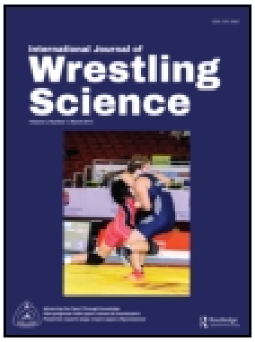

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Digit Ratio, Testosterone/Cortisol Levels, and Hand Grip Strength Among Elite Iranian Wrestlers

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ABSTRACT. Wresting is a weight-categorized sport with many handgrips used during the competition. Many studies have reported some predictors of hand grip strength, but none of them has studied the complete hand dimensions and hormone levels in elite wrestlers. Thus, the aim of this study is to investigate the relations among digit ratios and various hand dimensions, anthropometrical characteristics, grip strength, and testosterone/cortisol levels among elite Iranian male wrestlers. For this purpose, 13 male Iranian national team wrestlers voluntarily participated in this study. The finger parameters were evaluated using the Visnapuu method, and a salivary hormonal assay was performed using an enzyme-immunoassay kit. Statistical analysis was conducted using SPSS 19. The statistical analysis of data showed significant correlations ($p < .05$) between hand grip strength and hand-specific variables including finger perimeters P1, P2, P3, P5; finger lengths of the thumb, index, middle, ring and little finger lengths (TL, IFL, MFL, RFL, LFL, respectively); and the ratios of the index finger length to the little finger length (I:L), and the index finger length to the ring finger length (2D:4D), with the highest correlation being observed between the index finger length and handgrip strength ($r = 0.85$, $p = .001$). Furthermore, additional anthropometrical characteristics including wrist girth, arm span, shoulder width (biacromial breadth) and forearm girth were found to have strong correlations with hand grip strength ($r = 0.77$, $r = 0.77$, $r = 0.73$ and $r = 0.70$, respectively) and thus can be used as simple predictors of hand grip strength in wrestling.

Keywords: digit ratio, salivary testosterone/cortisol, wrestling

Elite athletes are the best examples of people who have reached the highest performance levels in their sport through some specific attribute. This superior performance is often related to their particular body characteristics. If these characteristics or factors are elucidated, it can lead to better talent identification or selection of new athletes in any sport. In addition, it is important that these specified factors can be easily measured without complex laboratory instrumentation.

Many factors can lead to the advantage some athletes have over others. Some studies have related physical differences between these athletes, especially in power-dependent sports, to testosterone and to its prenatal or adult effects (Hönekopp, Manning, & Müller, 2006) that could be a determining factor in explaining differences in performance among male athletes. Wrestling is a sport that uses many hand grips to control and move an opponent, and higher hand grip strength could lead to better performance of techniques and could thus affect a wrestler's performance. Grip strength has been shown to be significantly higher in elite wrestlers when compared with amateurs (García-Pallarés, López-Gullón, Muriel, Díaz, & Izquierdo, 2011). Cortell-Tormo and colleagues (2013) reported that in judo some hand-specific measurements positively correlated with hand grip strength, sport achievement (García-Pallarés et al., 2011). Thus, if some predictors for hand grip strength could be defined, they could possibly be used for talent identification.

Androgenic hormones have a significant role in the development of muscle mass and positive muscle protein balance through either its anabolic and anticatabolic effects (García-Pallarés et al., 2011; Vingren et al., 2010). Because

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of the direct relation between muscle mass and power output, this can be a determining factor in the performance of athletes in sports with physical contact such as wrestling. Another hormone that is responsible in the protein balance is cortisol. This hormone is a glucocorticoid hormone with known catabolic effects and causes a negative protein balance in the body. These hormones have multiple effects on neural development, which can, in turn, affect neural and muscular performance (Crewther, Cook, Cardinale, Weatherby, & Lowe, 2011; Vingren et al., 2010). Many studies have investigated the ratio of testosterone and cortisol as a marker of physiological stress, which can show the status of net protein balance in the body, and of their effects on the performance of different subjects, especially elite athletes (Crewther et al., 2011; Passelergue, Robert, & Lac, 1995).

