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Digit ratio: comparative analysis between professional volleyball players and medical students

Ozan Turamanlar[1], İlknur Çöllü[1], Önder Çalışkan[2]

[1]*Department of Anatomy, Faculty of Medicine, Izmir Kâtip Çelebi University, Izmir, Türkiye*
[2]*Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Mudanya University, Bursa, Türkiye*

Abstract

Objectives: The ratio of the length of the 2nd digit to the 4th digit of the hand, known as the digit ratio (2D:4D), has been widely studied in health, behavioral, and sports sciences as a potential indicator of prenatal testosterone exposure. This study aimed to compare the 2D:4D ratios of male individuals who are athletically and academically successful and to evaluate whether 2D:4D can serve as a marker for occupational selection, talent identification, and the impact of individual characteristics on job performance.

Methods: This study included 32 male professional volleyball players and 39 male medical students. The lengths of the 2nd and 4th digits of both hands were measured using a digital caliper, and the 2D:4D ratio was calculated. The dominant hands of the participants were also recorded for analysis.

Results: Intra-group comparisons of the right-hand and left-hand 2D:4D ratios within both the student and volleyball player groups showed no statistically significant differences (p=0.225; p=0.922). Inter-group comparisons of the 2D:4D ratios for the right hand and left hand were also statistically similar (p=0.388; p=0.939). Additionally, the difference between the right-hand and left-hand 2D:4D ratios (Dr-l) did not differ significantly between the groups (p=0.525). Comparisons based on dominant hand preferences revealed no statistically significant findings.

Conclusion: This study highlights the need for larger, multicenter studies with more participants to further explore the potential relationship between 2D:4D ratios and occupational or performance traits. We hope this research serves as a foundation for future investigations and provides valuable insights for researchers in this field.

Keywords: digit ratio; medical students; performance; 2D:4D; volleyball players

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Introduction

One of the most frequently asked questions today is which profession young individuals are more likely to pursue or should pursue. Although various psychological and biological tests and methods have been utilized throughout history, providing a definitive answer to this question remains challenging. However, comparative, easily applicable, and low-cost tests may offer insights. Measurements related to an individual's physical structure, for instance, can provide clues about their personality traits, which could potentially simplify career selection. Digit ratios are one such commonly used measurement tool in physical assessments.[1]

The digit ratio, denoted as 2D:4D, refers to the ratio of the length of the 2nd digit (index finger = 2D) to the length of the 4th digit (ring finger = 4D).[2] These measurements are obtained by measuring from the midpoint of the basal creases on the ventral surface of the hand, where the digits meet the hand, to the tip of the digit (**Figure 1**).

There is evidence suggesting that the 2D:4D ratio negatively correlates with prenatal testosterone exposure

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and positively correlates with estrogen levels.[3,4] Specifically, a low 2D:4D ratio is associated with higher prenatal testosterone and lower estrogen levels, while a high 2D:4D ratio correlates with lower testosterone and higher estrogen levels during fetal development.[4,5]

The 2D:4D ratio has been widely recognized as a potential marker of prenatal testosterone exposure across various fields, including health, behavioral sciences, and sports sciences. Research suggests that prenatal androgens influence brain development, enhancing its sensitivity to testosterone later in life. These hormones are thought to regulate brain structure and function, with 2D:4D often considered a reliable indicator of athletic potential.[6–8] A low 2D:4D ratio has been linked to success in financial endeavors, admission to medical schools, and strong performance in sports such as basketball, skiing, and football.[9–13] Elevated levels of fetal androgens are believed to contribute to the development of the cardiovascular system, improve visual-spatial skills, enhance physical stamina and speed, and increase tendencies toward aggressive behavior—traits that may provide competitive advantages in sports.[12,13]

The relationship between 2D:4D and academic performance has also been explored,[14–18] with some studies showing a negative correlation between 2D:4D and academic success.[14,16] However, there is limited research comparing individuals excelling in both physical and cognitive domains. Therefore, this study aims to compare the 2D:4D ratios of male individuals who are successful in sports with those who excel in academic fields. By doing so, we seek to investigate whether 2D:4D can serve as an indicator for career selection, talent identification, and assessing the impact of individual characteristics on job performance.

