

CORRELATIONS BETWEEN AGGRESSION AND EXPLOSIVE FORCE OF ADOLESCENTS IN THE NORTH-EASTERN PART OF ROMANIA

M.A. COTEAŢĂ¹ D.G. IACOB¹

Abstract: *The study aims to test the correlation between aggressiveness, evaluated with 2D:4D test, and the explosive force of 45 adolescents aged 15-19 years. The 2D:4D ratio has been determined, as well as the height of squat jump (SJ), countermovement jump (CMJ) and CMJ with arm swing (CMJ-AS), using Just Jump. Correlations were found between the ratio of the two hands, both among girls ($p=0.003$) and boys ($p=0.002$). Compared to girls, boys had strong connections between the 2D:4D of the right hand with SJ ($p=0.008$), CMJ ($p=0.006$), CMJ-AS ($p=0.012$) and the average height of the 4 consecutive jumps ($p=0.016$). Our hypothesis is confirmed, and there are correlations between 2D:4D ratios of both hands and jumps protocols.*

Key words: *2D:4D ratio, teenagers, vertical jump, testosterone, JustJump.*

1. Introduction

Aggression was noted in 3 forms: verbal, physical and indirect. The verbal one adopted equally by both genders, while boys are more physically aggressive and girls used more indirect aggression [3]. From the age of 8 they are already capable of being indirectly aggressive [28]. Vaillancourt et al. [39] found from the age of four children were able to be indirectly aggressive.

Positive correlations were found between the 2D:4D ratio of right hands and verbal intelligence, and a negative correlation between the ratio and numerical [24]. The 2D:4D ratio has been

associated with health status, behavioral traits, and athletic ability [25]. The lower ratio of the two finger lengths indicates a higher prenatal exposure to testosterone, and a higher value of the ratio reflects less exposure to this hormone. In general, among the male gender the 2D:4D ratio is lower compared to that of the female gender [6], [23]. Laws have been observed between this low-value ratio and prominent traits found in boys (high athletic performance, left-handedness, autism etc.) [22].

The 2D:4D ratio of athletes can be used as an indicator in predicting potential sports capabilities, especially of young practitioners [30].

¹ Department of Physical Education and Sport, Faculty of Physical Education and Sport, "Alexandru Ioan Cuza" University of Iasi, Romania

Many studies have found correlations between low values of the 2D:4D ratio and activities that require high physical capacity. Significant relationships were found between palmar flexor strength and the ratio of the lengths of the two fingers (index and ring) among men [40]. Also, in both genders, aerobic performance was negatively correlated with the 2D:4D ratio of both hands [17]. Prenatal testosterone has a much stronger impact on men's athletic ability than on the degree of aggression [18]. One study looked at the length of the index and ring fingers of both hands of subjects from Europe, East Africa and Central Asia. The authors argue that maturation was slower in the African population, the developmental processes of a different trajectory compared to the European and Asian samples [5].

Correlations between 2D:4D and certain physical tests from the Eurofit battery were found among Polish military students [23].

The 2D:4D test is a good indicator of the degree of aggression, which is closely related to the level of testosterone and estrogen. The lower the value of the 2D:4D ratio, the more intense the aggression caused by the internal environment [26].

This method being accessible and non-invasive can be performed using a calliper [2], [5, 6], [12], [23], digital photographs of the palmar surface [9, 10], [29], [33], [38], [40], a digital compass (MarCal Digital Compasses) or a calliper with palm scanning [14].

Explosive force measurement is performed following the vertical jump protocol (eg: SJ, CMJ, CMJ-AS, Abalakov Jump etc.) [1], [9], [13] or standing long jump [15].

Specialists [4], [7], [11], [27], [35, 36] included in their studies the JustJump system in the determination of explosive strength among adolescents.

Tomkinson and Tomkinson (2017) looked at the relationship between 2D:4D digit ratio and handgrip strength. They only looked at teenage boys. Using the Vernier digital calliper (accuracy of 0.01 mm) and the Takei digital dynamometer, they reproduced the aggressiveness and clamping force. Results showed that 2D:4D was negatively correlated with handgrip strength.

