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Section II - Exercise Physiology & Sports Medicine

The Second-to-Fourth Digit (2D:4D) Ratio of Male Combat Athletes is Associated with the Choice of Sport

by

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The second-to-fourth-digit (2D:4D) ratio has been widely used as a putative marker of prenatal exposure to testosterone in health, behavioral and sport sciences, but it has only been used few times regarding combat athletes. This study involved 200 male elite combat athletes (Olympic wrestling, kickboxing, judo, taekwondo and karate) and 179 males not participating in any sports. The lengths of the index finger (2D) and ring (4D) finger were measured using computer-assisted image analysis (AutoMetric 2.2 software). The 2D:4D ratio of combat athletes was significantly lower than that of the controls. Moreover, a lower 2D:4D ratio was found among wrestlers, judo athletes and kickboxers than in the control group, and a higher 2D:4D ratio was found, but with borderline significance, among karate and taekwondo athletes. Moreover, multivariate analysis adjusted for age showed that judo, Olympic wrestling and kick-boxing athletes combined had 2D:4D ratios significantly lower (by 0.035 on average) than those of the rest of the subjects and that karate and taekwondo athletes together had 2D:4D ratios significantly higher (by 0.014 on average) than those of the rest of the subjects. The research results and literature review indicate that knowledge about the functional meaning of the 2D:4D ratio is still too fragmentary and it is too early to use the 2D:4D ratio in the selection of sport talent; however, it may be a useful criteria when screening prospective athletes to be recruited to a team. That is why 2D:4D reference values should be defined for particular sports.

Key words: *digit ratio (2D:4D), combat sports, sport selection, aggression, predispositions.*

Introduction

Physical dimorphism in humans, including many behavioral sex differences and multifactorial characteristics of males' advantage in sport, are partly a result of the organizational (prenatal) effects of androgens (foremost, testosterone) on the brain and the cardiovascular system. The direct measurement of testosterone levels in human fetuses is not feasible, and biomarkers for prenatal sex hormone action are being sought. One such a marker is the second-to-fourth-digit (2D:4D) ratio, i.e., the ratio of the lengths of the index finger (2D) and the ring finger (4D),which is a negative correlate of fetal testosterone and a positive correlate of fetal estrogen (Manning, 2002).

The 2D:4D ratio is a nonfunctional trait that shows sexual dimorphism, with males tending to have longer 4Ds relative to 2Ds than females, i.e., the 2D:4D ratio of males is lower

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than that of females. Some authors (Manning and Churchill, 2007) have suggested that a low 2D:4D ratio correlates with high testosterone and low estrogen levels in the fetus and a high 2D:4D ratio correlates with low fetal testosterone and high fetal estrogen levels. Thus, high prenatal levels of testosterone and low levels of estrogen could explain part of the reported link between the 2D:4D ratio and sport performance (Crewther et al., 2015). Sexual dimorphism in the digit ratio is seen by the age of two and is thought to be stable thereafter, even through puberty (Hönekopp and Watson, 2010).

There is a genetic basis for the level of sex steroid exposure during fetal life and length of the digits. The common genes (Hoxa and Hoxd) underlie the development of both fingers and the urogenital tract (Lutchmaya et al., 2004). The Hox gene relationship is stronger in the right hand than in the left (Manning and Churchill, 2007). Additionally, allelic variation in androgen-receptor sensitivity influences the digit ratio. More masculine finger ratios occurred in the presence of androgen receptor alleles with few CAG base-pair microsatellite repeats in the terminal domain. An increased number of such repeats produce receptors with low androgen sensitivity (Kazemi-Esfarjani et al., 1995).

It has been suggested that prenatal androgens affect the developing brain by increasing its sensitivity to testosterone later in life and that the 2D:4D ratio may contribute as a reliable predictor of athletic potential (Reed and Meggs, 2017). High fetal androgen levels promote the development and maintenance of endurance, pace, and speed, good visuospatial abilities, an efficient cardiovascular system, increased self-confidence, a preference for risk-taking, intensified vigilance, quickened reaction time, and increased aggressiveness, competitiveness and general sporting performance (Crewther et al., 2015; Mailhos et al., 2016; Ribeiro et al., 2016b). Several of these personal traits are advantageous for combat sports, and thus, a low 2D:4D ratio may be expected in combat sport athletes. As the 2D:4D ratio has been reported to be connected with a testosterone level and a tendency toward aggressiveness (Ribeiro et al., 2016a), it is important to mention that combat sports and martial arts have beneficial effects for dealing with stress. Moreover, self-control, self-assurance and ability to maintain the balance between manifesting and controlling anger are enhanced through combat sports and martial arts training (Ortenburger et al., 2015). Furthermore, androgens provide a competitive advantage in sports by influencing muscular performance (e.g., aerobic and strength) as well as rapidly effecting the brain (Wood and Stanton, 2012).