Materials and Methods

Power analysis for two independent groups determined that the minimum required sample size was 68, with at least 32 participants in one group and 36 in the other. Under these conditions, the test power was estimated to be approximately 81.03%. In this study, we compared two groups: 32 male professional volleyball players competing in the top league (Efeler League) under the Turkish Volleyball Federation, and 39 male students from the Faculty of Medicine at Izmir Kâtip Çelebi University. The lengths of the 2nd and 4th digits of both hands were measured using a digital caliper (Rohs Norm 2002/95/EC) after obtaining informed consent from all participants. The 2D:4D ratio was calculated, and the dominant hands of the participants were recorded (**Figure 1**).

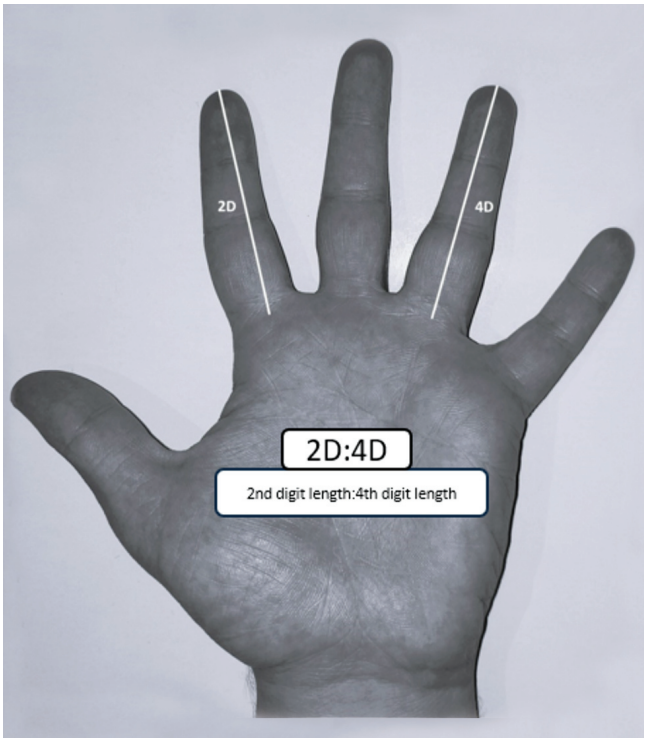

Figure 1. Measurement of digit lengths, left hand. **2D:** 2nd digit length; **4D:** 4th digit length.

The exclusion criteria for this study included individuals with systemic diseases, finger anomalies or pathologies in any extremity, those under 18 years of age, and female participants to eliminate gender-related differences. Additionally, among the university student participants, individuals who engaged in any form of sports, even at an amateur level, were excluded.

Data analysis was conducted using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA). Summary statistics were presented as frequencies (n), percentages (%), mean ± standard deviation ($\bar{X}$± sd), median (M), minimum (min), and maximum (max) values. The Shapiro-Wilk test was used to assess the normality of numerical data, while the Levene test evaluated the homogeneity of variances. For comparisons between two groups, the "Independent two-sample t-test" was applied when parametric assumptions were met; otherwise, the "Mann-Whitney U test" was used. Intra-group and inter-group comparisons of right and left hand measurements

Table 1
Participant characteristics.

Participant	Right-handed n (%)	Left-handedn (%)	Total (n)
Volleyball players	29 (90.62%)	3 (9.38%)	32
University students	35 (89.74%)	4 (10.26%)	39
Total	64 (90.14%)	7 (9.86%)	71

n: number of participants.

were analyzed using "Mixed Order ANOVA." Statistical significance was defined as $p<0.05$.

Results

The number of participants and their hand dominance are presented in **Table 1**. The 32 volleyball players had an average age of 26.96 years, an average height of 193.40 cm, and an average weight of 83.75 kg (**Table 2**). The 39 university students had an average age of 20.74 years, an average height of 178.64 cm, and an average weight of 75.16 kg (**Table 3**).

Intra-group comparisons of the right-hand and left-hand 2D:4D ratios within the student and volleyball player groups showed no statistically significant differences (**Table 4**). Similarly, inter-group comparisons of the right-hand and left-hand 2D:4D ratios were statistically similar (**Table 4**). The inter-group comparison of the difference between the right-hand and left-hand 2D:4D ratios (Dr-l) also showed no significant differences (**Table 5**).

