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Relationship between the 2D:4D ratio, physical performance variables, and body composition in elite wrestling athletes

Relación entre la proporción 2D:4D, variables de rendimiento físico y composición corporal en atletas de lucha libre élite

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Abstract. Background: The 2D:4D ratio in various sports has revealed significant relationships between this digit indicator and sports performance, but few studies have focused on elite wrestlers. Thus, the present study has two main objectives: firstly, to present descriptive data comparing it between genders, and secondly, to identify significant correlations with the 2D:4D ratio. Methods: A total of 22 wrestlers participated in the study, and their anthropometric variables, bilateral 2D:4D ratio, muscle power (CMJ), isometric traction strength, and handgrip strength were compared. Results: The findings show significant correlations between the right 2D:4D ratio and residual mass ($r = .46$; $p < .05$); Z-Score transverse thorax ($r = .61$; $p < .01$); inversely with ectomorphy ($r = -.46$; $p < .05$) and handgrip strength ($r = .43$; $p = .042$); and the left 2D:4D with Z-Score chest girths ($r = .45$; $p < .05$) and Z-Score weight ($r = .43$; $p = .042$). Conclusions: It is concluded that the 2D:4D ratio could be a predictive indicator of body composition components as well as a measure of handgrip strength performance and respiratory capacity in Olympic wrestling athletes.
Keywords: digit ratios, anthropometry, body weights and measures, physical examination, body size

Resumen. Antecedentes: La proporción 2D:4D en varios deportes ha revelado relaciones significativas entre este indicador digital y el rendimiento deportivo, pero pocos estudios se han centrado en luchadores de élite. Por lo tanto, el presente estudio tiene dos objetivos principales: primero, presentar datos descriptivos comparándolos entre géneros, y segundo, identificar correlaciones significativas con la proporción 2D:4D. Métodos: Un total de 22 luchadores participaron en el estudio, y se compararon sus variables antropométricas, proporción bilateral 2D:4D, potencia muscular (CMJ), fuerza de tracción isométrica y fuerza de agarre manual. Resultados: Los hallazgos muestran correlaciones significativas entre la proporción 2D:4D derecha y la masa residual ($r = .46$; $p < .05$); Z-Score del tórax transversal ($r = .61$; $p < .01$); inversamente con el ectomorfo ($r = -.46$; $p < .05$) y la fuerza de agarre manual ($r = .43$; $p = .042$); y la proporción 2D:4D izquierda con el Z-Score de las circunferencias del pecho ($r = .45$; $p < .05$) y el Z-Score de peso ($r = .43$; $p = .042$). Conclusiones: Se concluye que la proporción 2D:4D podría ser un indicador predictivo de componentes de la composición corporal, así como una medida del rendimiento de la fuerza de agarre manual y la capacidad respiratoria en atletas de lucha olímpica.
Palabras clave: proporciones digitales, antropometría, peso y medidas corporales, examen físico, tamaño corporal

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Introduction

Wrestling is an Olympic sport that is subdivided by weight categories and consists of two styles: freestyle and Greco-Roman (Yaşar & Sağlr, 2021). In this sport, two individuals compete, with the objective of dominating each other through attack and defense techniques (García-Pallarés et al., 2011). In addition to technical and tactical aspects, research findings show the relationship between body composition and somatotype with anaerobic power, strength, and balance, which are considered important components of physical performance (Yıldırım et al., 2019). The evaluation of these capacities is crucial for Olympic wrestlers, as it provides valuable information for tactical planning and training. These findings highlight the importance of understanding the unique physical characteristics of wrestlers to optimize their performance (Ramirez-Velez et al., 2014).

Body composition is known to be a highly important factor in various aspects of competitive performance, where previous research has highlighted the significance of fat-free mass in anaerobic performance, demonstrating a positive relationship between peak power and this component in elite young wrestlers (Vardar et al., 2007). Additionally, other studies have provided valuable information on the anthropometric characteristics and body composition of Italian national wrestlers, including the determination of minimum wrestling weight based on body fat percentage (Zaccagni, 2012). Collectively, these studies emphasize the critical importance of body composition in the fundamental aspects of training, performance, and weight management in the realm of wrestling (Roemmich & Frappier, 2016).