One of the proposed predictors of prenatal testosterone is the ratio of the length of the second digit of the hand (2D) to the length of the fourth digit, or digit ratio (2D:4D; de la Cruz-Sánchez, García-Pallarés, Torres-Bonete, & López-Gullón, 2015; Voracek, Reimer, Ertl, & Dressler, 2006). This ratio of index finger to ring finger (2D:4D) is a sexually dimorphic trait in which men tend to have lower values than women (Passelergue et al., 1995; Voracek et al., 2006). It is well known that the homeobox (HOX) gene sequence plays a role in anatomical development, including an effect on the differentiation in the length of fingers and the formation of gonads (Jürimäe et al., 2008; la Cruz-Sánchez et al., 2015; Voracek et al., 2006). Thus, the (2D:4D) ratio has been proposed as a marker of prenatal androgen levels, which can be associated with many mental and physical variables. This relation might be seen in elite wrestlers, where the demands for grip strength are high. Prenatal hormone levels define the measures of digit ratio, and while prenatal testosterone promotes the growth of the fourth digit, prenatal estrogen promotes the growth of the second digit (Passelergue et al., 1995; Voracek et al., 2006). There is ample evidence showing that digit ratio sex differences are not affected by puberty, and thus it seems that it is established early in life (Jürimäe et al., 2008; la Cruz-Sánchez et al., 2015; Muller et al., 2011). The negative correlation between digit ratio and prenatal testosterone has been reported to be higher in men and remains so throughout puberty (Jürimäe et al., 2008; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Muller et al., 2011). There are reports of a relation between this digit ratio and sex-dependent psychological, behavioral, and cognitive variables, as well as studies showing a negative correlation between digit ratio and the performance of athletes in soccer, skiing, fencing, hockey, martial arts, rugby, running, soccer, squash, swimming, and tennis (Manning, 2002; Manning, Bundred, & Taylor, 2003; Manning et al., 1998; Muller et al., 2011; Voracek et al., 2006). These relations may indicate a simple method to predict future hand grip strength and therefore aptitude for wrestling. Wrestling in Iran is a very important Olympic sport with a history of great achievements, and thus an investigation of factors that can be used in talent identification could be beneficial for the wrestling community. Therefore, this study has been designed to evaluate the relations among grip strength, selected digit ratios, testosterone/cortisol levels, various hand anthropometric dimensions consisting of finger spans, finger lengths, finger perimeters, arm span, humerus-bicondylar diameter, shoulder width, and wrist girth among world-class Iranian wrestlers.

METHOD

Participants

Thirteen Iranian male world class wrestlers (*M* ± *SD*, age: 25.21 years ± 1.92 years; body weight: 80.92 ± 21.06 kg; body height: 1.76 ± 0.10 meters; BMI: 25.65 ± 3.64 kg/m^2) voluntarily participated in this study all of whom had won the multiple Asian and/or world championship medals. Before starting the study, all of the participants completed the health questionnaire and also an informed consent was obtained. the weight of the athletes were measured using Seca meter and scale (Germany) to the nearest 0.1 cm and 0.1 kg, respectively.

Hand Anthropometry

For evaluating the hand dimensions, the standard Visnapuu and colleagues (2007) method has been used (Manning et al., 2003; Manning & Taylor, 2001; Visnapuu & Jürimäe, 2007). The subject sits comfortably on a suitable chair and places the dominant hand on a paper with the fingers open in a full abduction state. Then, the shape of the hand was drawn by one examiner for all subjects, using a thin marker held perpendicular to the paper. Three categories of hand anthropometric dimensions were measured as showed in Figures 1–3. Finger spans were all measured from the tip of the thumb (T). Finger span 1 (FS1) from the tip of T to the tip of the index

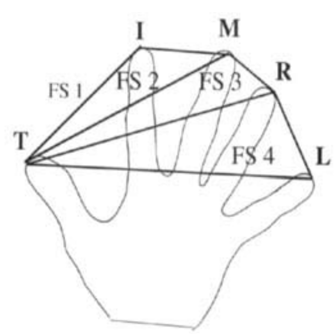

FIGURE 1 Finger spans: From the tip of thumb (T) to the tip of the: index finger (I): (FS1); middle finger (M): (FS2); ring finger (R): (FS3); little finger (L): (FS4); each finger:(TIMRL): (FS5).

