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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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RELATIONSHIPS BETWEEN THE DIGIT RATIO (2D:4D) AND GAME-RELATED STATISTICS IN PROFESSIONAL AND SEMI-PROFESSIONAL MALE BASKETBALL PLAYERS

by

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This thesis, submitted by Katelyn Lea Klapprodt in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by Faculty Advisory Committee underwhom the work has been done and is hereby approved.

Dr. Grant Tomkinson, Committee Chairperson

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This thesis being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

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Date

PERMISSION

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Katelyn Lea Klapprodt

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For my Family

ABSTRACT

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 male players based on their position in the starting lineup.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 partial correlations adjusted for playing experience, height, mass and competitive standard. Differences in mean 2D:4Ds between starting and reserve players were quantified using unpaired *t*-tests.2D:4D was a weak to moderate negative correlate of points scored, offensive and defensive rebounds, and assists-to-turnovers ratio, indicating that males with lower 2D:4Ds were generally better offensively as they recorded more points, rebounds, and assists relative to turnovers. The difference in mean 2D:4D between starting and reserve players was negligible.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.

Keywords

Finger ratio, anthropometry, sport, physical performance, males.

CHAPTER 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 stableand fixed as early as the second semester of pregnancy (19), which is why it has been used as a marker of prenatal testosterone and estrogen. Males typically have lower 2D:4Ds (i.e., relatively longer 4Ds) than females (20)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 (22,39).

Prenatal testosterone has long-term organizational effects on the structure and function of several bodily systems (e.g., the cardiovascular and musculoskeletal systems) (10) 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 (e.g., in competitive sports) (17,18), and 2D:4D modulates the effects of exogenous testosterone application on empathy, moral judgments, cooperation, aggression and para-hippocampal activity associated with mental rotation task scores (in men [3] and women [36,37]).

2D:4D has consistently been shown to be a negative correlate of sportsperformance, athletic performance and physical fitness; that is individuals with low 2D:4Ds are more likely to perform better than individuals with high 2D:4Ds (7,9,13,15,24,35).This link was first demonstrated in English professional football (soccer) players by Manning and Taylor (24) and subsequently across a range of sports including (but not limited to) American football (gridiron) (33), basketball (7,9), rowing (15), rugby (1), running (both sprinting [23] and cross-country [26]), slalom skiing (21), surfing (16), swimming (30) and volleyball (29).

The available research has mostly considered the relationship between 2D:4D and closed-skill sports performance, with more research necessary for open-skilled sports performance in order to understand true relationships. Closed-skill sports require athletesto initiate the action and perform in stable, predictable, and self-paced environments, whereas open-skill sports requireathletes to react to a stimulus and perform in unstable, unpredictable, and externally paced environments (38). Three studies have examined the relationship between 2D:4D and basketball performance (7,9,34). Tester and Campbell (34) 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. (9) 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. (7) observed that semi-professional female players with low 2D:4D had better game-related statistics (specifically better defensive statistics, e.g., higher rebound and block counts) and were more likely to play in the starting line-up. The aim of this study therefore was to expand the participant pool of Frick et al. (9) 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 male players based on their position in the starting lineup (i.e., starters vs. reserves). It is hypothesized that in this more mixed group of male basketball players, 2D:4D will be a meaningful negative correlate of basketball game-related statistics and that starters will exhibit lower mean 2D:4Ds.

CHAPTER 2

METHOD

Experimental Approach to the Problem

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 (9). Previously, Frick et al. (9) examined relationships between 2D:4D and game-related statistics in only professional male basketball players, whereas this study expanded the participant poolto include data on both professional and semi-professional male basketball players. 2D:4D was measured using a validated photographic technique and Cartesian coordinate geometry. Basketball game-related statistics, collected by statisticians and published as open access official game statistics, were standardized to 36 minutes of game time.Partial correlations adjusted for playing experience, height, mass and competitive standard were used to quantify linear relationships between 2D:4Ds and game-related statistics. Unpaired *t*-tests were used to quantify the differences in mean 2D:4Ds between starting and reserve players.

Subjects

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 (i.e., 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/m^2; right 2D:4D (2D:4D$_R$), 0.955 (0.038); and left 2D:4D (2D:4D$_L$), 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 haveplayed 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 (25). Participants who self-reported a major injury (e.g., 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.

