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The Relationship Between The Digit Ratio (2d:4d) And Explosive Muscular Strength In College Football Players

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THE RELATIONSHIP BETWEEN THE DIGIT RATIO (2D:4D) AND EXPLOSIVE MUSCULAR STRENGTH IN COLLEGE FOOTBALL PLAYERS

by

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

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This thesis is 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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PERMISSION

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Jacob Disterhaupt

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ABSTRACT

Prenatal testosterone, reflected by digit ratio (2D:4D), is thought to benefit the cardiovascular and musculoskeletal systems and has been shown to benefit long-duration exercise performance, but little is known about the relationship between 2D:4D and short-duration exercise performance (e.g., explosive muscular strength). This study describes the relationship between 2D:4D and lower-body explosive strength, a key factor in successful sports performance, in college athletes. Sixty-one Division I American Football players from a Midwestern U.S. university had their 2D:4D measured digitally and squat jump performance measured using force-platform jumping mechanography. In addition to the primary outcome of jump height, secondary outcomes depicting the execution of the jump were also recorded (peak force, peak Rate of Force Development [RFD], average RFD, starting gradient, and acceleration) from the better of two jumps. Linear relationships between 2D:4D and lower body explosive performance were quantified using partial correlations adjusted for height, mass, age and race. In college football players, 2D:4D was a weak negative correlate of jump height (partial r [95%CI]: −0.26 [−0.48, −0.01]), indicating that athletes with lower 2D:4Ds (i.e., relatively longer 4th digits) tended to jump higher. Jump execution variables were negligible to weak and in the expected direction, although they failed to reach statistical significance. The favorable link between 2D:4D and lower body explosive strength in a homogenous athlete group is the likely result of the long-term organizational benefits of prenatal testosterone. It is possible 2D:4D analyzing can be used as a large scale screening tool for young athletes, allowing parents or future coaches to detect future athletic potential.

Chapter 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 correlated with health, fertility, behavior, and athletic ability (25). 2D:4D is determined during early fetal development by the balance between sex steroid hormones testosterone and estrogen, with the fetal 4D having large numbers of receptors for both hormones (27,50). Males generally have lower 2D:4Ds than females, the likely result of a sex-related difference in prenatal testosterone and estrogen levels (25). 2D:4D remains relatively stable throughout life (46).

Zheng and Cohn (50) argue that exposure to high levels of prenatal testosterone provides long-term organizational benefits, such as better growth and development of the cardiovascular, musculoskeletal and urogenital systems. Studies examining relationships between 2D:4D and muscular fitness have often examined hand grip strength — the ability to isomterically exert force in a single contraction (24) — with results indicating that it is favorably linked with 2D:4D in men (i.e., men with lower 2D:4Ds tend to be stronger). For example, the relationship between 2D:4D and muscular strength (operationalized as handgrip strength) has been reported as: (a) weak to moderate and negative in men (17;49); (b) negligible to weak and typically positive in women (17; 47; 49); (c) negligible to weak and typically negative in young college students (13); (d) moderate and negative in adolescent boys aged 13–18 years (45); and (e) negligible in children aged 8–12 years (39). Negligible relationships between 2D:4D and other strength measures (e.g., static upper body and torso strength/endurance and explosive lower body strength) have been reported for adolescent girls aged 13–18 years (37). In elite male athletes (e.g., track, volleyball, and handball), the 2D:4D is favorably related to vertical jumping ability (3). In addition to the links with fitness-performance, 2D:4D is also a negative correlate of performance in numerous sports and athletic events (e.g., American football, basketball, handball, rowing, running [short- and long-distance], soccer, slalom skiing, swimming, tennis, volleyball, and wrestling [Greco-Roman and sumo]) (2; 6; 11; 19; 21; 22; 23; 26; 28; 30; 31; 36; 38; 42; 43). Furthermore, Giffin et al. (15), using a sample of 221 university students, reported that varsity athletes had significantly lower 2D:4Ds (effect size [ES]: 0.78, moderate) than their non-athletic peers.

Jumping mechanography is commonly used to assess lower-body explosive force production (32; 34) and to track change in explosive movement performance in athletes (5). Mechanography (evaluating ground reaction force data) allows for the assessment of jump height and task execution during the vertical jump test. Though jump height is the primary outcome of the test, force-time variables, such as rate of force development (RFD), depicting task execution, provide additional information about rapid movement performance ability (34; 7; 10). Furthermore, early phase (<100 ms) RFD (starting gradient), may be sensitive to force generated by type II muscle fibers (48). Thus, evaluating task execution may provide additional insight into motor and physiological differences between individuals.