Gümüs and Tutkun [15] suggest that the 2D:4D ratio may be associated with certain parameters of motor and functional dominance [15]. Crewther et al. [8] concluded that the 2D:4D ratio of the right hand and testosterone are co-predictors of CMJ height among boys aged 9 to 18 years.

A significant association was found between a reduced finger length ratio and increased physical activity. Disterhaupt's study concluded that there is a weak correlation between explosive strength and 2D:4D. However, subjects with a lower 2D:4D tended to jump higher than those with a higher 2D:4D [9].

The 2D:4D ratio value, calculated by Cartesian coordinate geometry and digital photographs of right hands, is an indicator of explosive force [10].

Hsu et al. [20] found a significant

negative correlation between long jump distance and 2D:4D ratio in boys.

Ranson et al. [33] found that the standing long jump did not correlate with the ratio of the lengths of the 2 hands.

Pasanen et al. [29] reviewed 22 studies and concluded that those with greater handgrip strength have a reduced 2D:4D ratio.

Ilhan et al. [21] found in a group of 179 young athletes correlations between the countermovement vertical jump and the lengths of the index ($p=0.01$) and ring ($p<0.05$) fingers of both the right and left hands ($p<0.05$). In contrast, no associations were found between the 2D:4D ratio of both hands with CMJ.

Eklund et al. [13] involved in their study 104 Olympic female athletes from various disciplines and 117 sedentary individuals to see the relationship between finger length ratio (2D:4D) and physical performance. The results indicate a correlation between a lower 2D:4D ratio and superior sports performance.

Considering the data from the existing specialized literature, the purpose of our research is to establish the association

between aggressiveness and explosive force in teenagers from the north-east of Romania.

2. Material and Methods

The present study is a cross-sectional one through which we aim to find out the statistical links between aggression, represented by the 2D:4D ratio of both hands, and the explosive strength of the lower body of adolescents.

The sample of this research included 46 students from the north-east of Romania aged 15-19. The group consisted of 29 girls (16.69 ± 1 years, 163 ± 7.2 cm and 57.86 ± 9.63 kg) and 17 boys (16.18 ± 0.8 years, 175.2 ± 7.1 cm, 67.08 ± 7.7 kg) whose anthropometric data are presented in Table 1.

The evaluation took place in the summer of 2023 and was carried out by a group of students from the Faculty of Physical Education and Sport in Iasi. The protocol consisted of measuring the length of the index and ring fingers of both hands, then the explosive force using the three types of jumps: SJ, CMJ and CMJ-AS.

Subject anthropometrics

Table 1

	N	Age (years) Mean \pm SD	Height (cm) Mean \pm SD	Weight (kg) Mean \pm SD	BMI (kg/m ²) Mean \pm SD
Girls	29	16.69 ± 1	163 ± 7.2	57.86 ± 9.63	21.76 ± 3.12
Boys	17	16.18 ± 0.8	175.2 ± 7.1	67.08 ± 7.7	21.93 ± 2.61

Anthropometry

Anthropometric data collected were height, body mass and body mass index.

Adolescents' height was measured with a Handy electronic level on the end of which was placed the Bosch GLM80 Professional

rangefinder, which was positioned on the crown of the subjects' head. Body mass was recorded by the Tanita BC-601 CG analyzer, and body mass index was subsequently calculated by dividing body mass by height squared.

Digit ratio 2D:4D

2D (second finger on each hand - index) and 4D (fourth finger on each hand - ring) values were determined by measuring the length in mm from the basal fold to the tip of the finger using digital calipers. The results were mathematically processed, making the reference of the index to the ring finger.

