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SHORT REPORT

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The relationship between the digit ratio (2D:4D) and vertical jump performance in young athletes

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Abstract

Background: Digit ratio (2D:4D), a putative marker of prenatal testosterone, is a negative correlate of sports, athletic, and fitness performance.

Objectives: To describe the relationship between 2D:4D and vertical jump performance in athletes.

Methods: Sixty-one Division I American Football players from a Midwestern U.S. university had their 2D:4D measured digitally and their vertical jump performance measured using jump mechanography. The primary outcome was jump height, with secondary outcomes depicting jump execution also recorded. Linear relationships between 2D:4D and vertical jump performance were quantified using partial correlations adjusted for age, height, mass, and ethnicity.

Results: 2D:4D was a statistically significant weak negative correlate of jump height (partial r [95% confidence interval]: −0.26 [−0.48, −0.01]), indicating that athletes with lower 2D:4Ds (i.e., relatively longer 4th digits) jumped higher. Relationships with jump execution variables were negligible to weak and negative, but not statistically significant.

Conclusions: The significant relationship between 2D:4D and jump height probably reflects both the long-term organizational and short-term activational benefits of testosterone. Therefore, 2D:4D may be a useful indicator of explosive strength among young athletes.

1 | INTRODUCTION

Digit ratio (2D:4D), the ratio of the length of the second digit (2D; the index finger) and fourth digit (4D; the ring finger), is favorably associated with health, fertility, behavior, and athletic ability (Manning, 2008). 2D:4D is considered to reflect the balance between prenatal testosterone and estrogen (Zheng & Cohn, 2011), although debate exists regarding this association (McCormick & Carré, 2020; Swift-Gallant et al., 2020). Prenatal testosterone exposure has long-term organizational effects on the growth and development of numerous bodily systems (e.g., cardiovascular, musculoskeletal, central nervous systems; Zheng & Cohn, 2011), and may influence peak testosterone kinetics, behavioral responses (e.g., aggression), and physical performance in response to stress challenge (Crewther et al., 2011).

2D:4D has been consistently reported as a negative correlate of sports, athletic, and fitness performance. In their meta-analysis, Hönekopp and Schuster (2010) found that 2D:4D was a weak negative correlate of a range of sports/athletic/fitness performances, indicating that individuals with lower 2D:4Ds outperformed individuals with higher 2D:4Ds. However, Hönekopp and Schuster (2010) found substantial heterogeneity between studies, with stronger relationships between 2D:4D for long-duration exercise performance requiring high cardiorespiratory fitness (e.g., middle- and long-distance running) than for short-duration exercise performance requiring high muscular fitness (e.g., handgrip strength, sprinting). More recently, there has been a preponderance of studies examining relationships between 2D:4D and muscular fitness, most of which have measured muscular fitness as maximal handgrip strength (Pasanen et al., 2021). Several studies have, however, examined relationships between 2D:4D and explosive strength (measured as jump performance) and have failed to find statistically significant correlations (e.g., Kozieł et al., 2017; Ranson et al., 2015). None though, has used jump mechanography to assess vertical jump height and jump execution. The primary aim of this study, therefore, was to quantify the relationship between 2D:4D and vertical jump height in young athletes. The secondary aim was to examine relationships between 2D:4D and jump execution variables. We predicted that athletes with lower 2D:4Ds had higher jump heights and better jump execution.

2 | METHODS

2.1 | Study design and participants

This study used a cross-sectional design. Sixty-one males (aged 18–24 years), who competed for the University of North Dakota in American football at the National Collegiate Athletic Association (NCAA) Division I level, volunteered for this study. Mean $\pm$ *SD* for the sample were: age, 19.9 ± 1.4 years; height, 188 ± 7 cm; body mass, 102 ± 16 kg; right hand 2D:4D, 0.945 ± 0.028; and maximum jump height, 39 ± 7 cm. Participants who self-reported a major injury (e.g., dislocation, break) to the 2D, 4D, or lower body were excluded. All participants gave signed informed consent. The Institutional Review Board of the University of North Dakota approved this study (IRB-201711-120).