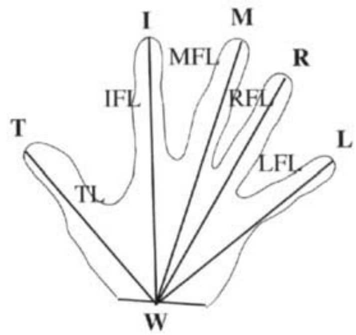

FIGURE 2 Finger lengths: From wrist (W) to the tip of the thumb (T); index finger (I); middle finger (M); ring finger (R); little finger (L).

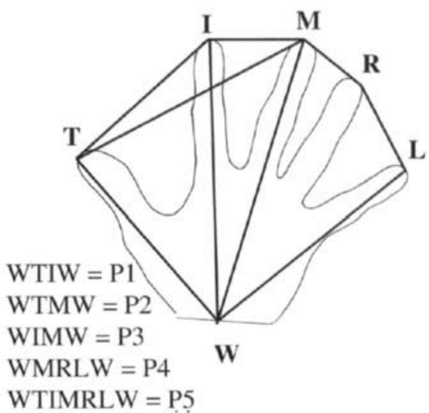

FIGURE 3 Finger perimeters.

finger (IF); finger span 2 (FS2) from the tip of T to the tip of the middle finger (MF); finger span 3 (FS3) from the tip of T to the tip of the ring finger (RF); finger span 4 (FS4) from the tip of T to the tip of the little finger (LF); and finger span 5 (FS5) is the sum of the distances from the tip of T to the tip IF, tip of IF to the tip of MF, tip of MF to the tip of RF and the distance from the tip of RF to the tip of LF. Finger lengths were measured from the from the wrist joint (W) to the tip of each finger. The perimeters were derived from outlines of various shapes all beginning and ending at (W). P1 equals the perimeter described by the shape WTIW; P2 = WTMW; P3 = WIMW; P4 = WMRLW; and P5 = WTIMRLW.

Biacromial breadth (shoulder width) was evaluated from the acromion process of one side to the same point on the other side of shoulder girdle. The forearm girth (bicondylar circumference) was measured at the point of the greatest circumference. The wrist girths were measured at the highest point and wrist of the dominant hand. The arm span (the length of two opened arm) was measured while participants opened their arms horizontally as far as possible (Abdollah, Khosrow, & Sajad, 2014; Manning & Taylor, 2001; Visnapuu & Jürimäe, 2007).

Measurement of Hand Grip Strength

The hand grip strength was measured three times using hand grip dynamometer (Yagami, YDM-110D, 5–110 kg) and the highest reading was recorded as a personal record. For the adequate provision of fingers, the adjustable rod of dynamometer had been adjusted before the test according to the subjects' hand size. In addition, for the sake of preventing fatigue, a 3-min rest was allowed between the tests. The test was performed when the hand was in anatomical position and without any flexion in the elbow joint (Abdollah, Khosrow, & Sajad, 2014; Manning & Taylor, 2001; Visnapuu & Jürimäe, 2007).