Explosive force

It was determined by vertical jumps performed according to international protocols. These were squat jump (SJ), countermovement jump (CMJ), countermovement jump with arm swing (CMJ-AS) and 4 consecutive jumps. Their height was measured with the JustJump System (Probotics, Huntsville, Alabama, USA), whose operation is based on the timing of foot contact. The SJ was performed by positioning the subject on the back half of the mat, with the feet shoulder-width apart, the knee flexed to 90°, and the hands fixed on the hips. When agreement was received from the evaluator, after holding the position for approximately 3 seconds, a vertical power liftoff was performed. During this, the knees were stretched, and the hands were in contact with the pelvis, landing in the same place. CMJ followed the same protocol, the difference being the exclusion of isometric maintenance of the

initial position. In the CMJ-AS, the possibility of the subject to use the hands for the elk was added. The test of the 4 jumps aimed to assess the possibilities of the legs to perform mechanical work in conditions of speed. Thus, climbing on the mat, as in the other tests, the subject started at the evaluator's signal the execution of 4 consecutive jumps, the condition being to do them as quickly and as high as possible. 3 values were noted on the results sheet: the average contact time, explosive leg power factor (air time/ground time) and the average height of the 4 jumps.

Statistical analysis

The statistical analysis followed the organization of the data in order to generate the parameters that could allow the verification of the hypothesis. The software used is GraphPad Prism 9, within which a database was created that was initially checked for the existence of outliers. As no such results were detected, we continued with the generation of descriptive statistics based on the mean and standard deviation. Gender differences were found by applying the unpaired t test. Later, the data series were analyzed from the point of view of correlations that could prove the hypothesis. By its strength, the Pearson r coefficient and the significance threshold of this interaction (set at 0.05) could characterize insignificant (r below 0.29), moderate (r between 0.30 and 0.49), strong (r between 0.50 and 0.69), very strong (r between 0.70 and 0.89) and almost perfect (r above 0.90) [19].

3. Results

Our sample was split by gender, making it possible to differentiate the results we obtained. Applying the unpaired t test makes it possible to assess the results by comparing girls to boys. Table 2 shows the level of the 2D:4D ratio similar for the left hand and with a higher value in girls ($t=3.28$, $df=44$, $p=0.002$). Explosive leg strength has higher values in boys, they surpass girls in SJ ($t=9.19$, $df=44$, $p<0.0001$), CMJ ($t=9.85$, $df=44$, $p<0.0001$) and CMJ-AS ($t=10.27$, $df=44$, $p<0.0001$). The reactivity during the jumps is

differentiated only by the average height of the jumps, the higher value belonging to the boys (16.58 ± 2.85 cm). The contact time of the 4 jumps and explosive leg power factor were similar for the two genders.

Our interest in this research is to identify the extent to which adolescent aggression is related to their explosive strength. Pearson correlations can clarify this by their significance and strength. Considering the fact that aggression, as we treat it, is influenced by hormonal factors and quantified by anthropometry, we analyzed the 2 genders separately.

Descriptive statistics of variables by gender

Table 2

	Girls (N=29) Mean \pm SD	Boys (N=17) Mean \pm SD	t test (girls - boys)
2D:4D-R	1.01 \pm 0.03**	0.97 \pm 0.03	$t=3.28$, $df=44$, $p=0.002$
2D:4D-L	1.01 \pm 0.03	0.99 \pm 0.02	$t=1.89$, $df=44$, $p=0.065$
SJ (cm)	11.48 \pm 1.87	17.52 \pm 2.57****	$t=9.19$, $df=44$, $p<0.0001$
CMJ (cm)	11.94 \pm 1.97	18.31 \pm 2.35****	$t=9.85$, $df=44$, $p<0.0001$
CMJ-AS (cm)	13.32 \pm 2.03	20.45 \pm 2.65****	$t=10.27$, $df=44$, $p<0.0001$
4JumpsCT (s)	0.52 \pm 0.16	0.55 \pm 0.19	$t=0.57$, $df=44$, $p=0.57$
4JumpsELFP	1.01 \pm 0.31	1.13 \pm 0.44	$t=1.08$, $df=44$, $p=0.28$
4JumpsH (inch)	11.27 \pm 1.97	16.58 \pm 2.85****	$t=7.46$, $df=44$, $p<0.0001$

