:4D$_R$ and 2D:4D$_L$ were moderate negative correlates of blocks, indicating that females with lower 2D:4Ds recorded more blocks. 2D:4D$_R$ was a weak negative correlate of field goal percentage and rebounds, and 2D:4D$_L$ was a weak negative correlate of rebounds, indicating that females with lower 2D:4Ds were more efficient scorers and recorded more rebounds (Figure **1**).

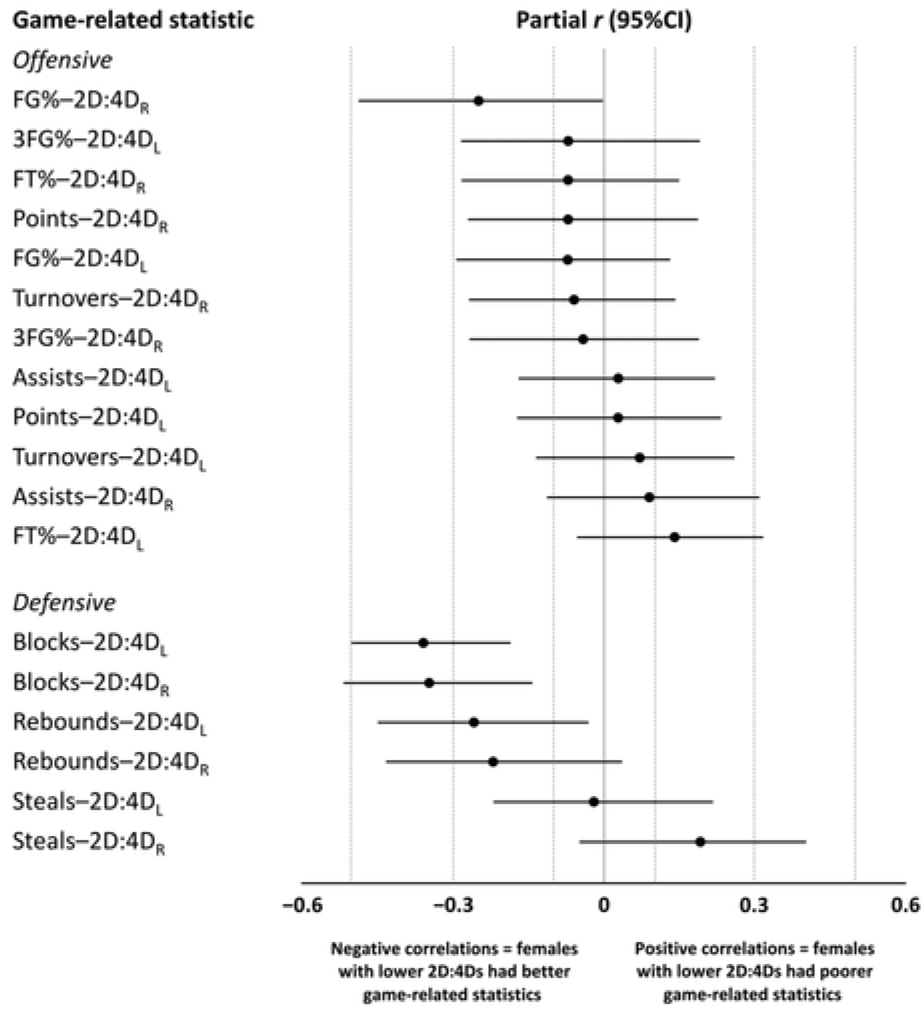

Figure 1

Forest plot of the age- and BMI-adjusted partial correlations (95% CIs) between 2D:4D and basketball game-related statistics. The black dots represent the correlations between 2D:4D and individual game-related statistics and the solid horizontal lines represent the corresponding 95% confidence intervals. Negative correlations indicated that females with lower 2D:4Ds had better game-related statistics and positive correlations indicated that they had poorer game-related statistics. The dashed vertical lines represent Cohen's standardized thresholds for weak, moderate, and strong correlations. Note:

$2D{:}4D_R$ = right 2D:4D; $2D{:}4D_L$ = left 2D:4D; FG% = field goal percentage; 3FG% = 3-point field goal percentage; FT% = free throw percentage

Mean 2D:4D differed by position in the starting lineup, with starters exhibiting lower $2D{:}4D_R$(difference in means [95% CI]: absolute units, −0.020 [–0.038, −0.003]; standardized units, −0.61 [–1.14, −0.08]; effect size, moderate) and trending toward lower $2D{:}4D_L$ (difference in means [95% CI]: absolute units, −0.014 [–0.033, 0.005]; standardized units, −0.39 [–0.92, 0.13]; effect size, small) values than reserves.

