The Second to Fourth Digit Ratio in Elite and Non-Elite Greco-Roman Wrestlers

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A low second-to-fourth digit ratio (2D:4D) has been reported to correlate with high performance and athletic potential of an individual in sport. It has been suggested that 2D:4D is a relatively weak predictor of strength and a stronger predictor of efficiency in aerobic exercise. Comparing extreme groups on a continuum of sports performance requiring high power (physical strength) output would be helpful to resolve this issue. Therefore, the purpose of the present study was to compare the 2D:4D ratio of world-class elite Greco-Roman wrestlers (n = 10) taking part in Olympic fitness camps in 2013 with the 2D:4D ratio of non-elite collegiate wrestlers (n = 20), and age-matched sedentary males (n = 40). The 2D:4D ratios of elite wrestlers were lower compared to non-elite athletes (p < 0.01, right hand d = 1.70, left hand d = 1.67) and the control group (p < 0.0001, right hand d = 3.16, left hand d = 2.00). No significant differences were noted among the groups for right - left 2D:4D. We concluded that 2D:4D may discriminate between non-elite and world-class wrestlers. We also suggest that a low 2D:4D ratio could be linked to performance potential in wrestlers. As such, 2D:4D may provide additional information, which is valuable in determining the potential athleticism of an individual, when it is used in conjunction with other measures.

Key words: 2D:4D ratio, finger length, prenatal testosterone.

Introduction

The lengths of the index (2D) and ring (4D) fingers would represent a lot of information in humans. In fact, the 2D:4D ratio has been studied in different research related to human's physical or even psychological characteristics. For example, males have a lower 2D:4D ratio than females, and this reflects high utero testosterone exposure in their prenatal period (Fink et al., 2006; Manning and Bundred, 2000). Moreover, longitudinal studies have shown that values of 2D:4D are relatively stable with growth (McIntyre et al., 2005; Trivers et al., 2006). However, there is evidence that in females 2D:4D fluctuates due to changes of soft tissues across the menstrual cycle (Mayhew et al., 2007). Extensive studies in humans have found correlations between digit

ratios and a variety of physiological and psychological conditions, including fertility, athletic ability, sex-biased diseases, social behaviors, and sexual orientation (Manning et al., 2000; Manning, 2011; Zheng and Cohn, 2011). High fetal androgen levels promote the development of efficient cardiovascular systems, good visuo-spatial abilities, physical endurance, speed and a propensity for aggressive behaviors that may be helpful in sports (Manning and Taylor, 2001). In men, there is a significant negative association between 2D:4D and performance in sports and activities which require speed and endurance, such as rugby (Bennett et al., 2010), running (Manning et al., 2007), skiing (Manning, 2002), soccer (Manning and Taylor,

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2001) and gym-based exercises (Hönekopp et al., 2006). However, there is a limited number of studies exploring the value of 2D:4D in determining the potential performance of an individual in power-based sports.

Scientific evidence shows the importance of a low 2D:4D ratio in athletic performance. Manning and Taylor (2001) indicated that feature in professional soccer players (league player in the first team or reserve player, international or non-international player). Further work found that men with a low 2D:4D ratio tended to run faster than men with a high 2D:4D ratio, and that the digit ratio explained up to 25% of variance in endurance running (Manning et al., 2007). As we mentioned before, there are plenty of reports about the importance of the 2D:4D ratio in speed and endurance based sports, although Manning and Hill (2009) have suggested that 2D:4D is a relatively weak predictor in sports which require strength and power. On the other hand, Longman et al. (2011) reported that a digit ratio was a predictor of ability in male rowers, a sport requiring major energetic contributions from both the aerobic and anaerobic systems. Bennett et al. (2010) found significant relationships between low 2D:4D and performance measures in rugby, and this might suggest that links between 2D:4D and rugby performance are at least in part dependent on power; similar negative correlations between 2D:4D and hand-grip strength in men (but not women) have been reported in Han Chinese (Zhao et al., 2012) and white participants from the USA (Hone and McCullough, 2012). It can therefore be argued that if there is a relationship between low 2D:4D and high performance in strength and power-based sports, it is most likely to be detected by comparing extreme groups on a continuum of sports performance. Studies including both sedentary subjects and objectively assessed elite-status athletes are limited (Bennett et al., 2010; Peeters and Claessens, 2012) and there are no studies concerning the 2D:4D ratio in elite Greco-Roman wrestlers.