Procedures

Participants self-reported age, ethnicity, playing team, playing position (guard, forward or center), and position in the starting lineup (starter or reserve). Standing height was measured to the nearest 0.1cm using a stadiometer, body mass was recorded to the nearest 0.1 kg using a digital weighing scale, and with body mass index (BMI) 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. (15). 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) (7,9,15). 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 author and the senior author (KSK vs. GRT).The 2D:4Dsdemonstrated 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).The2D:4Dsalso 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, and average minutes played. All game-related statistics 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 (9).

$$\left(\frac{game - relatedstatistic_{total}}{gamesplayed}\right) \times \left(\frac{36}{minutespergame}\right)$$

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. Partial correlations and 95% confidence intervals were calculated for offensive (points, offensive rebounds and assists-to-turnovers ratio [assists:turnovers]) and defensive (defensive rebounds, steals and blocks) game-related statistics separately. 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 (5). 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 unpaired *t*-tests. 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 of 0.2, 0.5 and 0.8 were used as thresholds for small, moderate and large respectively, with ES<0.2 considered to be negligible and ES>0.2 considered to be meaningful (5).

CHAPTER 3

RESULTS

Partial correlations (adjusted for playing experience, height, mass and competitive standard) between 2D:4D and game-related statistics ranged from moderate negative to negligible positive (Figure 1). Both 2D:$4D_R$ and 2D:$4D_L$ were weak to moderate negative correlates of points and assists:turnovers, and 2D:$4D_R$ was a weak negative correlate of offensive and defensive rebounds, indicating that males with lower 2D:4Ds scored more points and recorded more rebounds and more assists relative to turnovers. Somewhat stronger relationships were observed between 2D:4D and offensive statistics (mean partial *r*[range]: −0.27 [−0.33 to −0.17] than between 2D:4D and defensive statistics (mean partial *r* [range]: −0.10 [−0.21 to 0.04]) (Figure 1).

Mean 2D:4D did not differ by position in the starting lineup (difference in means [95%CI]: 2D:$4D_R$,0.005 [−0.012, 0.022],ES=negligible; 2D:$4D_L$, −0.008 [−0.026, 0.010], ES=negligible).