A potential reason for the correlation between 2D:4D and athletic performance, is 2D:4D's connection with short-duration explosive exercise performance. 2D:4D and lower-body explosive ability has been evaluated, suggesting lower digit ratios impact jumping ability (3; 20). In many sports, vertical jumping ability plays an important role in successful execution of sportsspecific skills and overall team performance (e.g., football [soccer], American football, Australia football, rugby, volleyball, basketball, netball) (1; 33). In American football specifically, starting players have substantially better vertical jump performance than reserve players (12), and vertical jump performance has been identified as the strongest physiological determinant of playing ability (41). Vertical jump ability is also tied to wide recievers statistics, found to be associated with receiving yards per catch, over the athletes career (44). The primary aim of this study therefore, was to quantify the relationship between 2D:4D and vertical jump height in D-I college football players; the secondary aim was to examine the relationship between 2D:4D and squat jump execution variables. It was hypothesized that football players with lower 2D:4D will jump higher and have better jump execution variables.

Chapter 2
METHODS

Experimental approach to the problem

This study used a cross-sectional design to examine the relationship between 2D:4D and explosive muscular strength in NCAA Division I American football players. 2D:4D was assessed with a photographic technique and Cartesian coordinate geometry. Squat jump performance was measured on a force platform (Bertec Corp, Columbus, OH, USA) as the better of two jump heights, with jump execution variables (peak force, starting gradient, acceleration, and the average and peak rate of force development [RFD]) also measured. Partial correlations adjusted for height, mass, age and race were used to quantify linear relationships between 2D:4Ds and jump height and force-time variables.

Subjects

Sixty-one men (aged 18 years and older) who competed for the University of North Dakota (UND) American football team volunteered for this study. Players identified as offense (49% or 30/61), defense (48% or 29/61), or special teams (3% or 2/61), and had an average of 2.4±1.2 years of college football experience. Means±SD for the sample were: age, 19.9±1.4 years; height, 188±7 cm; mass, 102±16 kg; right 2D:4D ($2D{:}4D_R$), 0.945±0.028; and best jump height, 39±7 cm. All players were informed of the benefits and risks of the study prior to providing signed informed consent, and must have been part of the 2017–18 UND football roster. Participants who self-reported a major injury (e.g., dislocation or break) to either the 2D or 4D, or lower body extremities were excluded. The UND Institutional Review Board approved this study.

Procedures

Participants self-reported age, ethnicity, and playing position (offense, defense, or special teams). Testing took place in the morning between six and noon, participants refrained from a heavy breakfast, and caffeine/tobacco 3 hours prior to testing. Alcohol was prohibited 24 hours before testing They arrived for testing in a well-hydrated state and wore appropriate clothing for jumping (e.g., light clothing that did not restrict movement and comfortable enclosed footwear). Participants were tested in groups of 2–3 in the Human Performance and Biomechanics laboratories at UND. Standing height was measured to the nearest 0.1 cm using a stadiometer

(Model 213; Seca Corp., Hamburg, Germany), and body mass was recorded to the nearest 0.1 kg using the force platform (Bertec Corp, Columbus, OH, USA).

After a 5-minute warm-up jog around an indoor running track, participants performed two maximal squat jumps on the force platform (Bertec Corp, Columbus, OH, USA) using the detailed procedures described by Fitzgerald et al. (9). Participants were instructed to step onto the force platform with their hands on hips, standing still till their weight calibrated, squat to (and hold for 3 seconds) a self-selected depth of ~90° knee flexion, and then to jump vertically as quickly and as high as possible prior to landing on the platform. Jumps were repeated if they failed to follow instructions or if any countermovement motion was detect pre-jump. The better of two squat jumps was used for subsequent data analysis on jump height, the average of the two jumps was used to calculate jump execution variables. Participants were granted 1-minute of rest between both jump. Jump height and jump execution variables (peak force, starting gradient, acceleration, and the average and peak RFD) were calculated in a macro program created in Visual Basic (Microsoft Corp., Redmond, WA, USA) (see 7 for details). Briefly, the maximal vertical force trace and the peak time derivative during the jump was recorded as peak force and peak RFD. Average RFD was calculated by dividing peak force by the time from jump start to peak force. Starting gradient (half peak force divided by time to half peak force) and acceleration (half peak force divided by time to peak force minus time to half peak force) were calculated to evaluate early- and late-phase concentric force production. Jump height exhibits good repeatability in athletes (CV: 2.8%; ICC: 0.97) (34). Jump execution variables demonstrate good repeatability with small systematic errors (mean±95%CI: 0.2±0.1), moderate random errors (mean±95%CI: 17.8±3.7%), and very strong test-retest correlations (range: 0.73–0.97) (9).