When participants were grouped by hand dominance, the right-hand 2D:4D, left-hand 2D:4D, and Dr-l values were statistically similar for both right-handed (**Table 6**) and left-handed dominant participants (**Table 7**). Of the total participants, 64 were right-handed dominant and 7 were left-handed dominant. Analysis of right-hand 2D:4D, left-hand 2D:4D, and Dr-l values, grouped by dominant hand, did not yield any statistically significant results (**Table 8**).

Table 2
Demographic characteristics of volleyball players.

Variables	n	Min-Max	Mean±SD
Age (years)	32	18–49	26.96±8.33
Height (cm)	32	180–210	193.40±7.19
Weight (kg)	32	68–112	83.75±9.68

Max: maximum; **Min:** minimum; **n:** number of participants; **SD:** standard deviation.

Table 3
Demographic characteristics of university students..

Variables	n	Min-Max	Mean±SD
Age (years)	39	19–26	20.74±1.48
Height (cm)	39	160–191	178.64±7.47
Weight (kg)	39	54–111	75.16±12.91

Max: maximum; **Min:** minimum; **n:** number of participants; **SD:** standard deviation.

Table 4
Comparison of 2D:4D values within and between groups.

		Groups		Test statistics*		
		Student	Player	F	p-value	η^2
2D:4D value	Right	0.9863±0.0408	0.9932±0.0212	0.754	0.388	0.011
	Left	0.9921±0.0429	0.9927±0.0247	0.006	0.939	0.001
Test statistics†		F=1.498 p=0.225 η^2=0.021	F=0.010 p=0.922 η^2=0.001			

F: mixed design ANOVA; η^2: effect size; *comparison between groups: †comparison within groups. Descriptive statistics are given as mean±standard deviation. The statistical significance level is $p<0.05$.

Table 5
Comparison of Dr-l (right hand) in groups (2D:4D minus left hand 2D:4D difference).

		Groups		Test statistics	
		Student	Player	z-value	p-value
Dr-l	x̄±sd	-0.0058±0.0338	0.0005±0.0229	0.636	0.525
	M (min-max)	-0.0021 (-0.10–0.07)	-0.0002 (-0.06–0.06)		

x̄: mean; **sd:** standard deviation; **M:** median; **z:** Mann-Whitney U test.

Table 6
Comparison by group in right dominant hands (Dr-l:Right hand 2D:4D minus left hand 2D:4D difference).

		Groups		Test statistics	
		Student	Player	Test value	p-value
2D:4D right	x̄±sd	0.9874±0.0412	0.9938±0.0226	z=0.636	0.525
	M (min-max)	0.9939 (0.9008–1.1092)	0.9942 (0.9509–1.0356		
2D:4D left	x̄±sd	0.9921±0.0433	0.9927±0.0264	z=0.298	0.766
	M (min-max)	0.9854 (0.9031–1.1041)	0.9893 (0.9550–1.0669)		
Dr-l	x̄±sd	-0.0047±0.0350	0.0011±0.0243	t=0.753	0.454
	M (min-max)	0 (-0.10–0.07)	0.0006 (-0.06–0.06)		

x̄: mean; **sd:** standard deviation; **M:** median; **t:** independent two-sample t test; **z:** Mann-Whitney U test.

Table 7
Comparison by group in left dominant hands (Dr-l: Right hand 2D:4D minus left hand 2D:4D difference).

		Groups		Test statistics	
		Student	Player	t-value	p-value
2D:4D right	x̄±sd	0.9733±0.0416	0.9893±0.0072	0.775	0.474
	M (min-max)	0.9850 (0.9270–1.0079)	0.9910 (0.9769–0.9955)		
2D:4D left	x̄±sd	0.9915±0.0475	0.9930±0.0047	0.063	0.952
	M (min-max)	1.0131 (0.9370–1.0244)	0.9918 (0.9891–0.9991)		
Dr-l	x̄±sd	-0.0182±0.0091	-0.0037±0.0081	0.221	0.078
	M (min-max)	-0.016 (-0.03–0.01)	-0.025 (-0.01–0.0)		

x̄: mean; **sd:** standard deviation; **M:** median; **t:** independent two-sample t test.