Among the relevant capabilities, muscular power plays a fundamental role in wrestling, with an emphasis in both lower and upper limb strength. This is due to the nature of the movements, where leg extensor strength and arm movement speed become essential elements in generating power during grappling and throwing actions against opponents (Pojednic et al., 2012). Research has consistently underscored the relevance of muscular power in the lower limbs of wrestlers (Gierczuk et al., 2012), and it has been shown that wrestlers exhibit superior relative peak and average power, both in their upper and lower extremities, compared to other combat sports (Hübner-Woźniak et al., 2011).

Some studies mention that the 2D:4D ratio is a marker of

prenatal testosterone exposure, and it has been linked to sports performance in various manuscripts. For example, it has been observed that lower 2D:4D ratios are associated with greater athletic ability in women (Paul et al., 2006) and in combat sports in men (Adamczyk et al., 2021), as well as better performance in fencing for men (Voracek et al., 2006). This ratio has also been related to handgrip strength in men (Nanda & Samanta, 2017). However, the relationship between 2D:4D and adult sex hormone levels is less clear, with some studies suggesting an association (Hönekopp et al., 2007), while others have found no relationship (Manning & Taylor, 2001). Hypothetically, we believe that the 2D:4D ratio could be a useful tool for predicting sports performance due to the relationship between hormones and the development of physical abilities, especially in Olympic wrestling.

Despite the abundance of studies on wrestlers, there is a scarcity of research analyzing body composition characteristics, somatotype, physical performance, and their relationship with the 2D:4D digit ratio in both men and women. For this reason, the primary objective of the present study was to describe these characteristics in elite wrestlers. Additionally, the secondary objective was to investigate the relationships between physical performance variables and body composition in elite Colombian wrestlers.

Methods

Subject and procedure

The number of participants in the study was determined using the G*power® 3.1.6 software. Twenty-two wrestlers of both genders: males (n = 16; age 23.4 years ± 4.0; body mass 72.2 kg ± 13.6; height 171.2 cm ± 6.3; and sport experience 7.2 years ± 3.8), and females (n = 6; age 20.2 years ± 4.1; body mass 59.2 kg ± 5.8; height 157.3 cm ± 4.0; and sport experience 7.1 years ± 2.3), who are in the competitive stage with a view to the 2023 national games, all belonging to the Huila Wrestling League located in the city of Neiva (Colombia). The athletes have experience in both international and national competitions, earning significant positions in South American, Central American, Pan-American Games, and qualifiers for World Championships and the Olympic Games. Data collection was conducted on two separate days within the same week starting at 7:00 hr. On the first day, participants underwent body composition assessments including measurements of 2D and 4D finger lengths using anthropometry, while muscular strength (i.e., hand and trunk strength) and lower limb power, including the counter-movement jump (CMJ), were measured on the second visit. All participants were informed about the nature and possible risks of the experimental procedures prior to the tests. The study was approved in accordance with Resolution 8430 of the Ministry of Health and Social Protection of Colombia, and all procedures were conducted in accordance with the Declaration of Helsinki. After reading the informed consent document, the volunteers accepted the procedures by signing the form for their inclusion in the research.

Body composition

The anthropometric evaluation and its derivatives (i.e., somatotype and Phantom) were conducted starting at 7:00 am, following the protocol established by The International Society for the Advancement of Kinanthropometry (ISAK). The measurements were performed by an ISAK level three anthropometrist, who employed the full profile.

Second to fourth digit length ratio (2D:4D)

The 2D:4D ratio was evaluated on both hands by measuring the lengths of the ratio finger (2D) and the ring finger (4D) from the basal metacarpophalangeal crease to the fingertip. Accordingly, measurements were taken on the ventral surface of the hand, considering the basal crease closest to the palm in cases of multiple creases (Manning & Taylor, 2001; Trivers et al., 2006). A digital Vernier caliper with a precision of 0.01 mm was used, in accordance with established guidelines in the literature. Thus, the 2D:4D ratio was calculated by dividing the length of the index finger (2D) by the length of the ring finger (Trivers et al., 2006).

Muscle power

The muscular power of the lower limbs was evaluated using the Counter-Movement Jump (CMJ) on a Chronojump-Boscosystem® contact mat, and the results were obtained and recorded using the Chronojump 2.3.0-1283 software. After completing familiarization trials, three maximum attemps were performed, with a 30-second rest. Jump power was estimated using the jump height and the athlete's body mass, according to the equation proposed by Sayers (1999): Peak Power (W) = 60.7 (jump height [cm]) + 45.3 (body mass [kg]) – 2055 (Monterrosa et al., 2019).