2D and 4D lengths were measured (blind from the squat jump measures) from digital photographs of the palmar surface of each participant's outstretched right hand using Cartesian coordinate geometry (see 21 for details), with 2D:4D subsequently calculated. This method demonstrates very good repeatability and validity (vs. direct caliper measurements) (6;11; 21; 23; 45). Intra-tester and inter-tester repeatability and validity were assessed using a pilot sample of 20 adults. Intra-tester repeatability was determined by comparing duplicate digital measurements of the lead author (JD vs. JD) and inter-tester repeatability by comparing single measurements of the lead and senior (a Level 3 accredited anthropometrist with the International Society for the Advancement of Kinanthropometry) authors (JD vs. GRT). The 2D:4Ds demonstrated very good intra- and inter-tester repeatability, with small systematic errors (change in means: intra-rater and inter-rater, <1.0%), small random errors (typical error: intra-rater, <1.4%; inter-rater, <1.6%), and nearly perfect test-retest correlations (intra-class correlation: intra-rater, >0.94; inter-rater, >0.92). The 2D:4Ds also demonstrated very good validity with small systematic errors (change in means: <0.5%), small random errors (typical error: <1.0%), and nearly perfect test-retest correlations (intra-class correlation: >0.90).

Statistical analyses

Linear relationships between the 2D:4D and jump height and jump execution variables were quantified using partial correlations adjusted for height, mass, age and race. 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 meaningful. A negative correlation indicated that athletes with lower 2D:4Ds had better vertical jump performance and force-time execution than those with higher 2D:4Ds.

Chapter 3

RESULTS

The height-, mass-, age- and race-adjusted partial correlation between 2D:4D and squat jump performance was weak and negative (partial r [95%CI]: −0.26 [−0.48, −0.01]) (Figure 1). Adjusted partial correlations between 2D:4D and jump execution variables were negligible to weak and in the expected direction, although they failed to reach statistical significance (Figure 1).

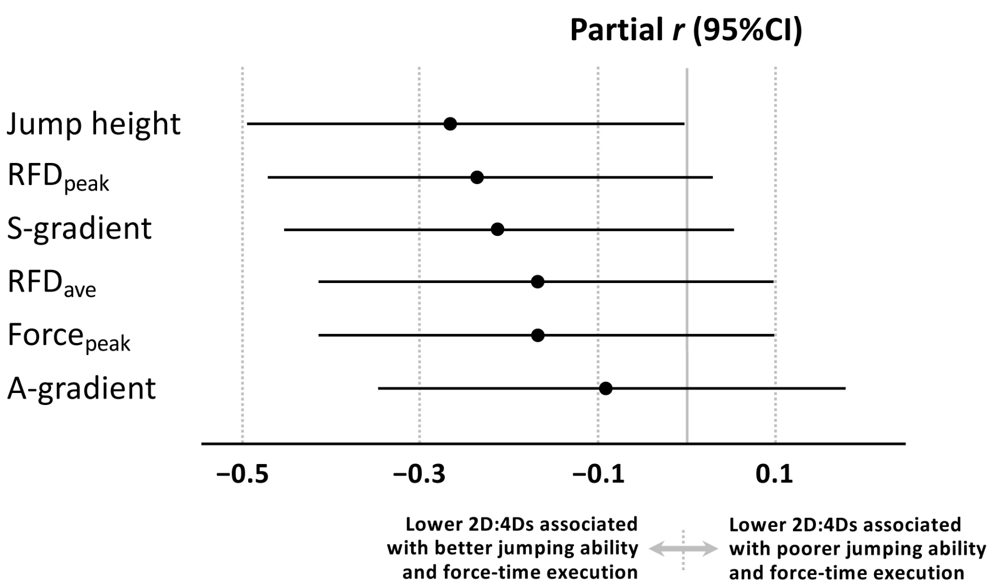

Figure 1. Forest plot of the partial correlations (95% CIs) (adjusted for height, mass, age and race) between 2D:4D and vertical jump height and force-time execution variables.