2D:4D-R – right hand 2D:4D ratio; 2D:4D-L – left hand 2D:4D ratio; SJ – squat jump; CMJ – countermovement jump; CMJ-AS – countermovement jump with arm swing; 4JumpsCT - average ground time of 4 jumps test; 4JumpsELFP – explosive leg power factor of 4 jumps test; 4JumpsH - average jump height of 4 jumps test; ** - $p < 0.01$; **** - $p < 0.0001$

Girls show strong correlations among explosive strength parameters and a single moderately positive correlation between the 2D:4D ratio of the right hand to that of the left hand ($r=0.53$, $p<0.01$). Table 3 shows the strong positive links between SJ, CMJ and CMJ-AS, as well as

the moderate positive association of each of them with the average height of the 4 consecutive jumps performed. The contact time of the 4 jumps is in a strong negative correlation with the explosive leg power factor ($r=-0.93$, $p<0.0001$), which in turn shows a moderately positive

correlation with the average jump height identified between the 2D:4D ratio of the faces and indices of explosive strength. ($r=0.43$, $p < 0.05$). No correlation was

Table 3

Correlation between indicators of aggression and explosive leg strength in girls

	2D:4D-R_G	2D:4D-L_G	SJ_G (cm)	CMJ_G (cm)	CMJ-AS_G (cm)	4JumpsCT_G (s)	4JumpsELFP_G (s)
2D:4D-L_G	0.53 **						
SJ_G (cm)	-0.08	0.06					
CMJ_G (cm)	-0.07	0.12	0.91****				
CMJ-AS_G (cm)	-0.07	0.15	0.87****	0.89****			
4JumpsCT_G (s)	0.04	0.08	-0.04	-0.07	0.01		
4JumpsELFP_G (s)	-0.05	-0.05	0.27	0.27	0.21	-0.93****	
4JumpsH_G (s)	-0.06	0.17	0.72****	0.73****	0.69****	-0.16	0.43 *

2D:4D-R_G – girls right hand 2D:4D ratio; 2D:4D-L_G – girls left hand 2D:4D ratio; SJ_G – girls squat jump; CMJ_G – girls countermovement jump; CMJ-AS_G – girls countermovement jump with arm swing; 4JumpsCT_G – girls average ground time of 4 jumps test; 4JumpsELFP_G – girls explosive leg power factor of 4 jumps test; 4JumpsH_G – girls average jump height of 4 jumps test; * – $p < 0.05$; ** – $p < 0.01$; **** – $p < 0.0001$

Table 4

Correlation between indicators of aggression and explosive leg strength in boy

	2D:4D-R_B	2D:4D-L_B	SJ_B (cm)	CMJ_B (cm)	CMJ-AS_B (cm)	4JumpsCT_B (s)	4JumpsELFP_B (s)
2D:4D-L_B	0.70 **						
SJ_B (cm)	-0.62 **	-0.43					
CMJ_B (cm)	-0.63 **	-0.44	0.88****				
CMJ-AS_B (cm)	-0.60 *	-0.54 *	0.89****	0.83****			
4JumpsCT_B (s)	-0.33	0.17	0.15	0.32	0.11		
4JumpsELFP_B (s)	-0.12	-0.48	0.02	-0.12	0.11	-0.75***	
4JumpsH_B (s)	-0.57 *	-0.11	0.69 **	0.70 **	0.67 **	0.71 **	-0.44

2D:4D-R_B – boys right hand 2D:4D ratio; 2D:4D-L_B – boys left hand 2D:4D ratio; SJ_B – boys squat jump; CMJ_B – boys countermovement jump; CMJ-AS_B – boys countermovement jump with arm swing; 4JumpsCT_B – boys average ground time of 4 jumps test; 4JumpsELFP_B – boys explosive leg power factor of 4 jumps test; 4JumpsH_B – boys average jump height of 4 jumps test; * – $p < 0.05$; ** – $p < 0.01$; **** – $p < 0.0001$

As in the case of girls, the 2D:4D values are moderately related for the 2 hands ($r=0.70$, $p<0.01$). Regarding the strength of the correlations between the results of the jumping events, it has a similar strength to that of the girls. The average height of the 4 consecutive jumps correlates with SJ ($r=0.69$, $p<0.01$), CMJ ($r=0.70$, $p<0.01$), CMJ-AS ($r=0.67$, $p<0.01$) and their contact time ($r=0.71$, $p<0.01$).