2.2 | Measures

Participants self-reported their age and ethnicity. Height was measured using a stadiometer (Model 213; Seca Corp., Hamburg, Germany) and body mass was measured using a force platform (Bertec Corp, Columbus, OH).

After a 5-min warm-up, participants performed two maximal vertical (squat) jumps (spaced 60 s apart) on the force platform using procedures described elsewhere (Fitzgerald et al., 2018). Jump height was calculated as the maximum of two vertical jump heights, with the average of two jumps used to calculate force-time variables (peak force, starting gradient, acceleration gradient, and the average and peak rate of force development) to reflect jump execution (Fitzgerald et al., 2018). Jump height and force-time variables were calculated using Visual Basic (Microsoft Corp., Redmond, WA). Jump height and force-time variables demonstrate good repeatability (Fitzgerald et al., 2018; McLellan et al., 2011).

2D and 4D lengths were measured using Cartesian coordinate geometry and digital photographs (Nikon Coolpix L11, Tokyo, Japan) of the palmar surface of each participant's outstretched right hand using procedures described elsewhere (Hull et al., 2015). 2D:4D was calculated by dividing the 2D length by the 4D length. This method demonstrates very good repeatability and validity (vs. direct caliper measurements; Hull et al., 2015).

2.3 | Statistical analyses

Partial correlations (adjusted for age, height, mass, and ethnicity) were used to quantify linear relationships between 2D:4D and jump height and force-time variables. Negative correlations indicated that athletes with lower 2D:4Ds had higher jump heights and better jump execution, while positive correlations indicated that athletes with lower 2D:4Ds had lower jump heights and poorer jump execution. 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 (Cohen, 1988).

3 | RESULTS

The adjusted partial correlation between 2D:4D and jump height was statistically significant, weak, and negative (partial r [95%CI]: -0.26 [-0.48, -0.01]), indicating that athletes with lower 2D:4Ds jumped higher irrespective of their age, body size, and ethnicity (Figure 1). Each 1 *SD* decrease in 2D:4D was associated with a 2 cm increase in jump height. Adjusted partial correlations between 2D:4D and force-time variables were negligible to weak and negative, but not statistically significant.

4 | DISCUSSION

This study showed that 2D:4D was a weak negative correlate of jump height (even after adjustment for age, body size, and ethnicity), but was not significantly related to jump execution. Our primary finding probably reflects

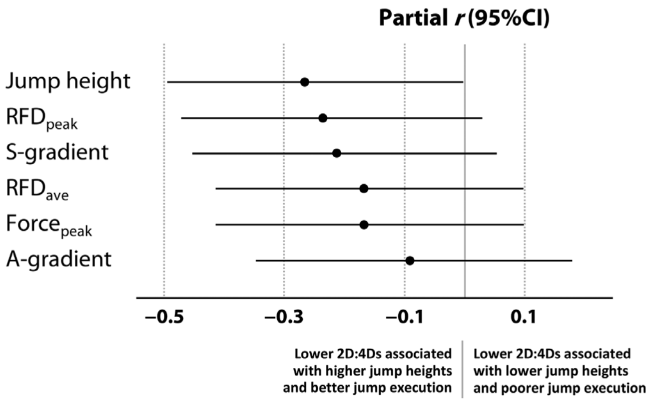

FIGURE 1 Forest plot of the partial correlations (adjusted for height, mass, age, and ethnicity) between 2D:4D and jump height and force-time variables. The black dots represented the correlations between 2D:4D and jump height and force–time variables, and the solid horizontal lines represented the corresponding 95%CIs. The dashed vertical lines represented Cohen's thresholds for weak, moderate, and strong correlations. Negative correlations indicated that athletes with lower 2D:4Ds had higher jump heights and better jump execution, and positive correlations indicated that athletes with lower 2D:4Ds had lower jump heights and poorer jump execution. 2D:4D, digit ratio; 95% CI, 95% confidence interval; *r*, correlation; A-gradient, acceleration gradient (half peak force divided by time to peak force minus time to half peak force [N/s]); $Force_{peak}$, peak force (the maximal vertical force trace during jumping [N]); RFD_{ave}, average rate of force development (peak force divided by the time from jump start to peak force [N/s]); RFD_{peak}, peak rate of force (peak time derivative during jumping [N/s]); S-gradient, starting gradient (half peak force divided by time to half peak force [N/s])