Table 8
Comparison according to the dominant hand (Dr-l: Right hand 2D:4D minus left hand 2D:4D difference).

		Groups		Test statistics	
		Right handed dominant	Left handed dominant	z-value	p-value
2D:4D right	x̄±sd	0.9902±0.0342	0.9824±0.0260	0.775	0.474
	M (min-max)	0.9940 (0.9008–1.1092)	0.9877 (0.9270–1.0079)		
2D:4D left	x̄±sd	0.9924±0.0366	0.9923±0.0276	0.501	0.616
	M (min-max)	0.9877 (0.9031–1.1041)	0.9944 (0.9370–1.0244)		
Dr-l	x̄±sd	-0.0022±0.0307	-0.0099±0.0110	0.215	0.210
	M (min-max)	0.0006 (-0.10–0.07)	-0.0100 (-0.03–0.0)		

x̄: mean; **sd:** standard deviation; **M:** median; **z:** Mann-Whitney U test.

Discussion

Prenatal testosterone levels may play a pivotal role in excelling at certain sports activities. Traits influenced by testosterone, such as muscle fiber growth, enhanced strength, reduced fat mass, and elevated hematocrit levels, are likely contributors to athletic success.[19] The 2D:4D ratio has been shown to correlate with performance in various individual and team sports, including basketball, skiing, volleyball, fencing, and football.[12,13,20–22]

In a study comparing athletes in judo, wrestling, and kickboxing with a control group of non-athletes, the 2D:4D ratio was found to be significantly lower in the athlete group.[23] This finding aligns with research suggesting that a low 2D:4D ratio is associated with elevated testosterone levels and tendencies toward aggression, traits often beneficial in combat sports.[24–26] Additionally, athletes participating in contact sports have been reported to have significantly lower 2D:4D ratios compared to those in non-contact sports.[7] Reed and Meggs[7] found that athletes in contact sports exhibited both lower 2D:4D ratios and higher physical aggression compared to their non-contact counterparts.

The population of study included the male athletes belonged to a professional volleyball team, representing a non-contact sport. The lack of a statistically significant difference in the 2D:4D ratio among professional athletes in our study may be attributed to their involvement in a non-contact sport.

Manning et al.[26] found that the right-hand 2D:4D ratio is more sensitive to prenatal sex steroids than the left-hand 2D:4D. Similarly, Hönekopp and Watson,[25] in their 2010 meta-analysis, reported higher prenatal androgenization in the right-hand 2D:4D compared to the left-hand 2D:4D. Research on 2D:4D generally examines both right- and left-hand ratios, while also considering the difference between them (Dr-l) as an additional marker. This difference, calculated as the right-hand 2D:4D minus the left-hand 2D:4D, has been proposed as a negative marker for prenatal testosterone exposure and a positive marker for prenatal estrogen exposure.[26] Dr-l is sexually dimorphic, with males consistently exhibiting lower values than females. This distinction emphasizes its potential as a marker for prenatal hormone exposure. Hill et al. identified a negative correlation between lower Dr-l values and VO2 max.[27] VO2 max, the maximum rate of oxygen consumption during exercise, reflects cardiovascular capacity and determines the upper limit of performance in endurance sports.[28] The regulatory effects of prenatal testosterone on the developing cardiovascular system may influence aerobic performance levels later in life.

Kim et al.[29] also reported that the right hand tends to exhibit stronger sex differences and is more sensitive to prenatal androgens compared to the left hand. For instance, in a study conducted on female Olympic athletes, only the right-hand 2D:4D showed a significant difference compared to the control group, while in another study on gymnast girls, the left-hand 2D:4D did not show a significant difference from the control group.[30,31] Although the digit ratio of the right and left hands was not found to be associated with hand preference, the Dr-l (difference between right-hand and left-hand 2D:4D) was shown to be linked to hand preference. Studies have found that left-handed individuals exhibit significantly lower Dr-l values compared to right-handed individuals.[32,33] This suggests that considering hand dominance in future research may help in interpreting the results more accurately. The results of our study showed no significant relationship between Dr-l and hand dominance in the statistical analyses. However, this result may be attributed to the relatively small sample size, which could have limited the statistical power to detect significant differences. It is suggested that future studies with larger sample sizes be conducted to clarify this relationship.