The value of the ratio between the index and ring finger of the right hand is moderately negatively correlated in boys with SJ ($r=-0.62$, $p<0.01$), CMJ ($r=-0.63$, $p<0.01$), CMJ-AS ($r=-0.60$, $p<0.05$) and the mean height of ground reactivity jumps ($r=-0.57$, $p<0.05$). In the case of jumps performed with the help of arms, a link with the same strength and the same direction is added from the left hand side ($r=-0.54$, $p<0.05$) (Table 4).

4. Discussion

This study proposes to identify the extent to which aggression, which could be determined non-invasively in adolescents, is related to the strength of the lower train, knowing that it can be determined by gender and the biological characteristics of the individual.

It was observed that the upper level of heights achieved by vertical jump in boys was preserved, an aspect that has been demonstrated countless times. Instead, ground reactivity is differentiated only by the average of the 4 jumps that were executed. In this test, ground contact time and explosive leg power factor are close in value for the two genders.

7582 subjects were evaluated to determine the 2D:4D ratio of both hands. At puberty, Asian and European boys had higher values in both fingers than girls.

Boys in Africa had finger lengths equal to those of girls, suggesting that they matured more slowly. Thus, the developmental processes of children in Africa had different trajectories compared to samples from Europe and Asia [5].

Correlations were found between the index and ring ratio and physical parameters, supporting its association with motor and functional dominance [15].

Eklund et al. [13] initiated the first investigation of the relationship between the 2D:4D ratio and the serum and urinary androgenic profile, as well as with the physical performance of 104 female athletes and 117 non-athletes aged over 18 years. Olympic athletes had a lower ratio of right handedness compared to non-athletes, suggesting a possible more significant prenatal exposure to androgens. Negative correlations were seen between the 2D:4D ratio and urinary androgen levels, both variables being associated with physical performance, including strength and running, among female athletes.

Crewther et al. [8] aimed to establish the relationship between vertical jump and digit ratio among 173 boys. Following the CMJ protocol, they determined vertical jump height using the Kistler force platform. It was observed that the 2D:4D ratio of the right hand ($p=0.005$) and testosterone ($p=0.035$) are co-predictors of CMJ height among boys.

The squat jump was used by Disterhaupt et al. [10] to study the correlations between vertical jump height and 2D:4D ratio in 18- to 24-year-old youth American football players. They noted that players with lower 2D:4D test scores had higher vertical jump height, with a significant correlation between the two measures (partial r [95% confidence interval]: 0.26

[0.48, 0.01]).

In 2018, 61 men aged 19.9 ± 1.4 years were evaluated. They had their explosive force determined through the Bertec force platform by performing SJ. The 2D:4D ratio was measured based on digital photographs of the hands and Cartesian coordinate geometry was applied with 2D:4D subsequently calculated. A weak correlation was observed between explosive force and the index-to-ring length ratio. Men with a lower ratio had higher jumps than those with higher values of the 2D:4D ratio [9].

Hönekopp et al. [16] investigated the association of 2D:4D with girls' physical abilities. The authors determined that 2D:4D was negatively correlated with fitness in both men and women. Eler [14] advanced with the same aim in his research. Considering the correlations between the 2D:4D ratio of the boys' right hand and the vertical ($r = -0.25$; $p = 0.06$) and standing long jumps ($r = -0.01$; $p = 0.17$), these were found to be non-significant. In the case of girls, the same relationships were found between the ratio of the left hand with the two jumps.

2D:4D ratio does not show any correlation with the explosive power of the lower limbs in prepubertal subjects ($p > 0.05$) [12].

Explosive power and 2D:4D ratio was studied among 541 prepubertal children (9–10 years). The 2D:4D ratio was found to be negatively associated with standing long jump performance in boys only, with no correlation observed in girls [20].

