Acta Medica Ruha
International Journal of Medicine and Health Sciences

E-ISSN: 2980-1184

ORIGINAL ARTICLE
Volume:2 Issue:2 Year:2024

https://doi.org/10.5281/zenodo.11382931

Investigation of the Relationship of Wrist Range of Motion with 2D:4D Ratio in Healthy Individuals

Sağlıklı Bireylerde El Bileği Eklem Hareket Açıklığının 2P:4P Oranı İle İlişkisinin İncelenmesi

Gökçe Bağcı Uzun[1], İlyas Uçar[2], Caner Karartı[3], Muhammed Furkan Arpacı[1], Emre Demirel[1], Muhammet Değermenci[4], Ayla Arslan[5], Hatice Güler[2]

[1]Malatya Turgut Özal University, Faculty of Medicine, Department of Anatomy, Malatya, Türkiye
[2]Erciyes University, Faculty of Medicine, Department of Anatomy, Kayseri, Türkiye
[3]Kırşehir Ahi Evran University, Department of Physiotherapy and Rehabilitation, Kırşehir, Türkiye
[4]Ordu University, Faculty of Medicine, Department of Anatomy, Ordu, Türkiye
[5]Ağrı İbrahim Çeçen University, Faculty of Medicine, Department of Anatomy, Ağrı, Türkiye

ABSTRACT

Introduction: Range of motion (ROM) is widely used in the diagnosis of musculoskeletal disorders and in the evaluation of treatment prognosis. The 2D:4D ratio is the ratio of the second finger to the fourth finger.
Objective: The aim of our study is to investigate whether there is a possible relationship between ROM and finger length.
Method: In our study, 120 asymptomatic individuals (37.50% female) with a mean age of 33.73±14.12 years and a mean body mass index of 24.66±4.60 kg/m2 were included. After voluntary consent was obtained, ROM was measured using a goniometer and 2D:4D ratio was measured using a digital caliper. The IBM SPSS Statistics for Windows software (version 22.0; IBM, Armonk, NY) was used to analyze the data.
Results: In this study there was no any significant correlation between 2D:4D digit ratio for right hand and the other variables (p=0.127-0.902). There was a significant correlation between 2D:4D digit ratio for left hand and the weight (r=-0.288;p=0.001), and the body mass index (r=-0.282; p=0.002,). The stepwise multiple regression analysis demonstrated that the weight was significant and independent factor of the 2D:4D digit ratio for the left hand with 4.9% of the variance.
Conclusion: The lack of a study examining the relationship between ROM and 2D:4D ratio in the existing literature reveals the importance of the study data. Our suggestion is that the relationship with the 2D:4D ratio can be examined by measuring ROM measurements in patients and healthy individuals.

Keywords: Range of Motion, 2D:4D Digit Ratio, Goniometer, Digital Caliper.

ÖZET

Giriş: Eklem hareket açıklığı (EHA), kas-iskelet sistemi bozukluklarının tanısında ve tedavi prognozunun değerlendirilmesinde yaygın olarak kullanılmaktadır. 2D:4D oranı ikinci parmağın dördüncü parmağa oranıdır.
Amaç: Çalışmamızın amacı EHA ile parmak uzunluğu arasında olası bir ilişkinin olup olmadığını araştırmaktır.
Yöntem: Çalışmamıza yaş ortalaması 33,73±14,12 yıl, vücut kitle indeksi ortalaması 24,66±4,60 kg/m2 olan 120 asemptomatik (%37,50 kadın) birey dahil edildi. Gönüllü onam alındıktan sonra ROM gonyometre kullanılarak ölçüldü ve 2D:4D oranı dijital kumpas kullanılarak ölçüldü. Verileri analiz etmek için IBM SPSS İstatistikleri Windows yazılımı (versiyon 22.0; IBM, Armonk, NY) kullanıldı.
Bulgular: Bu çalışmada sağ el için 2D:4D parmak oranı ile diğer değişkenler arasında anlamlı bir ilişki saptanmadı (p=0,127-0,902). Sol el için 2D:4D parmak oranı ile ağırlık (r=-0,288;p=0,001) ve vücut kitle indeksi (r=-0,282; p=0,002) arasında anlamlı korelasyon vardı. Aşamalı çoklu regresyon analizi, ağırlığın sol el için %4,9 varyansla 2D:4D rakam oranının anlamlı ve bağımsız bir faktörü olduğunu gösterdi.
Sonuç: Mevcut literatürde EHA ile 2D:4D oranı arasındaki ilişkiyi inceleyen bir çalışmanın bulunmaması, çalışma verilerinin önemini ortaya koymaktadır. Bizim önerimiz hasta ve sağlıklı bireylerde ROM ölçümleri ölçülerek 2D:4D oranı ile olan ilişkinin incelenebilmesidir.

Anahtar Kelimeler: Eklem Hareket Acıklığı, 2D:4D Rakam Oranı, Gonyometre, Dijital Kumpas.