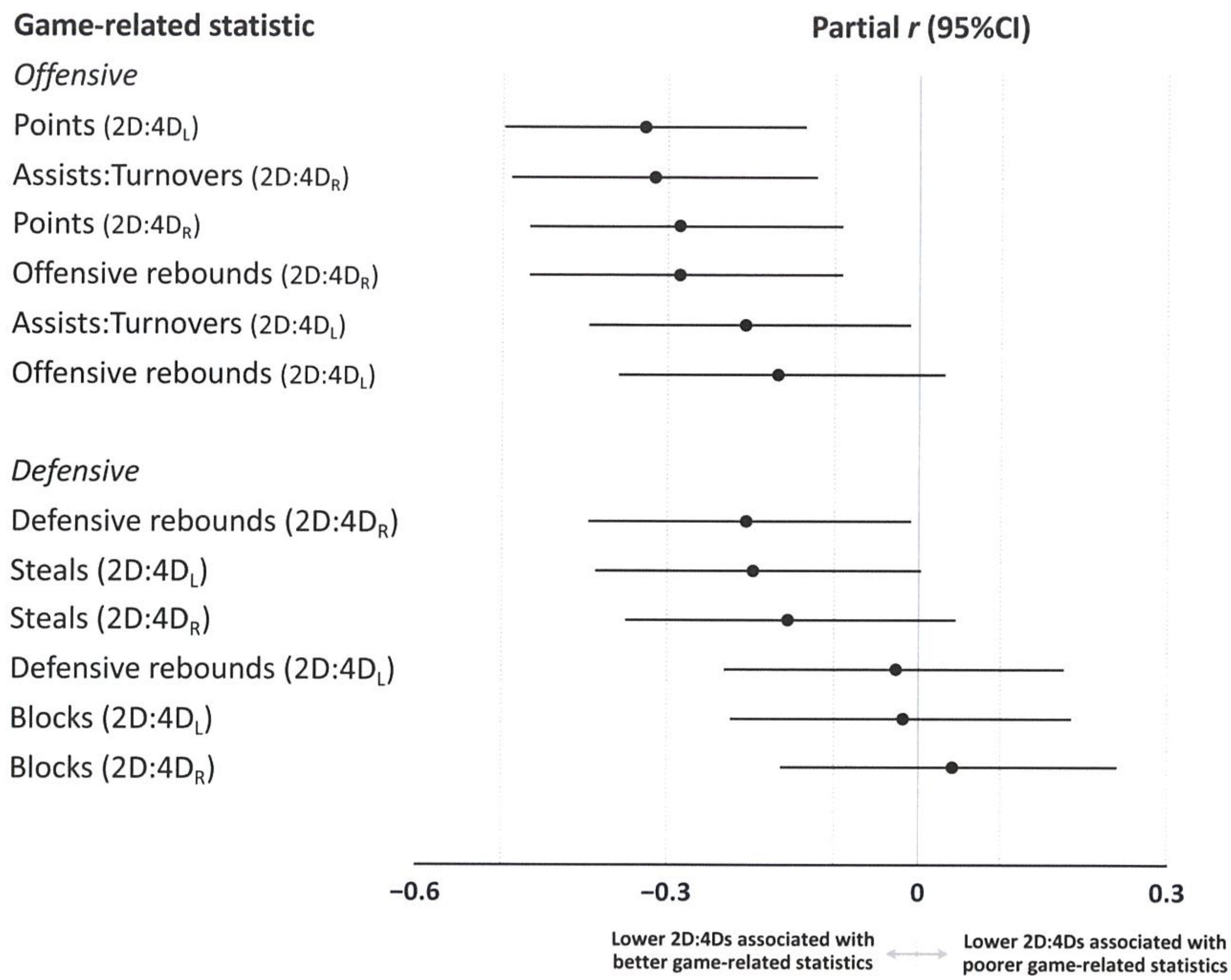

Figure 1. Forest plot of the partial correlations (95%CIs) (adjusted for playing experience, height, mass and competitive standard) between 2D:4D and basketball game-related statistics. The black dots represent the correlations between 2D:4D and game-related statistics and the solid horizontal lines 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: $2D{:}4D_R$=right 2D:4D; $2D{:}4D_L$=left 2D:4D; 95%CI=95% confidence interval.

CHAPTER 4

DISCUSSION

In this study, 2D:4D was a weak to 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 rebounds and more assists relative to turnovers. This study also found that mean 2D:4D did not differ meaningfully by position in the starting lineup.

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 (10), 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 enduranceall favorablycorrelated with game-related statistics, especially offensive statistics (4,27).Upper body strength for example is required for players to maintain their position when contesting for a rebound;lower body explosive strength is required to jump for a contested ball and 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 burst efforts. 2D:4Dhas been favorablycorrelated with cardiorespiratory endurance (e.g., maximal oxygen uptake [$\dot{V}O_{2max}$], running speed at $\dot{V}O_{2max}$, and peak blood lactate concentration [12]), muscular strength(e.g., upper body strength [8,35]and lower body explosive strength [14]) and speed (e.g., both short- and long-distance running speed [23,26]) 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 (6). Mental toughness has beenfavorably linked with cognition, physical fitness and basketball performance (6,28). In a study of 122 British athletes, Golby and Meggs (11) 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 markedspikes in testosterone in men during challengingsituations,such as when exposed to aggressive stimuli and/or intense exercise (17,18). This suggests that men with low 2D:4D will be more aggressive and will take more risks when they are challengedsuch 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 (30).

The results of this study are theory-consistent, showing that 2D:4D is meaningfully linked with sports, athletic and fitness test performance (7,9,13,15,24,35). They also support those of Dyer et al. (7) 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 testosteronebenefits numerous bodily systems and behaviorsthat are important for basketball performance, which seemingly manifest in different ways for males (offensively) and females (defensively).Unlike Frick et al. (9) 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 selectedby a stricter set of physical, physiological, skill, and behavioralcriteria than semi-professional players, resulting in reducedperformance variabilityand 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 (2). 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 (e.g., cross-country running [26], rowing [15], slalom skiing [21], swimming [30]).

This study adds to a growing body of literature examining the relationship between 2D:4D and sports/athletic performance, and builds upon the lack of 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 (25).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 (32). Fourth, it adjusted the relationships between 2D:4D and game-related statistics for playing experience, body size and competitive standard, which were meaningful correlates of game-related statistics.

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. 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.

Consistent with theory, this study found that 2D:4D was a meaningfulnegative correlate of basketball 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.

Practical applications

Our results indicate that men with low 2D:4Ds tend to perform better in professional and semi-professional basketball, especially offensively as they score more points and record more rebounds and more assists relative to turnovers than men with high 2D:4D.This result remains even after adjusting for playing experience, body size and competitive standard, and when coupled with recent research in women (7), suggests that the 2D:4D may be a useful complement to traditional physical, physiological, skill, and behavioral predictors of basketball success. While longitudinal studies are required to fully understand the utility of the 2D:4D for talent identification, the fact that the 2D:4D is fixed by birth and remains stable during rapid periods of growth throughout childhood and adolescence, suggests that it may provide additional and early insight as an indicator of future basketball prowess.

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