5. Conclusion

The explosive strength of adolescents from the north-eastern area of Romania differs according to gender, with boys

recording higher values of vertical jump height.

In girls there are correlations between explosive strength parameters, with the 2D:4D ratio linking only the 2 hands.

In addition, boys have associations between the 2D:4D ratio of the right hand and the height of all jumps performed. Of these, only the free-arm release correlates with the ratio of both hands. All these links are moderately negative, meaning that the height of a jump is greater the higher the aggression. Thus, there is a significant correlation between boys' aggressiveness and their explosive strength.

Even if the indicator of girls' aggressiveness does not establish links with parameters of explosive strength, our hypothesis is confirmed by the contribution of boys who present the links we predict.

Acknowledgements

This work was supported by a grant by „Alexandru Ioan Cuza” University of Iaşi, within the Research Grants program, Grant UAIC no. 09/2021, “The biomotor profile of primary school students in Iaşi County and their potential for sports performance” (GI-UAIC-2021-09).

References

1. Arede, J., Esteves, P., et al.: *Jump higher, run faster: effects of diversified sport participation on talent identification and selection in youth basketball*. In: *Journal of Sports Sciences*, 37(19), 2019, p. 2220-2227. <https://doi.org/10.1080/02640414.2019.1626114>

2. Arede, J., Ferreira, A.P., et al.: *Maturational development as a key aspect in physiological performance and national-team selection in elite male basketball players.* In: *International Journal of Sports Physiology and Performance*, 14(7), 2019, p. 902-910. <https://doi.org/10.1123/ijsp.2018-0681>
3. Björkqvist, K., and Österman, K.: *Sex differences in aggression.* In: *The Routledge international handbook of human aggression*, 2018, p. 19-30. <https://doi.org/10.1016/j.copsy.2017.03.030>
4. Burr, J.F., Jamnik, V.K., et al.: *Evaluation of jump protocols to assess leg power and predict hockey playing potential.* In: *The Journal of Strength & Conditioning Research*, 21(4), 2007, p. 1139-1145.
5. Butovskaya, M., Burkova, V., et al.: *Sex, population origin, age and average digit length as predictors of digit ratio in three large world populations.* In: *Scientific reports*, 11(1), 2021, 8157. <https://doi.org/10.1038/s41598-021-87394-6>
6. Butovskaya, M., Fedenok, J., et al.: *Sex differences in 2D: 4D and aggression in children and adolescents from five regions of Russia.* In: *American journal of physical anthropology*, 152(1), 2013, p. 130-139. <https://doi.org/10.1002/ajpa.22337>
7. Comfort, P., Stewart, A., et al.: *Relationships between strength, sprint, and jump performance in well-trained youth soccer players.* In: *The Journal of Strength & Conditioning Research*, 28(1), 2014, p. 173-177. <https://doi.org/10.1519/JSC.0b013e318291b8c7>
8. Crewther, B.T., Pastuszak, A., et al.: *The digit ratio (2D: 4D) and testosterone co-predict vertical jump performance in athletic boys: Evidence of organizational and activational effects of testosterone on physical fitness.* In: *Physiology & Behavior*, 2022, 251. <https://doi.org/10.1016/j.physbeh.2022.113816>
9. Disterhaupt, J.: *The Relationship Between The Digit Ratio (2d: 4d) and Explosive Muscular Strength In College Football Players.* *The University of North Dakota*, 2018.
10. Disterhaupt, J.W., Fitzgerald, J.S., et al.: *The relationship between the digit ratio (2D: 4D) and vertical jump performance in young athletes.* In: *American Journal of Human Biology*, 34(3), 2022, :e23679. <https://doi.org/10.1002/ajhb.23679>
11. Dupler, T.L., Amonette, W.E., et al.: *Anthropometric and performance differences among high-school football players.* In: *The Journal of Strength & Conditioning Research*, 24(8), 2010, p. 1975-1982. <https://doi.org/10.1519/JSC.0b013e3181e4f9ec>
12. Eghbali, E.: *The relationship between digit ratio (2D: 4D) and physical fitness in boys 7 to 13 years.* In: *Physical Activity Review*(4), 2016, p. 154-162. <http://dx.doi.org/10.16926/par.2016.04.19>
13. Eklund, E., Ekström, L. et al.: *Digit ratio (2D: 4D) and physical performance in female Olympic athletes.* In: *Frontiers in Endocrinology*, 2020, 11, 292. <https://doi.org/10.3389/fendo.2020.00292>