It is recognized that 2D:4D ratios vary among individuals from different ethnic groups, regardless of sport. In a study, average 2D:4D values were reported to differ between ethnic groups, irrespective of gender.[34] Therefore, ethnic differences should be considered in future research, as the current study was conducted on a Turkish population. In a study conducted in India, volleyball players were compared with a control group, and the 2D:4D ratios of both hands were found to be significantly lower in volleyball players. However, no statistically significant difference in Dr-l was observed between the volleyball players and the controls.[21] In the present study, male university students with no prior involvement in sports were compared with professional male volleyball players, but no significant differences were detected in the statistical analysis.

In a study examining the association between 2D:4D and performance in both practical and theoretical exams among dental students in Brazil, a significant negative correlation was found between 2D:4D and exam scores in male students.[16] Similarly, Coco et al.[14] reported a

notable relationship between 2D:4D and success in medical school entrance exams in Italy. Additionally, a multicenter study conducted across Russia and the Philippines identified a non-linear, quadratic correlation between 2D:4D and academic success.[17]

It has been proposed that prenatal testosterone influences cognitive abilities, such as intelligence and learning, by affecting key developmental processes, including neuronal proliferation, migration, differentiation, and apoptosis. This influence is thought to enhance the density of neural networks in specific brain regions.[35] Prenatal exposure to testosterone may directly affect intelligence by altering neuronal migration, leading to greater development of the right hemisphere and improved coordination within and between hemispheres.[36] This process promotes the development and organization of dense neuronal networks in areas associated with cognition, learning, and memory, potentially through reduced apoptosis or increased neuronal migration to these regions during development.[6,35] Androgens have also been shown to have an organizational effect on brain development, suggesting that prenatal testosterone may act as a programming mechanism that influences behavior later in life.[37] Supporting this, a study found that individuals presenting with "boxer's fracture" had significantly lower 2D:4D ratios compared to the general population, linking 2D:4D to physical and behavioral traits associated with testosterone exposure.[38]

It has been reported in several studies that no significant correlation exists between 2D:4D and physical performance. It has also been suggested that claims regarding a relationship may be somewhat overstated. Based on these findings, it is indicated that 2D:4D is unlikely to serve as a reliable predictive marker for athletes' physical performance and abilities.[39–41] In the present study, the absence of statistically significant differences in the results may be attributed to the limited sample size and the lack of additional measurement parameters.

Conclusion

Studies have shown that digit ratios can reflect performance across various domains. In our study, comparisons were made between volleyball players who had achieved a high level of physical performance and medical students who demonstrated their abilities through academic success. No significant differences were found between the measurement results of the two groups. It is suggested that the lack of differences observed in our study may stem from the fact that both groups excelled in their respective fields. This indicates that 2D:4D may be more closely associated with behavioral characteristics rather than being limited to specific activities or professions.

Future studies should consider larger sample sizes and include a broader range of populations. It would also be valuable to examine the relationship between digit ratios and specific psychological or personality traits using validated tests. However, it is essential to approach such associations cautiously, taking into account the potential influence of cultural differences on the validity and reliability of these tests.

We believe that our study can serve as a foundation for more detailed analyses to be conducted in multicenter studies with larger participant groups. It also provides a valuable perspective for researchers interested in exploring this area further.

Conflict of Interest

All authors participating in the study declare that there is no conflict of interest regarding the study.

Author Contributions

OT: project development, data management, data analysis, manuscript writing, manuscript editing; İÇ: project development, data collection, data analysis, manuscript writing, manuscript editing; ÖÇ: data collection.

Ethics Approval

Necessary permissions for this study were obtained from the Izmir Kâtip Çelebi University Clinical Research Ethics Committee (approval number: 2022/587). The study was conducted in accordance with the principles outlined in the Declaration of Helsinki on Human Rights.

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References

1. Serpell BG, Cook CJ. Exploring finger digit ratios (2D:4D) in surgeons, professional rugby players, and political journalists to form a directional hypothesis: could finger length predict attention and focus? Front Behav Neurosci 2022;16:873129.
2. Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: a predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. Hum Reprod 1998;13:3000–4.
3. Manning JT. Digit ratio: a pointer to fertility, behavior, and health. New Brunswick (NJ): Rutgers University Press; 2002. p. 198.