4 DISCUSSION

The results showed that in semi-professional female basketball players, 2D:4D was a substantial negative correlate of several game-related statistics, specifically defensive statistics, even when adjusted for age and BMI. In other words, female players with lower 2D:4Ds tended to perform better statistically in basketball games, especially defensively in terms of accumulating more blocks and rebounds, and being more efficient scorers, irrespective of their age and body size. A secondary finding was that mean 2D:4D differed by position in the starting lineup; that is, female players with lower 2D:4Ds were more likely to be included in the starting lineup as they are considered (by their coach at least) the best players on the team in their respective positions.

These results probably reflect the long-term organizational benefits of prenatal testosterone (and possibly the short-term activational benefits of adolescent/adult testosterone) that are important for the development of particular physical (eg, muscle mass), mental (eg, visual-spatial awareness, cognitive functioning), physiological (eg, muscular strength, cardiovascular efficiency), and behavioral systems (eg, aggressiveness, dominance) (Cohen-Bendahan, Buitelaar, Van Goozen, Orlebeke, & Cohen-Kettenis, **2005**; Manning & Taylor, **2001**; Zheng & Cohn, 2011). These benefits may help explain why players with lower 2D:4Ds were generally better defensively as evidenced by better block and rebound statistics, and may reflect players' aggressiveness/competitiveness, ability to handle physical contact, ability to read the play (eg, enhanced visual-spatial awareness leading to an improved ability to read the flight of the ball following a missed shot, resulting in a rebound), and/or underlying physical abilities (eg, enhanced explosive muscular strength leading to an improved jumping ability which is a strong positive correlate of the number of recorded blocks and rebounds in basketball; McGill, Andersen, & Horne, **2012**). Nonetheless, it is important to understand that single physical measures (such as the 2D:4D) are not usually favorably related to performance in open-skill sports (or open-skill dominant sports such as basketball) because numerous factors (determined by the collective actions of all players, not one individual) are involved in sporting success (Burgess & Naughton, **2010**; Jonker, Elferink-Gemser, & Visscher, **2010**).

While the results of this study are theory-consistent, showing that 2D:4D is substantially linked with physical performance (Hönekopp & Schuster, **2010**; Moffit & Swanik, **2011**; Tester & Campbell, **2007**), they are in contrast to those of Frick et al. (**2017**) who did not find any meaningful correlations between 2D:4D and game-related statistics in professional male basketball players. Differences between this and the Frick et al. (**2017**) study might be explained by sex differences, although larger 2D:4D-performance relationships in males were expected a priori. A more likely explanation is sample heterogeneity, which is known to affect correlation estimates. Athlete selection in elite sport is based on a range of very strict physical, physiological, skill, and behavioral criteria that often act to decrease performance variability, resulting in an athletic “survival of the fittest.” These performance range restrictions in professional male basketball, which are almost certainly stricter than those in semi-professional female basketball, may in part explain the observed between-study differences.

This study adds to a growing body of literature examining the 2D:4D-performance link in females, and especially adds to the paucity of literature examining the 2D:4D-performance link in open-skill sports. It used a validated photographic technique and Cartesian coordinate geometry to determine digit lengths and 2D:4Ds, thus avoiding the potential confound of placing fingers downward (resulting in distorted fat pads of the finger tips) onto a glass surface of a scanner or photocopier (Ribeiro et al., **2016**). It also applied strict inclusion/exclusion criteria, by including only females who played in at least half of the regular Premier League season games (leading to more reliable per 36-minutes game-related statistics) and who were of European descent (because of known ethnic differences in 2D:4Ds; Manning et al., **2007**). In addition, relationships between 2D:4D and game-related statistics were adjusted for age and BMI, both of which were substantially related to various basketball game-related statistics.

While every effort was made to measure all Premier League players, it proved difficult because the players were in competition at the time of testing, resulting in a smaller than anticipated sample. Nonetheless, small samples do not systematically bias correlational estimates, but they do unfortunately reduce statistical power. Future studies should examine relationships between the 2D:4D and open-skill sports performance in both field-based and court-based sports, as well as within and between competitive standards, in order to better understand these relationships.

5 CONCLUSION

Contrary to male evidence indicating that 2D:4D is not meaningfully related to basketball game-related statistics, this study found substantial age- and BMI-adjusted negative (and theory-consistent) relationships between 2D:4D and several basketball game-related statistics in semi-professional female basketball players. Females with lower 2D:4Ds were more likely to be better defensively and record more blocks and rebounds, were more efficient scorers, and were more likely to be included in the starting lineup. These results are probably due to the underlying organizational benefits of prenatal testosterone. This study adds to a limited body of research examining the 2D:4D-performance link in open-skill sports, and encourages additional research in order to more confidently draw conclusions as to the true relationships in open-skills sports.

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Conflict of interest

We declare no conflicts of interest.

Author Contributions

MD and GRT developed the research question 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, editing and critical reviewing of the final report, and approved the final report.

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