14. Eler, N.: *The correlation between right hand finger ratio (2D: 4D) and the parameters of anthropometric and physical fitness in children*. In: Journal of Human Sciences, 15(1), 2018, p. 656-664. <https://doi.org/10.14687/jhs.v15i1.5268>
15. Gümüş, M., and Tutkun, E.: *The Relationship between Physical Fitness Levels and Digit Ratio (2D:4D) of High School Students Engaged Actively in Sports*. In: Journal of Education and Training Studies, 6(10), 2018, p. 207-212. <https://doi.org/10.11114/jets.v6i10.3613>
16. Hönekopp, J., Manning, J.T. et al.: *Digit ratio (2D: 4D) and physical fitness in males and females: Evidence for effects of prenatal androgens on sexually selected traits*. In: Hormones and behavior, 49(4), 2006, p. 545-549. <https://doi.org/10.1016/j.yhbeh.2005.11.006>
17. Hönekopp, J., and Schuster, M.: *A meta-analysis on 2D: 4D and athletic prowess: Substantial relationships but neither hand out-predicts the other*. In: Personality and Individual Differences, 48(1), 2010, p. 4-10. <https://doi.org/10.1016/j.paid.2009.08.009>
18. Hönekopp, J., and Watson, S.: *Meta-analysis of the relationship between digit-ratio 2D: 4D and aggression*. In: Personality and individual differences, 51(4), 2011, p. 381-386. doi:<https://doi.org/10.1016/j.paid.2010.05.003>
19. Hopkins, W., Marshall, S., Batterham, A.J.: *Progressive statistics for studies in sports medicine and exercise science*. In: Medicine+ Science in Sports+ Exercise, 41(9), 2009, 3. doi:<https://doi.org/10.1249/MSS.0b013e31818cb278>
20. Hsu, C.C., Fong, T.H., Chang, H.M., . . . M.C.: *Low second-to-fourth digit ratio has high explosive power? A prepubertal study*. In: The Journal of Strength & Conditioning Research, 32(7), 2018, p. 2091-2095. <https://doi.org/10.1519/JSC.00000000000002435>
21. İlhan, A., Çelik, E., et al.: *The Relationship Between Some Physical Performance Parameters and 2D:4D Digit Ratio in Young Athletes*. In: AMBIENT SCIENCE, 7(1), 2020, p. 339-344. <https://doi.org/10.21276/ambi.2020.07.sp1.ta15>
22. Kilduff, L., Cook, C.J., et al.: *Right-left digit ratio (2D: 4D) predicts free testosterone levels associated with a physical challenge*. In: Journal of sports sciences, 31(6), 2013, p. 677-683. <https://doi.org/10.1080/02640414.2012.747690>
23. Koziel, S., Kociuba, M., et al.: *Physical fitness and digit ratio (2D: 4D) in male students from Wrocław, Poland*. In: Collegium antropologicum, 41(1), 2017, p. 31-37. <https://doi.org/10.1017/S0021932016000523>
24. Luxen, M., and Buunk, B.: *Second-to-fourth digit ratio related to verbal and numerical intelligence and the Big Five*. In: Personality and Individual Differences, 39(5), 2005, p. 956-966. <https://doi.org/10.1016/j.paid.2005.03.016>