According to different classifications, there are ten to more than thirty combat sports. To date, the 2D:4D ratio has been reported only for Japanese sumo wrestlers (Tamiya et al., 2012), Korean male and female taekwondo athletes (Bong-Seok, 2016) and elite and non-elite Greco-Roman wrestlers (Keshavarz et al., 2017). As the physical, physiological and mental demands of varied combat sports are different, we hypothesized that athletes with different 2D:4D values would be predisposed to different sport disciplines In this paper, we report the 2D:4D ratio for male athletes from five different combat sports.

Methods

Study design

A longer fourth digit compared to the second digit is indicative of increased intrauterine prenatal testosterone exposure, which has implications in sports. We investigated 200 elite combat sports athletes by measuring their 2D:4D ratio and using the type of sport (judo, Olympic wrestling, taekwondo, kick-boxing, karate) as an independent variable. We analyzed the right hand of athletes because the Hox gene dependence is stronger in the right hand (Manning and Churchill, 2007).

Participants and ethics statement

Participants were informed about the risks and provided their written informed consent. The Local Ethics Committee approved the study, which involved 200 male elite combat sport athletes (Olympic wrestling, kick-boxing, judo, taekwondo and karate: shinkyokushin, kyokushin and traditional); 179 males not participating in any sports formed the control group. The study group included 61 participants and medalists from the Olympic Games and world and European championships. The rest of the group (n = 139) represented the top national level, which means that they had at least won a medal during a national championship. All participants were Caucasian. Participants with evident former hand injuries (e.g., scars, deformation) were not included in the study.

Procedures

Digital photographs of the right hand of all subjects were taken to determine the 2D:4D ratio. Participants were asked to place their hand on a white, flat surface directly under the camera (Sony, DSC-WX80, 16.2 MPix), with the palm facing up, the fingers outstretched, and the third finger on the middle line of the surface. Attention was directed to ensure that the basal creases and the tips of the second and fourth fingers were well visible.

The 2D:4D ratio was determined only for the right hand. The lengths of the index finger (2D) and the ring (4D) finger were measured from the basal metacarpal-phalangeal crease, as the lower bound, to the fingertip, as the upper landmark, using computer-assisted image analysis (AutoMetric 2.2 software). It has been shown that digit ratios (e.g., 2D:4D) determined by computer-assisted analysis are more reliable than those using other methods (Allaway et al., 2009).

Statistical analyses

The Student's t-test was used to compare the 2D:4D ratios between the two groups. ANOVA followed by the Tukey's test and the Dunnett's test were performed to determine homogenous groups and significant differences among multiple groups in relation to the control group, respectively. A general linear model (GLM) was used for multivariate analysis of the factors associated with the 2D:4D ratio as the dependent variable. The sample size of the athlete and control groups was sufficient to detect, with 80% probability, a true effect size of the measured differences between the mean 2D:4D ratio of the groups equal to 0.015. The level of significance was set at $p < 0.05$. Statistica 12 software was used for the calculations.

Results

The mean age of the control group was 22.20 ± 1.85 years and was very similar to the mean age of all groups of athletes; on average, wrestlers were two years younger than the control group (Table 1). Training experience was shortest among kickboxers (4.97 ± 5.16 years) and longest among judo athletes (14.08 ± 4.03 years). The mean anthropometric variables of all groups of combat sport athletes were similar (Table 1). The 2D:4D ratio of judo, Olympic wrestling and kickboxing athletes was significantly lower than that of the control group and higher, though not significantly, than that of the karate and taekwondo athletes (Table 2). ANOVA with the Tukey's post hoc test showed that the athletes could be divided into two statistically homogenous (with respect to the 2D:4D ratio) groups: the first comprising judo, Olympic wrestling and kickboxing athletes with low 2D:4D values and the second including karate and taekwondo athletes with high 2D:4D ratios (Table 2). The 2D:4D ratio was significantly lower in the group consisting of judokas, Olympic wrestlers and kickboxers than in the control group. At the same time, there was borderline significance (p = 0.067) of the difference in the 2D:4D ratio between combined karate and taekwondo athletes and controls.

Multivariate analysis adjusted for age (Table 3), with effect sizes expressed as regression coefficients, showed that subjects from the combined group of judo, Olympic wrestling and kickboxing athletes had 2D:4D ratios significantly lower (by 0.035 on average) than the other subjects, and athletes from the combined karate and taekwondo group had 2D:4D ratios significantly higher (by 0.014 on average) than the rest of subjects.