Greco-Roman wrestling can only be executed by means of the upper body, with the ultimate goal of pinning the opponent's shoulders to the mat. It demands high levels of power maneuvers that require both absolute whole-body strength and explosiveness, integrating a large isometric component for technical performance (Barbas et al., 2011; Farzad et al., 2011). Recent rule changes in wrestling have made the anaerobic energy metabolism more important than aerobic performance, and this is because of shorting of the match duration and the reduction of the tournament to one day (Cankaya, 2012). Furthermore, it provides short and quick bursts of maximal power during the match (Callan et al., 2000). Yamaner et al. (2010) indicated that Greco-Roman wrestling required significant anaerobic fitness, and operated within a moderate-level of the aerobic system, with the contribution of about 60 and 40%, respectively. Moreover, combat effectiveness is necessary in wrestling, and it requires proper levels of coordination motor abilities (CMAs). For instance, some researchers have focused on observation of individuals' abilities such as quick reaction (Bujak, 2006) or perceptual skills (Kioumourtzoglou, 1998) in wrestlers. Gierczuk (2008) also showed that the Greco-Roman wrestlers represented a much higher level of motor adaptability and static balance.

To our knowledge, no research, focused on a sample of elite Greco-Roman wrestlers has been accomplished yet. Therefore, the main aim of this study was to compare the 2D:4D ratio of world-class elite Greco-Roman wrestlers with the 2D:4D ratio of none-elite collegiate wrestlers and sedentary age-matched control males.

Methods

Participants

Participants included 10 world-class elite Greco-Roman wrestlers taking part in Olympic fitness camps and were likely to participate in the World Cup in 2013 (almost all of them were medal winners in various international wrestling tournaments such as the Olympic Games (five gold medals), World or Asian championships). Their daily training program before the Olympic games included power training using power cleans in sports conditioning, plyometric training for sport-specific power, muscular endurance training, core strength conditioning, medicine ball exercises, kettlebell training, flexibility exercises and self myofascial release exercises. Twenty non-elite collegiate wrestlers were recruited from different universities of Tehran, Iran; they had wrestling training background of 4.3 ± 0.9 years

and trained for 6.0 h per week for the last 2 years. The control group consisted of forty male students who were mostly sedentary and did not undertake any physical activities more than once a week. All participants had Iranian ethnic origin. Body mass and standing height of the participants were measured to the nearest 0.05 kg and 0.1 cm, respectively, using a Martin metal anthropometer and a medical balance scale (A&D Instruments Ltd., UK). The body mass index (BMI) was calculated as body mass (kg) / height (m²) (Table 1). The study was approved by the Ethical Committee of the School of Medical Sciences of Tarbiat Modares University and was in accordance with the Declaration of Helsinki

Procedures

Participants were required to place their hands gently on the surface of a scanner (100dpi; HP Scanjet 5590 Digital Flatbed Scanner series, USA) with their digits 2 cm apart and scanned hand images were then transferred to a PC. Using computer-assisted image analysis (Kinovea 0.8.15 software), the lengths of the left and right second and fourth digits were measured from the midline of the flexion crease, the most proximal to the palm to the fingertip (Figure 1). 2D:4D ratios for the left and right hands were obtained by dividing the measurement of 2D by 4D. Directional asymmetry in digit ratios was calculated as DR – L = R2D:4D – L2D:4D (Bennett et al., 2010).

Statistical Analyses

All results are reported as a mean ± SD. The Kolmogorov-Smirnov test was used to test the normality of the distribution. It showed that the distribution of the variables in our study was not skewed. Therefore, to consider differences between the groups we used parametric tests. To evaluate whether there were significant differences between the three studied groups, analysis of variance (ANOVA) was performed.

When a significant difference was revealed, a Scheffe's post hoc test was used to specify where the difference occurred. We applied the Pearson correlation coefficient test to evaluate the relationship between measures. The alpha level for statistical significance was set at $p \leq 0.05$. All data were analyzed by the SPSS software package (SPSS for Windows; SPSS Inc., Chicago, IL, USA; Version 16.00). Effect sizes were calculated by Cohen'd (d) or Eta2 ($\eta2$).