25. Manning, J.: *The finger book: Sex, behaviour and disease revealed in the fingers*. In: Faber and Faber, 2008.
26. Manning, J.T., Scutt, D., et al.: *The ratio of 2nd to 4th digit length: a predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen*. In: Human Reproduction, 13(11), 1998, p. 3000-3004.
<https://doi.org/10.1093/humrep/13.11.3000>
27. Nuzzo, J.L., Anning, J.H., et al.: *The reliability of three devices used for measuring vertical jump height*. In: The Journal of Strength & Conditioning Research, 25(9), 2011, p. 2580-2590.
[doi:10.1519/JSC.0b013e3181fee650](https://doi.org/10.1519/JSC.0b013e3181fee650)
28. Österman, K, Björkqvist, K., et al.: *Cross-cultural evidence of female indirect aggression*. In: Aggressive Behavior, 24(1), 1998, p. 1-08.
[https://doi.org/10.1002/\(SICI\)1098-2337\(1998\)](https://doi.org/10.1002/(SICI)1098-2337(1998)24:1<1::AID-AB1098>3.0.CO;2-3)
29. Pasanen, B.E., Tomkinson, J.M., et al.: *The relationship between digit ratio (2D: 4D) and muscular fitness: A systematic review and meta-analysis*. In: American journal of human biology, 34(3), 2022,
<https://doi.org/10.1002/ajhb.23657>
30. Paul, S.N., Kato, B.S., et al.: *The big finger: the second to fourth digit ratio is a predictor of sporting ability in women*. In: British Journal of Sports Medicine, 40(12), 2006, p. 981-983.
<https://doi.org/10.1136/bjsm.2006.027193>
31. Podstawski, R., Boryśławski, K., et al.: *Sex differences in anthropometric and physiological profiles of Hungarian rowers of different ages*. In: International Journal of Environmental Research and Public Health, 19(13), 2022, 8115. <https://doi.org/10.3390/ijerph19138115>
32. Ramírez-Vélez, R., Correa-Bautista, J.E., et al.: *Vertical jump and leg power normative data for colombian schoolchildren aged 9–17.9 years: The FUPRECOL study*. In: Journal of strength and conditioning research, 31(4), 2017, p. 990-998.
<https://doi.org/10.1519/JSC.0000000000001550>
33. Ranson, R., Stratton, G., et al.: *Digit ratio (2D: 4D) and physical fitness (Eurofit test battery) in school children*. In: Early human development, 91(5), 2015, p. 327-331.
<https://doi.org/10.1016/j.earlhumdev.2015.03.005>
34. Sell, A., Eisner, M., et al.: *Bargaining power and adolescent aggression: The role of fighting ability, coalitional strength, and mate value*. In: Evolution and Human Behavior, 37(2), 2016, p. 105-116.
<https://doi.org/10.1016/j.evolhumbehav.2015.09.003>
35. Shamus, E, Shamus, J, et al.: *Vertical jump testing in relationship to participants' height and weight for sport integration*. In: Journal of Physical Therapy and Sports Medicine, 2(1), 2018, p. 1-4.
36. Stojanović, MD, Mikić, M, et al.: *Greater power but not strength gains using flywheel versus equivolumed traditional strength training in junior basketball players*. In: International Journal of Environmental Research and Public Health, 18(3), 2021, 1181.

- <https://doi.org/10.3390/ijerph18031181>
37. Taylor, M.J., Cohen, D., et al.: *Vertical jumping and leg power normative data for English school children aged 10–15 years*. In: *Journal of sports sciences*, 28(8), 2010, p. 867-872. <https://doi.org/10.1080/02640411003770212>
38. Tomkinson, J., and Tomkinson, G.: *Digit ratio (2D: 4D) and muscular strength in adolescent boys*. In: *Early Human Development*, 113, 2017, p. 7-9. <https://doi.org/10.1016/j.earlhumdev.2017.07.013>
39. Vaillancourt, T.F., Brendgen, M.F. et al.: *A longitudinal confirmatory factor analysis of indirect and physical aggression. Evidence of two factors over time?* In: *Child Development*, 74(6), 2003, p. 1628-1638. <https://doi.org/10.1046/j.1467-8624.2003.00628.x>
40. Zhao, D, Yu, K, et al.: *Digit ratio (2D: 4D) and handgrip strength in Hani ethnicity*. In: *PLoS One*, 8(10), 2013, 77958.