Discussion

The study showed statistically significant differences in the values of the 2D:4D ratio between athletes training in combat sports and the untrained control group. We used an indirect method of measuring finger length, which might show lower 2D:4D values than direct anthropometric measurements (Ribeiro et al., 2016a). However, this method avoids potential distortion of the handprints. To avoid this problem, we paid attention to not to press down the hand when making the photocopy. It should also be noted that there are still concerns regarding direct versus indirect measurements of the 2D:4D ratio (Ribeiro et al., 2016b). Therefore, as the same method was applied for both athletes and untrained subjects, the observed difference seems to be confirmed, and it supports other research results.

Table 1

Anthropometric and training variables for combat sport athletes

Group	n	Age (years)	Training (years)	Body height (cm)	Body mass (kg)	BMI
Athletes (All)	200	20.45 ± 5.26	9.49 ± 5.47	178.21 ± 7.98	76.79 ± 13.99	24.03 ± 3.12
Judo	25	22.00 ± 4.33	14.08 ± 4.03	179.62 ± 7.36	83.72 ± 10.87	25.86 ± 1.99
Olympic wrestling	90	18.72 ± 2.37	7.52 ± 3.82	176.87 ± 8.34	77.32 ± 16.08	24.49 ± 3.47
Kickboxing	19	23.16 ± 6.99	4.97 ± 5.16	179.89 ± 6.23	75.50 ± 9.41	23.33 ± 2.82
Karate	25	22.48 ± 9.36	13.3 ± 7.7	178.30 ± 5.71	75.36 ± 11.28	23.60 ± 2.59
Taekwondo	41	20.73 ± 5.32	11.12 ± 4.05	178.76 ± 9.21	71.15 ± 10.95	22.17 ± 2.09

Table 2

The 2D:4D ratio in different combat sport athletes and in controls

Group	n	2d:4d	*p*
Control	179	0.975 ± 0.041	-
Athletes (All)	200	0.955 ± 0.054	0.000073 [a]
Judo	25	0.915 ± 0.046	0.000026 [b]
Olympic wrestling	90	0.947 ± 0.051	0.000037[b]
Kickboxing	19	0.939 ± 0.043	0.0049[b]
Karate	25	0.979 ± 0.048	0.99 [b]
Taekwondo	41	0.995 ± 0.048	0.058 [b]
Judo+Wrestling+Kickboxing	134	0.940 ± 0.050	0.000026 [b]
Karate+Taekwondo	66	0.989 ± 0.049	0.067[b] <0.000001 [c]

[a] *All Athletes vs. Control (Student t-test)*
[b]*vs. Control (Dunnett post-hoc test)*
[c] *Karate+Taekwondo vs. Judo+Wrestling+Kickboxing (Student t-test)*

Table 3

General linear model analysis for the association of age and different combat sport groups with the 2D:4D ratio as the dependent variable in a combined group of 200 athletes and 179 controls

Independent variables	Regression coefficients (95% CI)	*p*
Age (years)	+0.0002 (-0.0009 - +0.0014)	0.73
Judo+Wrestling+Kickboxing athletes vs. others	-0.035 (-0.045 - -0.024))	<0.000001
Karate+Taekwondo athletes vs. others	+0.014 (+0.001 - +0.027)	0.034

Since the classic work of Manning et al. (1998), the second-to-fourth-digit (2D:4D) ratio has been widely used as a putative marker of prenatal exposure to testosterone in health, behavioral and sport sciences. Research on the relationship between the 2D:4D ratio and sport performance, measured in an objective manner or as an achievement rank (e.g., national vs. international level), has generally indicated that individuals with small (masculinized) 2D:4D values tend to perform better; however, the magnitude of this relation is inconsistent, ranging from negligible to strong (Hönekopp and Schuster, 2010). This relationship was first reported by Manning and Taylor (2001) in soccer players. Later, it was also reported in sports requiring physical contact with opponents and persistence, e.g., male and female endurance runners (Manning and Churchill, 2007) and rugby players (Bennett et al., 2010). In combat sports, a negative correlation between the 2D:4D ratio and sport performance was found in sumo wrestlers (Tamiya et al., 2012), boxers (Reed and Meggs, 2017) and male Greco-Roman wrestlers (Keshavarz et al., 2017), but not in male and female wrestlers (De la Cruz-Sánchez et al., 2015).

Moreover, in light of the data analysis, the choice of sport seems to be connected with the level of aggression as well as with the 2D:4D ratio. Our findings are consistent with the results of Reed and Meggs (2017) who stated that athletes from contact sports had significantly lower 2D:4D values and significantly higher levels of physical aggression compared to noncontact sport athletes. According to Crewther et al. (2015), combining physical exercise with aggressive scenes is an effective stimulus for increasing testosterone and cortisol production in men. Both of these factors occur in combat sports that involve contact.

Another important issue is the distribution of the 2D:4D ratio among athletes and the general population; the 2D:4D ratio of athletes (0.955) was significantly lower than that of controls and very close to the 2D:4D values for martial arts participants reported by Kozieł et al. (2016). The distribution is especially important if the 2D:4D ratio were to be applied in the selection of sports talent, as suggested in previous research (Malik and Malik, 2011; Moffit and Swanik, 2010; Pokrywka et al., 2005). Such studies have been reported for only few sports and almost never for combat sports.