Hormonal Tests

Free testosterone and cortisol levels were measured using a noninvasive saliva sampling that has been proposed as a practical and reliable method for determining free hormone levels (Abdollah, Khosrow, & Sajad, 2014; Arregger et al., 2007; Laudat et al., 1988; Visnapuu & Jürimäe, 2007). The participants provided a 2 ml saliva sample by passive drool into a 10 ml container, which was stored at –60 °C. After thawing and centrifugation (2000 g, 10 min), the saliva samples were assayed in duplicate for free testosterone concentrations using a commercial enzyme-immunoassay kit (IBL, Hamburg) and the manufacturer's instructions. The minimum detection limit for the testosterone assay was 2.0 pg/ml with intra- and interassay coefficients of variation (CV) of 2.0–9.8% (Arregger et al., 2007; Kilduff et al., 2013; Laudat et al., 1988). Saliva collection, for the resting levels of testosterone and for the first sample in the challenge group, was made between 8.00am and 9.00am.

Statistical Analysis

For statistical analysis of the data, SPSS 19 was used and the normality of data's distribution was determined using the Shapiro-Wilk test. In the case of normal distribution, correlation between different variables was assessed using Pearson's correlation coefficient; otherwise the Spearman's correlation coefficient was used. The data are presented as mean ± *SD* and the significant level was set at $p < .05$.

RESULTS

Descriptive statistics of the variables are presented in Table 1. Statistical analysis of the data showed the significant correlation ($p < .05$) between hand grip strength with part of the examined variables that for hand grip strength are presented in Table 2. Regarding testosterone level, it just has a significant correlation with forearm girth of the hand, RFL and MFL ($r = 0.77$, $r = 0.57$, and $r = 0.58$). The testosterone/cortisol ratio

TABLE 1 Mean ± *SD* of the Participants' Characteristics

Variable	*Mean* ± SD
Age (years)	24.64 ± 2.56
Weight (kg)	70.75 ± 9.25
Height (m)	1.72 ± 0.07
BMI (kg/m^2)	23.70 ± 1.38
Hand grip strength (N)	62.85 ± 7.61
Digit ratio (2D:4D)	1.02 ± 0.02
Testosterone (T))pg/ml(	21.91 ± 10.63
Cortisol (C))pg/ml(	13.76 ± 6.25
T/C	2.25 ± 1.69
Finger span 1 (FS1) (cm)	12.47 ± 1.70
Finger span 2 (FS2) (cm)	16.75 ± 1.76
Finger span 3 (FS3) (cm)	19.05 ± 1.81
Finger span 4 (FS4) (cm)	20.85 ± 1.43
Finger span 5 (FS5) (cm)	27.41 ± 2.57
Finger perimeter 1 (P1) (cm)	46.90 ± 3.78
Finger perimeter 2 (P2) (cm)	51.89 ± 3.99
Finger perimeter 3 (P3) (cm)	45.96 ± 3.60
Finger perimeter 4 (P4) (cm)	47.01 ± 3.41
Finger perimeter 5 (P5) (cm)	58.72 ± 4.96
TFL length (cm)	14.82 ± 1.24
IFL length (cm)	19.64 ± 1.66
MFL length (cm)	20.32 ± 1.59
RFL length (cm)	19.17 ± 1.48
LFL length (cm)	16.48 ± 1.14

TABLE 2 Relation Between the Hand Anthropometrical Parameters and Hand Grip Strength

Variable	p	*Pearson correlation coefficient*
Arm span	0.001	0.77
Shoulder width	0.003	0.73
Forearm girth	0.008	0.70
Wrist girth	0.001	0.77
TL	0.000	0.81
IFL	0.000	0.85
MFL	0.011	0.68
RFL	0.041	0.57
LFL	0.003	0.73
P1	0.020	0.61
P2	0.007	0.68
P3	0.032	0.57
P5	0.006	0.70
I/R (2D:4D)	0.037	0.58
I/L	0.009	0.67

was only correlated with FS1 ($r = -0.57$), while it was near the significance level with FS 2 ($p = .054$, $r = -0.54$).