Handgrip strength

To measure the maximum isometric hand strength, the athletes underwent a maximum grip strength test using a Takei, Japan® digital hand dynamometer. The dynamometer was adjusted according to the size of the athletes' hands, and the strength of the dominant hand (i.e., right hand) was evaluated. Three non-consecutive attempts were made with a two-minute interval between each attempt, and the highest value achieved by the participants was recorded. (Andreato et al., 2013).

Isometric mid-thigh pull protocol

The Isometric Mid-Thigh Pull (IMTP) test was employed to assess overall muscle strength, using an analog dynamometer from Takei Scientific Instruments Co. Ltd. (model TKK 5002 Back-A, Tokyo, Japan®). To ensure uniformity in the

participants' posture, an angle of 145° was established between the thigh and the knee, as well as between the trunk and the thigh, using two goniometers. Additionally, the handle height was individually adjusted so that the bar rested in the middle of the thigh (Dos'Santos et al., 2017). Participants, after confirming their position, extended their knees and trunk maximally for a time interval of three to five seconds, keeping their back straight, performing three attempts, and recording the maximum value in each case. (Orange et al., 2019).

Statistical analysis

For the statistical analysis, we utilized the Jamovi® program version 1.6 (https://www.jamovi.org), presenting the data as mean ± standard deviation (*M* ± *SD*), and the 95% confidence interval (*CI*) was calculated for the outcome in the studied variables. The assumption of normality was verified using the Shapiro-Wilk test; in case this criterion was not met, a logarithmic transformation was applied, and the normality of the data was verified again. If normality was not achieved, non-parametric tests were used. To evaluate differences between the mean values of the variables, the Student's *t*-test for independent samples and the Mann-Whitney U test were employed. Correlations between variables were assessed using the Spearman's rank correlation coefficient. To determine the effect size (*ES*), values < 0.20 were considered trivial, from 0.20 to 0.39 small, from 0.40 to 0.79 moderate, > 0.80 large (Cohen, 1977), > 1.20 very large, and > 2.0 enormous (Sawilowsky, 2009). The correlation coefficients scales were determined according to Hopkins (2002). A significance level of $p \leq .05$ was established for all analyses.

Results

Table 1 presents general descriptive values of the study population. Table 2 provides descriptive data of body composition and physical performance variables, and Table 3, along with Figure 1, shows significant correlations.

Table 1.
Descriptive characteristic of the wrestlers

Characteristics	Gender	*M*	*SD*	95% Confidence Interval		*p*
				LL	UL	
Age (years)	Female	20.25	4.19	15.85	24.65	.140 *
	Male	23.46	4.03	21.32	25.61	
Weight (kg)	Female	59.28	5.83	53.16	65.41	.038
	Male	72.20	13.64	64.93	79.47	
Height (cm)	Female	157.32	4.07	153.05	161.58	< .001
	Male	171.22	6.30	167.87	174.58	
BMI (kg/m^2)	Female	23.91	1.52	22.32	25.50	.695
	Male	24.54	3.74	22.55	26.54	
Experience (years)	Female	7.17	2.32	4.74	9.60	.947
	Male	7.28	3.86	5.23	9.34	

Note. LL = lower limit; UL = upper limit; * = Mann-Whitney U test; BMI = Body Mass Index.

The effect size of significant differences in weight was considered moderate (*ES*: 0.69), while in height, the effect was large (*ES*: 1.0) (Cohen, 1977).

Table 2.
Mean values of 2D:4D ratio and physical performance characteristics

Characteristics	Gender	*M*	*SD*	95% Confidence Interval		*p*
				LL	UL	
Right second (mm)	Female	66.14	2.66	63.35	68.94	< .001
	Male	75.80	4.87	73.20	78.39	
Right fourth (mm)	Female	69.40	4.73	64.43	74.36	.002
	Male	76.88	4.36	74.56	79.20	
Left second (mm)	Female	66.93	4.59	62.12	71.75	.006*
	Male	76.70	25.62	63.05	90.35	
Left Fourth (mm)	Female	68.19	5.35	62.57	73.81	< .001*
	Male	87.94	30.00	71.96	103.93	
Left 2D:4D	Female	0.98	0.05	0.93	1.04	.747*#
	Male	0.90	0.24	0.77	1.03	
Right 2D:4D	Female	0.96	0.05	0.91	1.00	.167#
	Male	0.99	0.05	0.96	1.01	
CMJ_H (cm)	Female	20.14	2.65	17.35	22.92	< .001
	Male	32.46	4.58	30.01	34.90	
CMJ_P (w)	Female	650.67	265.35	372.21	929.13	.034
	Male	1248.12	615.83	919.96	1576.27	
Handgrip strength (kg)	Female	24.87	2.69	22.04	27.69	< .001
	Male	41.27	7.04	37.51	45.02	
IMTP (kg)	Female	85.75	35.07	48.95	122.55	.038
	Male	139.84	54.98	110.55	169.14	