The research described in this paper highlights several new aspects of combat sport athletes. The 2D:4D ratio is significantly lower among wrestlers, judo athletes and kick boxers compared to the control group and, at the same time, significantly higher among karate and taekwondo athletes compared to the control group. The literature describes Olympic sports athletes as usually having higher levels of general aggression than non-Olympic combat sports athletes (Boostani et al., 2011; Kuśnierz et al., 2014). Taking the 2D:4D ratio as an indicator, the results obtained in our work partly support this thesis, as we found significant differences in the 2D:4D ratio in karate and taekwondo athletes when compared to other combat sport athletes. It should be noted that most of our taekwondo athletes were recruited from the non-Olympic ITF (International Taekwondo Federation). In some Karate federations and the ITF, most of the competition is devoted to kata, which means prepared forms of demonstrating attacks, defense and counterattacks. In kata, practitioners are forced to use many different attitudes and techniques, allowing them to achieve a high level of versatility and technical mastership. Some of them are designed to show speed, others to emphasize and exercise special methods of breathing, etc. In addition, there are various karate styles, e.g., light or semicontact in which athletes must control the performance of the fighting technique because, in the event of too strong strikes, they receive a penalty. It seems, therefore, that these forms of training have a major impact on controlling anger and aggression against the opponent (Mroczkowska et al., 2008), and predispositions for such training adaptation can be observed indirectly from higher 2D:4D values. The above-discussed aspects of combat sports may explain the observed trend (p = 0.067) of higher 2D:4D ratios in the combined karate and taekwondo group compared to the controls.

Another potential explanation is the existence of the so-called Kano paradox. In combat sports and martial arts theory, the Kano paradox refers to situations when competitors are less prepared for a real fight with an opponent because their sport uses kata training and pretending techniques (Watanabe and Avakin, 2001). Of course, subjects included in this work were elite athletes, however their selection of the sport was made many years ago, probably without checking predispositions for full-contact fighting. For these types of sports (examples include some karate federations and taekwondo), people not interested in real combat need to be recruited (e.g., judo, kick-boxing, Olympic wrestling). This is probably one of the reasons for the large popularity of karate for children. The emphasis is placed on the educational effect, the discipline, physical and functional fitness and at the end, training and fighting (Boguszewski et al., 2019). As a result of selection, only a few reach a competitive level in combat sports. On the basis of our results, we believe that predispositions for direct combat with an opponent can be indirectly defined by measuring the 2D:4D ratio at the early stage of training.

The most stressful situations during rivalry are considered to be fighting with stronger opponents and sustaining an injury during competition. It is worth mentioning that stressful situations may sometimes increase performance, and according to Ribeiro et al. (2016a), the 2D:4D ratio is negatively correlated with strength in challenging situations. On the other hand, greater experience, along with sport success expressed by achieving an international level of competition, seems to be an important factor in the ability to control emotions (Reed and Meggs, 2017). This suggests the possibility of using the 2D:4D ratio as one of the selection criteria (e.g., a predisposition for direct physical fighting with an opponent) for combat sports martial arts (Baker et al., 2013), especially given that some data suggest interdependence between biological markers of performance and physical fitness in combat sports. Thus, the 2D:4D ratio might be connected with the choice of sport as each sport has different physiological and mental requirements. This suggests that the 2D:4D ratio may provide important additional information, which may be valuable in determining the potential of athletes, but must be used in conjunction with other measures (Keshavarz et al., 2017; Kozieł et al., 2016).

Conclusions

In conclusion, this is one of the first reports on the 2D:4D ratio in a large group of combat sport athletes. We showed that the 2D:4D ratio was associated with particular combat sports. The ratio was significantly lower among wrestlers, judo athletes and kickboxers than among controls, and higher among karate and taekwondo athletes than among controls, with borderline significance. However, the 2D:4D ratio was significantly higher when karate and taekwondo athletes were compared to the remaining three groups of athletes. We hypothesize that this could be due to different forms of training, aimed at better control of anger and aggression, in these two sports. It seems possible that the 2D:4D can impact the choice of sport by influencing specific requirements. In general, we suggest that the 2D:4D ratio be considered as a supplementary criterion for assessing athletes to be recruited to a team.

Practical implications

The research results and the short literature review above indicate that knowledge about the 2D:4D ratio of athletes, especially in comparison to the sedentary population, is too fragmentary, and it is too early to use the 2D:4D ratio alone in the selection of sports talent. However, because of better evidence of a relationship between a low 2D:4D ratio and sports performance, the current study provides further support to the thesis that it may be a useful criterion when screening prospective athletes to be recruited to a team.

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