4. Robinson S. The ratio of 2nd to 4th digit length and male homosexuality. Evol Hum Behav 2000;21:333–45.
5. Crewther B, Cook C, Kilduff L, Manning J. Digit ratio (2D:4D) and salivary testosterone, oestradiol and cortisol levels under challenge: evidence for prenatal effects on adult endocrine responses. Early Hum Dev 2015;91:451–6.
6. Lenz B, Müller CP, Stoessel C, Sperling W, Biermann T, Hillemacher T, Bleich S, Kornhuber J. Sex hormone activity in alcohol addiction: integrating organizational and activational effects. Prog Neurobiol 2012;96:136–63.
7. Reed S, Meggs J. Examining the effect of prenatal testosterone and aggression on sporting choice and sporting longevity. Personality and Individual Differences 2017;116:11–5.
8. Alonso J, Di Paolo R, Ponti G, Sartarelli M. Facts and misconceptions about 2D:4D, social and risk preferences. Front Behav Neurosci 2018;12:22.
9. Coates JM, Gurnell M, Rustichini A. Second-to-fourth digit ratio predicts success among high-frequency financial traders. Proc Natl Acad Sci U S A. 2009;106:623–8.
10. Coco M, Perciavalle V, Maci T, Nicoletti F, Di Corrado D, Perciavalle V. The second-to-fourth digit ratio correlates with the rate of academic performance in medical school students. Mol Med Rep 2011;4:471–6.
11. Keith-Barnett N, Campbell A. Sporting achievement: what is the contribution of digit ratio? Journal of Personality 2007;75:663–78.
12. Manning JT. The ratio of 2nd to 4th digit length and performance in skiing. J Sports Med Phys Fitness 2002;42:446–50.
13. Manning JT, Taylor RP. Second to fourth digit ratio and male ability in sport: implications for sexual selection in humans. Evol Hum Behav 2001;22:61–9.
14. Coco M, Perciavalle V, Maci T, Nicoletti F, Di Corrado D, Perciavalle V. The second-to-fourth digit ratio correlates with the rate of academic performance in medical school students. Mol Med Rep 2011;4:471–6.
15. Tektas OY, Kapsner L, Lemmer M, Bouna-Pyrrou P, Lewczuk P, Lenz B, Kornhuber J. Digit ratio (2D:4D) and academic success as measured by achievement in the academic degree "Habilitation". PLoS One 2019;14:e0212167.
16. Hopp RN, De Moraes JP, Jorge J. Digit ratio and academic performance in dentistry students. Personality and Individual Differences 2012;52:643–6.
17. Nye JVC, Androuschak G, Desierto D, Jones G, Yudkevich M. 2D:4D asymmetry and gender differences in academic performance. PLoS One 2012;7:e46319.
18. Anas YI, Badamasi MI. Relationship between second to fourth digit ratio (2D:4D) and academic performance among students in Nigeria. Bayero Journal of Pure and Applied Sciences 2021;13:87–93.
19. Moffit DM, Swanik CB. The association between athleticism, prenatal testosterone, and finger length. J Strength Cond Res 2011;25:1085–8.
20. Frick NA, Hull MJ, Manning JT, Tomkinson GR. Relationships between digit ratio (2D:4D) and basketball performance in Australian men. Am J Hum Biol 2017;29:e22937.
21. Panda K, Majumdar P, Umesh V, Sudhakar H. Ratio of second to fourth digit as a predictor of performance in elite Indian volley ball players. National Journal of Physiology, Pharmacy and Pharmacology 2014;4:106–8.
22. Voracek M, Reimer B, Dressler SG. Digit ratio (2D:4D) predicts sporting success among female fencers independent from physical, experience, and personality factors. Scand J Med Sci Sports 2010; 20:853–60.
23. Adamczyk JG, Safranow K, Gajewski AK, Boguszewski D, Sozański H, Sołtyszewski I, Pepłońska B, Cięszczyk P, Siewierski M, Żekanowski C. The second–to–fourth digit (2D:4D) ratio of male combat athletes is associated with the choice of sport. J Hum Kinet 2021;78:59–66.
24. Ribeiro E, Neave N, Morais RN, Kilduff L, Taylor SR, Butovskaya M, Fink B, Manning JT. Digit ratio (2D:4D), testosterone, cortisol, aggression, personality and hand-grip strength: evidence for prenatal effects on strength. Early Hum Dev 2016; 100:21–5.
25. Hönekopp J, Watson S. Meta–analysis of digit ratio 2D:4D shows greater sex difference in the right hand. Am J Hum Biol 2010;22: 619–30.
26. Manning J, Kilduff L, Cook C, Crewther B, Fink B. Digit ratio (2D:4D): a biomarker for prenatal sex steroids and adult sex steroids in challenge situations. Front Endocrinol (Lausanne) 2014; 5:9.
27. Hill R, Simpson B, Manning J, Kilduff L. Right–left digit ratio (2D:4D) and maximal oxygen uptake. J Sports Sci 2012;30:129–34.
28. Lombardo MP, Otieno S. The associations between digit ratio, aerobic fitness, physical skills, and overall physical fitness of elite youth distance runners. Am J Hum Biol 2021;33:e23448.
29. Kim Y, Kim K, Kim TH. Domain specific relationships of 2D:4D digit ratio in risk perception and risk behavior. J Gen Psychol 2014; 141:373–92.
30. Eklund E, Ekström L, Thörngren JO, Ericsson M, Berglund B, Hirschberg AL. Digit ratio (2D:4D) and physical performance in female olympic athletes. Front Endocrinol (Lausanne) 2020;11: 292.
31. Peeters MW, Claessens AL. The left hand second to fourth digit ratio (2D:4D) does not discriminate world-class female gymnasts from age matched sedentary girls. PLoS One 2012;7:e40270.
32. Beaton AA, Rudling N, Kissling C, Taurines R, Thome J. Digit ratio (2D:4D), salivary testosterone, and handedness. Laterality 2011;16:136–55.
33. Stoyanov Z, Marinov M, Pashalieva I. Finger length ratio (2D:4D) in left- and right-handed males. Int J Neurosci 2009;119:1006–13.
34. Manning JT, Churchill AJG, Peters M. The effects of sex, ethnicity, and sexual orientation on self-measured digit ratio (2D:4D). Arch Sex Behav 2007;36:223–33.
35. Mrazik M, Dombrowski SC. The neurobiological foundations of giftedness. Roeper Review 2010;32:224–34.
36. Alexander JE, O'Boyle MW, Benbow CP. Developmentally advanced EEG alpha power in gifted male and female adolescents. Int J Psychophysiol 1996;23:25–31.
37. Lombardo MV, Ashwin E, Auyeung B, Chakrabarti B, Lai MC, Taylor K, Hackett G, Bullmore ET, Baron-Cohen S. Fetal programming effects of testosterone on the reward system and behavioral approach tendencies in humans. Biol Psychiatry 2012;72:839–47.