Results

Results are shown in Table 2. No significant differences were noted among the groups for the right and left second finger length, although significant differences were found in the right ($p = 0.035$; $d = 0.79$) and left ($p = 0.016$; $d = 0.87$) fourth fingers of elite wrestlers compared with the control group (longer fourth fingers for elite wrestlers). However, there were no significant differences in the right ($p = 0.16$; $d = 0.73$) and left ($p = 0.06$; $d = 0.89$) fourth fingers of elite wrestlers compared to non-elite athletes. The 2D:4D ratios in the right hand of elite wrestlers were lower compared to non-elite athletes ($p = 0.004$; $d = 1.78$) and the control group ($p < 0.0001$; $d = 3.16$). In addition, the 2D:4D ratios in the left hand of elite wrestlers were lower compared to non-elite athletes ($p = 0.002$; $d = 1.66$) and the control group ($p < 0.0001$; $d = 2.00$). No significant differences were noted among the groups for the right – left 2D:4D difference ($p > 0.05$; $\eta2 = 0.034$). Furthermore, correlations between the 2D:4D ratio and BMI were non-significant in elite and non-elite wrestlers ($p > 0.05$; Table 3).

Table 1

*Descriptive characteristics of the participants (means ± SD)*

	Elite (n = 10)	Non-Elite (n = 20)	Control (n = 40)
Age (yrs)	25.6 ± 1.8	22.1 ± 1.1	24.8 ± 2.2
Standing Height (cm)	178.60 ± 8.57	180.57 ± 6.94	176.88 ± 7.24
Body Mass (kg)	81.30 ± 20.60	75.22 ± 15.15	74.23 ± 11.60
Body Mass Index (kg/m²)	25.11 ± 3.98	22.99 ± 3.88	23.75 ± 3.71

Table 2

Mean values of digits among the groups and the results of ANOVA on both hands

	Elite (n = 10)	Non-Elite (n = 20)	Control (n = 40)	p value for ANOVA
Right Second	7.43 ± 0.43	7.42 ± 0.28	7.47 ± 0.38	0.866
Right Fourth	7.96 ± 0.54*	7.65 ± 0.25	7.57 ± 0.44	0.035
Right 2D:4D	0.93 ± 0.01*	0.97 ± 0.03†	0.98 ± 0.02	0.0001
Left Second	7.44 ± 0.54	7.44 ± 0.30	7.51 ± 0.37	0.758
Left Fourth	7.97 ± 0.55*	7.58 ± 0.28	7.54 ± 0.42	0.015
Left 2D:4D	0.93 ± 0.03*	0.98 ± 0.03†	0.99 ± 0.03	0.0001
Right – Left 2D:4D Difference	-0.0002 ± 0.022	-0.0116 ± 0.029	-0.0101 ± 0.027	0.526

Mean values of digits among the groups and the results of ANOVA on both hands.
*Values are given as mean ± SD. * Elite compared with Control.*
† Non-Elite compared with Elite.

Table 3

Relationships (product-moment correlations) between right,
left 2D:4D and right – left 2D:4D difference and body mass index among the groups

	Elite Wrestlers	Non-Elite Wrestlers	Control Group
Right 2D:4D	–0.533	–0.130	0.338*
Left 2D:4D	–0.089	–0.132	0.228
D_{R-L}	–0.322	0.042	0.092

*Significant <0.05 (two-tailed).
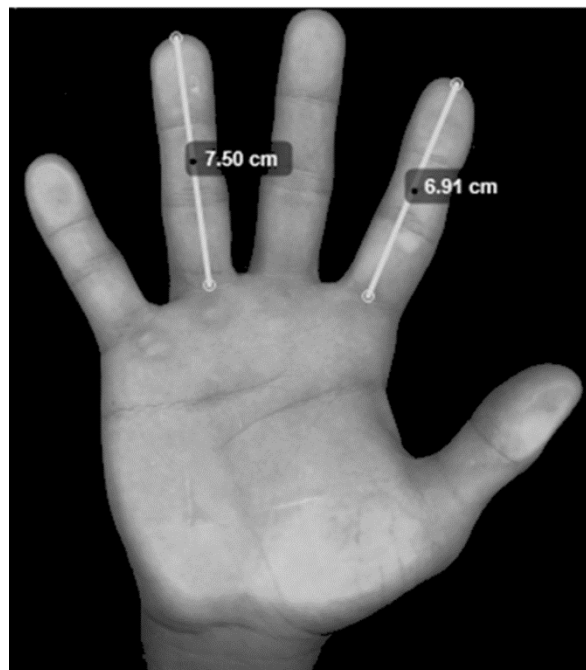
Figure 1