the long-term organizational benefits of prenatal testosterone and the short-term activational benefits of testosterone. Prenatal testosterone influences the regulation of numerous skeletogenic genes responsible for the growth and development of several bodily systems (e.g., the musculoskeletal system; Zheng & Cohn, 2011), with higher exposure to prenatal testosterone potentially resulting in greater explosive strength. Prenatal testosterone may also prime the endocrine system to respond to stress challenge by secreting short-term spikes in testosterone (Crewther et al., 2011). This suggests that athletes with low 2D:4D will be more aggressive when challenged (e.g., in response to maximal exercise; Kilduff et al., 2013), which may influence the 2D:4D-vertical jump performance relationship. Because vertical jump performance is an important correlate of sporting success, especially in sports requiring substantial force application such as American football (Saywer et al., 2002), our findings indicate that 2D:4D predicts explosive strength and potentially future sporting ability. The utility of 2D:4D for talent identification, however, requires a large prospective study that followed children through to their peak performance in senior elite sport. In addition, explosive strength is significantly associated with current and future health (e.g., cardiometabolic disease risk, adiposity, bone mass; García-Hermoso et al., 2019), which suggests that athletes with lower 2D:4Ds are healthier.

Our finding of a significant and independent negative correlation between 2D:4D and jump height may be particularly meaningful given our homogeneous sample of young athletes from a single sport. The young athletes comprising our sample were almost certainly selected to play NCAA Division I football using strict performance criteria (e.g., physical, physiological, technical, behavioral, game intelligence, psychological, emotional, and social), which may have resulted in reduced performance variability and weaker 2D:4D-vertical jump performance relationships. It is nonetheless challenging to explain why our findings differ from those of others (e.g., Kozieł et al., 2017; Ranson et al., 2015) which, despite having considerably larger sample sizes, failed to find statistically significant relationships (at the 95% level). Such between-study differences may be due to methodological differences in jump test measures, participant ages, and participant pools.

Strengths of this study included (a) objectively measured 2D:4D and criterion vertical jump performance, (b) the exclusion of athletes who self-reported major injuries, and (c) the use of partial correlations, which adjusted for potential confounding factors. Limitations included (a) the potential for unmeasured confounding (e.g., handedness, resistance training experience), (b) the small sample size, which resulted in reduced statistical power and meant that we could not calculate 2D:4D-vertical jump performance correlations by ethnic group or compare correlations among ethnic groups, and (c) the use of only the right hand 2D:4D, which nonetheless is considered a better indicator of prenatal testosterone compared to the left hand 2D:4D (Manning, 2008).

This study found a significant negative (theory-consistent) relationship between 2D:4D and jump height, which indicated that 2D:4D may be a useful predictor of explosive strength among young athletes independent of age, body size, and ethnicity. Our primary finding probably reflects both the long- and short-term benefits of testosterone. This study adds to a growing literature on 2D:4D-muscular fitness relationships, and encourages additional research among athletes differing in age, gender, sport, and competitive standard to better understand true relationships.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Investigation, project administration, writing (original draft): Jacob W. Disterhaupt. *Conceptualization, methodology, supervision*: John S. Fitzgerald. *Conceptualization, supervision*, Jesse L. Rhoades. *Conceptualization, methodology, writing (original draft), writing (review & editing), visualization, supervision*, Grant R. Tomkinson.

DATA AVAILABILITY STATEMENT

The data are available from the corresponding authors on reasonable request.

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