38. Joyce CW, Kelly JC, Chan JC, Colgan G, O'Briain D, Mc Cabe JP, Curtin W. Second to fourth digit ratio confirms aggressive tendencies in patients with boxers fractures. Injury 2013;44:1636–9.
39. Özden Yurdakul H, Özen G, Koç H. The relationship between digit ratio (2D:4D), anaerobic power and athletic ability of young athletes. Universal Journal of Educational Research 2018;6:2913–7.
40. Çel A, Aksu F, Tunar M, Da EN, Ada D, Topaço H. The relationship between physical performance levels and the digit ratio of master athletes. [Article in Turkish] Dokuz Eylül Üniversitesi Tıp Fakültesi Dergisi 2020;1:5–10.
41. Peeters MW, Claessens AL. Digit ratio (2D:4D) and competition level in world-class female gymnasts. J Sports Sci 2013;31:1302–11.

ORCID ID:
O. Turamanlar 0000-0002-0785-483X;
İ. Çöllü: 0000-0003-1605-6327;
Ö. Çalışkan: 0009-0000-5537-258X

Correspondence to: İlknur Çöllü, MD
Department of Anatomy, Faculty of Medicine,
Izmir Kâtip Çelebi University, Izmir, Türkiye
Phone: +90 507 258 02 10
e-mail: ilknurcollu1@gmail.com

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