Scan of the hand for second digit and fourth digit measurement

Discussion

The 2D:4D ratio has been suggested to be a biomarker in determining athletic potential (Manning and Taylor, 2001; Moffit and Swanik, 2011). Although correlational studies have examined the ratio and performance, little research has compared extreme groups on the continuum of sports performance. The present study is the first one to investigate the comparison between 2D:4D in a sample of male wrestlers of world-class level, and non-elite wrestlers and a sample of age-matched sedentary males. There was thus an obvious difference in training motor potential among the groups. Our findings showed that the 2D:4D ratio in world-class elite wrestlers was different from the 2D:4D ratio in non-elite athletes and the age-matched control group. Moreover, the effect sizes of the group differences were higher for the right 2D:4D ratio than for the left one. Right 2D:4D is thought to be more sensitive to prenatal testosterone levels, and often provides a stronger correlate with target traits (Bennett et al., 2010). Thus, the 2D:4D ratio would be considered as a predictor factor in wrestler's performance. Also with regard to stability of 2D:4D values with a growth process (McIntyre et al., 2005; Trivers et al., 2006), age does not play a significant role in this case.

As we mentioned, while low 2D:4D has been shown to correlate with endurance and speed based sports (Manning and Hill, 2009; Hönekopp and Schuster, 2010), it seems that evidence is more mixed for the relationship among 2D:4D, acceleration and strength. Some research reported that as a rather weak predictor (Fink et al., 2006; Zhao et al., 2010), and some did not replicate the same results (Longman et al., 2011). In sumo wrestlers, lower 2D:4D was shown to be linked to higher sumo ranks and better winning records (Tamiya et al., 2012). The significant but weak associations ($r = −0.174$ to $−0.192$; $\eta2 = 0.036$) between 2D:4D and the athletic prowess of sumo wrestlers provide further evidence of the possible link between high testosterone levels and muscle strength (Tamiya et al., 2012). Bennett et al. (2010) reported that rugby players had lower 2D:4D than controls for both hands with a large effect size. They asserted that low right 2D:4D and low right – left 2D:4D differences were predictors of high rugby performance. As rugby is a repeated-sprint sport,

this might suggest that links between 2D:4D and rugby performance are at least in part dependent on power (Hill et al., 2012). While Manning and Hill (2009) suggested that the widespread relationships between 2D:4D and sports performances may be more related with aerobic efficiency than strength, the results of our study provide some support for a link with measures of power. Enhancing the development of the cardiovascular system by prenatal androgen exposure has been confirmed (Manning and Bundred, 2000). However, regarding this issue, it raises a question if low 2D:4D is a marker of high prenatal testosterone exposure as testosterone has anabolic effects including growth of muscle mass as well as strength and increased power generation, while there is no strong relationship between the digit ratios and strength. The resolution of this question requires further work to measure androgen and estrogen levels in the studied subjects besides the digit ratios and objective performance.

In mouse models, androgen receptor (AR) and estrogen receptor α (ER-α) activity is higher in foetal digit 4 than in foetal digit 2. Inactivation of AR reduces growth of digit 4, which causes a higher 2D:4D ratio, whereas inactivation of ER-α increases growth of digit 4, which leads to a lower 2D:4D ratio (Zheng and Cohn, 2011). In fact, fourth digit length of the elite wrestlers was significantly greater compared to control group, while there were no significant differences for the second digit among the groups. These results further support the hypothesis that the ratio of androgen to estrogen signaling determines the length of 4D and, ultimately, affects the 2D:4D ratio.

The right–left 2D:4D difference is a third predictor variable of sports performance in some studies (Bennett et al., 2010; Hill et al., 2012). Hill et al. (2012) demonstrated that low right–left 2D:4D was associated with high maximal oxygen uptake (VO2max), high velocity at VO2max, and high maximum lactate concentration in a sample of teenage boys. They also suggested that low right–left 2D:4D was linked to performance in some sports as it was a proxy of high sensitivity to prenatal testosterone and might also be related to circulating testosterone and high VO2max. However, right–left 2D:4D did not differ among the groups in our study. It has been suggested

right–left 2D:4D is a stronger predictor of sports performance than right or left 2D:4D. In rugby players, first-choice players did not differ significantly from second-choice players in their 2D:4D, although they did have a lower right–left 2D:4D difference than second-choice players which is inconsistent with our findings (Bennett et al., 2010).

In conclusion, we found that elite wrestlers had significantly lower right and left hand 2D:4D ratios compared to non-elite wrestlers and sedentary controls. Therefore, the present study could discriminate between non-elite wrestlers and world-class wrestlers by 2D:4D ratios. We should not forget that 2D:4D does not explain all the variance in performance, especially for power-based sport disciplines. However, it seems that if 2D:4D is used in conjunction with other measures, it may provide additional information, which is valuable in determining the potential athleticism of an individual.

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