DISCUSSION

Hand grip strength is an important functional capacity that can improve performance in many sports (Abdollah et al., 2014; Cortell Tormo et al., 2013; García-Pallarés et al., 2011; Kilduff et al., 2013; Manning & Taylor, 2001; Visnapuu & Jürimäe, 2007). In wrestling, handgrips are very common for carrying out different techniques; thus, it seems that this capacity may be extremely valuable for wrestlers. Few researchers have investigated this factor among elite wrestlers and each one has only explored the relation of some hand dimensions with hand grip strength, whereas we have studied its presumable relation with many hand, arm, and shoulder dimensions such as lengths, girths, and widths. La Cruz-Sanchez and colleagues (2015) investigated the relation between digit ratio and successful performance among elite wrestlers but did not find any difference between successful and nonsuccessful wrestlers; they only reported the training experience as a factor related to level of achievement. This study assumed the results of athletes in only one competition as a scale for successful performance. Wrestling is an open-skill sport that many factors could affect athletes' performance including technical, tactical, psychological, and physical factors. Thus, it seems difficult to find the relation between one antropometrical characteristic and level of achievement among athletes in such a multidimensional sport. However, maybe it's more logical to search for such a correlation in sports which are among closed-skill sports such as weightlifting.

In the present study, we found that 15 factors have an approximately moderate to strong correlation with hand grip strength (min r = 057, max r = 0.85) with the highest correlations being related to TL and IFL (0.81 and 0.85, respectively). Hanger and colleagues (2002), Nicolay and colleagues (2005), Cortell-Tormo and colleagues (2013), and Rashidlamir and colleagues (2011) have indicated that different finger lengths can be a predictor of hand grip strength, which partly supports the results of present study. The best predictor for hand grip strength of both wrestling and judo elite athletes was IFL, which seems to have the highest correlation with hand grip strength in such sports with many hand grips. The differences found between this study and Rashidlamir and colleagues (2011) are related to the nonsignificant relation between hand grip strength and finger spans (FS1–FS5) that were as same as the results of the Corttell-Tormo and colleagues (2013). Furthermore, Rashidlamir and colleagues (2011) and Visnapuu and colleagues (2007) claimed that the more significant relation to be between ring finger and hand grip strength, whereas in the present study it was found to be more significant in the thumb and index finger of hand. In the case of digit ratio, it was correlated with hand grip strength, but was not correlated with testosterone and testosterone/cortisol ratio.

Also, this study scrutinized the hand grip strength relation with additional anthropometrical characteristics not used in earlier studies; specifically, it showed the strong relation among hand grip strength and shoulder width, humerus bicondylar diameter, arm span and wrist girth, which may be used as predictors of hand grip strength.

Previously, some studies demonstrated a correlation between some specific anthropometrical characteristics, like two opened arm's length, in other sports such as fencing (Abdollah et al., 2014; Manning & Taylor, 2001; Visnapuu & Jürimäe, 2007), but there was not any study in wrestling. Thus, these characteristics could be used as predictor of wrestlers' hand grip strength.

In the case of salivary hormonal levels, no significant correlation was observed. Laudat and colleagues (1988) and Arregar and colleagues (2007) reported that salivary cortisol and testosterone levels could be used as a practical approach for investigating plasma cortisol in normal participants (Abdollah et al., 2014; Visnapuu & Jürimäe, 2007), and many studies have used these hormones assessments as markers for metabolic condition of body (Cortell et al., 2013; Kilduff et al., 2013; Laudat et al., 1988; Maso et al., 2004). In terms of digit ratio, there was no significant correlation between hormonal levels and digit ratio of the hand, a finding which is supported by Beaton and colleagues (2011) who did not find any significant correlation between testosterone levels and digit ratios. Hence, the factors that have been found to be related with hand grip strength can be used to identify talents in sports such as wrestling. However, more work in studying elite athletes is needed to be done so that we may fully elucidate those specific characteristics of elite athletes.

In addition, there is a need to study these characteristics between nonathletes, nonelite wrestlers, and elite wrestlers, which could possibly increase the generalizability to wrestling specifically. Another limitation of this study was the number of participants, which, for correlational studies, should be as high as possible for increased reliability. It should be noted that there are many factors that could determine performance of athletes, and correlational studies, such as the present one, have their specific limitations that always should be considered.

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