Note. LL = lower limit; UL = upper limit; * = Significant differences using the Mann-Whitney U test, between female and male; # = differences ratio 2D:4D between left and right ($p = .075$) using Wilcoxon test; CMJ_H: Counter Movement Jump height; CMJ_P: Counter Movement Jump power; IMTP = Isometric Mid-Thigh Pull.

The results indicate a considerable effect size in various variables: the second right finger showed an enormous effect (*ES*: 2.18), while the fourth right finger exhibited a very large effect (*ES*: 1.68). On the other hand, the second left finger presented a moderate effect (*ES*: 0.75), and the fourth left finger showed a large effect (*ES*: 0.88). Additionally, the countermovement jump height (CMJH) revealed an enormous effect (*ES*: 2.94), while the countermovement jump power (CMJP) demonstrated a large effect (*ES*: 1.09). Handgrip strength also stood out with an enormous effect (*ES*: 2.63), as did IMTP with a large effect (*ES*: 1.07). These results align with the criteria established by Cohen (1977) and Sawilowsky (2009).

Table 3.
Correlation between 2D:4D ratio of both hands with body composition

	RR	RL
RR	1	
RL	.58**	1
Residual mass	.46*	-.03
Ectomorph	-.46*	-.42
Z-Score transverse thorax	.61**	.38
Z Score chest girths	.31	.45*
Z-Score weight	.29	.45*

Note. RR = ratio 2D:4D right; RL = ratio 2D:4D left; * $p < .05$, ** $p < .01$.

Several significant correlations were observed, some of a positive nature with moderate coefficients ($r = .3$ to $.5$), others of moderate magnitude but inversely related, and two of

large magnitude (r = .5 to .7), specifically in relation to the right-hand ratio. Additionally, two moderate correlations were found between body composition variables and the 2D:4D ratio of the left hand.

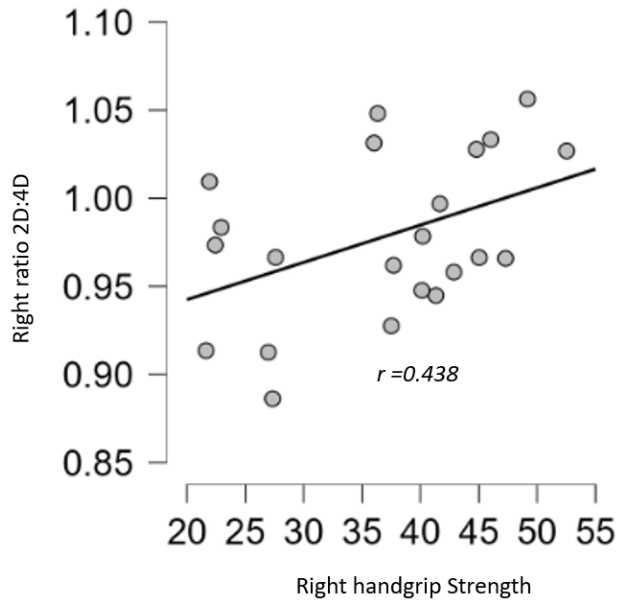

Figure 1. Correlation between ratio 2D:4D and handgrip strength (right)

Focusing on the relationship between physical performance and bilateral ratio, our analysis revealed a moderate positive correlation (p = .042) between handgrip strength and the 2D:4D ratio, as depicted in Figure 1.

Discussion

Research on the 2D:4D ratio in various sports has revealed significant relationships between this digit indicator and athletic performance. The results of several studies have shown consistency in ratio values when comparing the right hand with the left, especially in men participating in ball sports, assessing their performance without finding significant differences (Bennett et al., 2010; Ramos et al., 2020). On the other hand, in sports such as fencing, when evaluating gender differences, our findings are corroborated by not finding significant differences when comparing the right hand with the left based on gender (p = .775) (Voracek et al., 2006), and similarly when comparing the ratio of the right and left hand between men and women in elite Olympic wrestling athletes (see Table 2).