The black dots represent the correlations between 2D:4D and vertical jump height and force-time execution variables, and the solid horizontal lines represent the corresponding 95% CIs. Negative correlations indicate that athletes with lower 2D:4Ds had better jumping ability and force-time execution, and positive correlations indicated that athletes with lower 2D:4Ds had poorer jumping ability and force-time execution. The dashed vertical lines represent standardized thresholds for weak, moderate, and strong correlations. Note: RFD_{peak}=peak rate of force development (N/s); S-gradient=starting gradient (N/s); RFD_{ave}=average rate of force development (N/s); $Force_{peak}$=peak force (N); A-gradient=acceleration gradient (N/s).

Chapter 4
DISCUSSION

This study showed that 2D:4D was weak negative correlate of vertical jump performance, even after being adjusted for height, mass, age and race. The results show male athletes with low 2D:4Ds tended to jump higher than their teammates with larger 2D:4Ds. Similarly, although failing to reach statistical significance, adjusted partial correlations between 2D:4D and jump execution variables were negligible to weak and in the expected direction.

The results of this study probably reflect the long-term organizational benefits of prenatal testosterone, which has important long-term benefits to humans, including improved growth and development of the cardiovascular and musculoskeletal systems (14), which in turn benefits sports performance. 2D:4D has been favorably correlated with several physiological traits that are important for sporting success including cardiorespiratory fitness (e.g., maximal oxygen uptake ($\dot{V}O_{2max}$), running speed at $\dot{V}O_{2max}$, and peak blood lactate concentration) (16), muscular fitness (e.g., upper and lower body strength, lower body explosive strength) (8, 45) and speed (e.g., short- and long-duration running speed) (28, 31).For example, in American football, running backs must explode from a standing start, quickly generate speed, and change direction to evade defenders to advance the ball; offensive and defensive linemen must also explode out of a deep stance and collide with one another to dominate the line of scrimmage, creating a gap for their running back (offense), or to close a gap, in an attempt to tackle the opposing running back (defense); and wide receivers, like running backs, must explode from a standing start, quickly reach maximum speed, change direction, and often having to out-jump opposing players to catch the football.

This study adds to a growing body of literature examining the relationship between 2D:4D and sports/athletic/fitness performance. First, while previous studies have examined differences in mean 2D:4D between university varsity athletes and non-athletes (15), to the author's knowledge, this is the first study that has directly examined the relationship between 2D:4D and explosive strength in college athletes from a single sport. Second, it used only active D-I American football players who were jump squat tested using the gold-standard force platform. Third, it used partial correlation analysis to control for factors that were substantially related to one or both of the primary variable (2D:4D or vertical jump height). Fourth, it used a validated photographic technique and Cartesian coordinate geometry to measure digit lengths, which avoided the potential confound of placing fingers downwards onto a glass surface leading to fat pad distortion (40). In contrast, while the small sample size meant that the relationships between 2D:4D and jump execution variables failed to reach statistical significance, the correlational estimates should not have been systematically biased. This study also did not control for handedness, which has been shown to be meaningfully related to 2D:4D (29), and despite excluding athletes who self-reported major injuries to either their right 2D or 4D, it is possible that minor injuries (e.g., sprains, strains) affected the 2D:4Ds.

As expected, this study found that 2D:4D was a substantial negative correlate of explosive leg muscular strength in college American football players, indicating that those with lower 2D:4Ds tended to have better jumping ability than their peers with higher 2D:4Ds. This finding is probably underscored by the organizational benefits of prenatal testosterone. Future studies may wish to examine relationships between 2D:4D and other fitness components in athletic samples in order to more confidently understand true relationships.

Practical Application

This study indicates that collegiate American football players with low 2D:4Ds tend to have better explosive strength than players with higher 2D:4Ds. This result remains even after adjusting for body size, age and race, suggesting that the 2D:4D may be a useful complement to traditional physical, physiological, skill, and behavioral predictors of American football success. Despite the fact that longitudinal data are missing, this study suggests that 2D:4D may have utility as a screening tool for large-scale talent identification programs.

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