The literature demonstrates that the 2D:4D ratio positively correlates with body composition in women, especially concerning protein mass, bone mass, soft lean mass, and lean body mass (Čabrić et al., 2012). Other researchers have associated a lower 2D:4D ratio with greater muscle mass and strength (Manning & Taylor, 2001). According to the inquiry, the present study is the first to correlate body composition variables, including Z-score values based on the Phantom strategy, and physical performance jointly in elite Olympic wrestlers.

The present study establishes a correlation between residual mass (12.5% ± 1.3) and weight determined by the Phantom strategy (i.e., Z-Score = 0.80 *SD*) with the 2D:4D ratio of the right hand. We hypothesize that this relationship could be a determining factor in Resting Energy Expenditure (REE), as greater body size and adiposity can influence organ mass (Heymsfield et al., 2019). The scientific literature has consistently indicated that athletes exhibit a higher REE due to their increased muscle mass and physical activity. Therefore, we consider the 2D:4D ratio, particularly on the right hand, as an indicator of prenatal testosterone exposure, which could predict greater muscle mass and strength, as well as resting energy expenditure in elite Olympic wrestlers. However, we approach this assertion cautiously and advise the need for further studies to support this hypothesis (Keshavarz et al., 2017).

The ectomorphic somatotype is described as a slender body with predominant signs of slenderness, fragility, weak bones and musculature, small antero-dorsal diameters, rapid energy expenditure, few fat cells, and poor muscle mass increase (Tóth et al., 2014). Ectomorphy is prevalent in various sports such as elite rhythmic gymnastics, goalkeepers, and forwards in football (Cárdenas-Fernández et al., 2019; Purenović-Ivanović & Popović, 2014). On the other hand, a lower value of the 2D:4D ratio in the right hand is related to various factors, highlighting a higher athletic performance, including athletic achievement (Giffin et al., 2012), in elite rugby players (Bennett et al., 2010). Findings reveal an inverse relationship between 2D:4D and the ectomorphic component (i.e., 1.39), possibly due to the specific characteristics of the sport modality. In this regard, low ectomorphy scores may be advantageous in strength movements, where short levers are preferred (Ryan-Stewart et al., 2018).

The Phantom proportionality model is considered a human anthropometric reference strategy with asexual, interracial, timeless, adult, and asymmetric bilateral characteristics (Cabañas et al., 2008), allowing for the establishment of positive or negative values based on standard deviations (*SD*). The results were positive in transverse thorax (Z-Score = 2.22 *SD*) and chest girths (Z-Score = 2.19 *SD*). Correlating the above data with the 2D:4D ratio allows us to discern that these variables play a crucial role in physical capacity, especially in the cardiorespiratory capacity in elite wrestlers, as found in other studies with swimmers, where lung and ventilatory function correlated with trunk diameter (r = .424; p = .004) and perimeters (r = .709; p = .001), as reported by Torres et al. (2017).

Another important aspect found in the literature is the impact of the 2D:4D ratio on physical performance variables, where the results show that a lower ratio is associated with

better performance in fencing ($r = .87$; $p < .001$), rugby ($r = -.69$; $p = .005$), Greco-Roman wrestling, and athletics, with the 2D:4D ratio of the right hand being a particularly good predictor (Bennett et al., 2010; Keshavarz et al., 2017; Voracek et al., 2006). In our case, the results differ from other studies, when finding a moderate positive correlation between grip strength and the 2D:4D ratio of the right hand (Pasanen et al., 2022), and being similar with other sports such as volleyball ($r = .317$; $p = .162$) and basketball ($r = .536$; $p = .010$) (Kurtoğlu & Çiftçi, 2023). Hypothetically, we believe that hand dominance and the style of sport play an important role in hand strength, and may be influenced by the 2D:4D ratio (Adamczyk et al., 2021). Therefore, the findings should be interpreted with caution.

Conclusions

This study stands out as one of the few to examine the relationship between the 2D:4D ratio in elite wrestlers, and some variables related to physical performance and body composition. Our findings reveal significant correlations with the 2D:4D ratio in both hands, ranging from moderate to large, primarily in body composition variables assessed through the use of the Phantom strategy and handgrip strength. Theoretically, we posit that the 2D:4D ratio could be a predictive indicator of body composition components, as well as a measure of handgrip strength and respiratory capacity in Olympic wrestlers. However, we recommend interpreting these findings with caution, encouraging further studies with a larger number of athletes, considering gender and competition categories.

Data accessibility statements

The authors state that the data are reasonably available.

Compteing interest

The authors declare no conflicts of interest.

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