INTRODUCTION

The hand, an indispensable tool in our daily lives, seamlessly integrates motor and sensory capabilities to facilitate a wide array of movements crucial for our everyday activities. Its intricate combination of motor and sensory parameters enables us to perform tasks with precision and efficiency, underscoring

Corresponding Author: Gökçe Bağcı Uzun, e-mail: gokce.bagciuzun@ozal.edu.tr
Received: 02.05.2024, Accepted: 03.06.2024, Published Online: 20.06.2024
Cited: Bağcı Uzun G, et al. Investigation of the Relationship of Wrist Range of Motion with 2D:4D Ratio in Healthy Individuals. Acta Medica Ruha. 2024;2(2):92-99. https://doi.org/10.5281/zenodo.11382931

its pivotal role in our daily routines. Anchored by the shoulder, elbow, and wrist joints, the hand functions as a dynamic interface between our body and the surrounding environment, allowing us to grasp, manipulate, and interact with objects in our surroundings (1). Furthermore, the hand is not merely a functional tool but also a symbol of dexterity and craftsmanship, embodying a complex amalgamation of muscles, bones, and neurovascular structures that set it apart from other anatomical features (2). This complexity highlights the hand's significance in our upper extremity functionality, prompting extensive research into its anatomical, physiological, and functional aspects (3). Finger ratio studies, particularly those examining the 2D:4D digit ratio, have emerged as a focal point of inquiry within the scientific community (4–6). During prenatal development, the differential influence of sex hormones, namely estrogen and testosterone, shapes the growth patterns of the second (2D) and fourth (4D) digits, respectively. Consequently, variations in the 2D:4D ratio have been linked to gender-specific traits, with lower ratios often associated with male characteristics and higher ratios with female characteristics (7). While gender-based trends prevail, individual variations underscore the intricate interplay of genetic and hormonal factors, contributing to the diversity observed in digit ratios (8). Recent literature studies have investigated the relationship between finger length ratio and various factors. It has been observed that male infants have lower 2D:4D digit ratios on the left and right hand than female infants. In addition, a decrease in finger ratios was observed in families with consanguineous relationships, regardless of the gender of the infants (9). It was determined that male infants of mothers with longer 2D length in the right hand were heavier and had a larger head diameter (10).

Moreover, researchers have extended their inquiries to encompass the wrist, recognizing its pivotal role in both stability and mobility within the upper extremity (11–13). By measuring the 2D:4D digit ratios of university students in Northeast England who played sports at least once a week or participated in university sports teams, it was shown that individuals with a low 2D:4D digit ratios had higher levels of sporting ability and achievement (14). In addition to finger ratio research, studies have also been conducted on the wrist researches including our study (15,16). Bunnell's description of the wrist as a "keystone joint" underscores its significance in maintaining structural integrity while facilitating a wide range of movements essential for daily activities (3). Among these movements, the concept of range of motion (ROM) holds particular significance, serving as a fundamental measure in the assessment of musculoskeletal health and function. Defined as the extent of movement achievable at a joint, ROM provides valuable insights into joint flexibility, integrity, and overall functional capacity (17). Despite its clinical relevance, there remains a notable gap in the literature regarding the intercourse among finger length ratios, such as the 2D:4D ratio, and wrist ROM.

In light of this gap, our study seeks to address this space by investigating the potential correlation between finger length ratios and wrist ROM, thereby contributing to a deeper understanding of the intricate interplay between digit morphology and upper extremity function. Specifically, we aim to examine whether variations in the 2D:4D digit ratio correlate with differences in wrist ROM, particularly focusing on radial and ulnar deviation as well as flexion and extension.

Hypotheses

Building upon existing literature and theoretical frameworks, we have formulated the following hypotheses to guide our investigation:

H1: Individuals with a longer second digit (2D) relative to the fourth digit (4D), indicative of a lower 2D:4D ratio, will exhibit increased radial deviation and flexion of the wrist joint. Conversely, those with a shorter 2D relative to 4D, corresponding to a higher ratio, will demonstrate heightened ulnar deviation and extension.

H2: Moreover, we postulate that a longer 2D relative to 4D will be associated with greater radial deviation and flexion, whereas a shorter 2D will correlate with reduced ulnar deviation and extension.

These hypotheses serve as a framework for our study, guiding our exploration of the potential influence of digit ratios on wrist ROM. Through empirical research, we aim to elucidate the underlying mechanisms driving these relationships and contribute to knowledge in this area.

METHOD

Our research involved a cohort of 120 male and female volunteers who provided informed consent prior to participation. Approval for the study, designated as 2023/26, was granted by the Non-Interventional Clinical Research Ethics Committee of Malatya Turgut Özal University.

The study design comprised a single group, with a gender distribution of 37.5% female and 62.5% male among the volunteers.

Inclusion and Exclusion Criteria

Participants with a history of wrist, hand or finger surgery, those receiving physical therapy or rehabilitation, or any congenital or acquired deformities were not included in the study.

Demographic Assessment

Demographic information including age, height, weight, gender, presence of chronic diseases, psychological disorders, smoking status, occupation, marital status, and number of children, if any, was collected through structured questioning.

Measurements Conducted

Wrist Flexion Measurement:

Definition: Wrist flexion angle refers to the decrease in wrist angle when the wrist is in a neutral position.

Procedure: Goniometric measurements were performed using a standard universal goniometer with 1-degree accuracy. The pivot point of the goniometer was placed on the ulnar styloid process, with the forearm supported in pronation and the hand and wrist hanging freely. The fixed arm of the goniometer was parallel to the ulna, while the movable arm was aligned with the 5th metacarpal bone. Participants were instructed to flex their wrists downward until the end point of the movement, and the corresponding angle was recorded (17).

Wrist Extension Measurement:

Definition: Wrist extension angle refers to the increase in wrist angle when the wrist is in a neutral position.

Procedure: Similar to wrist flexion measurement, goniometric measurements were taken with the participant's forearm in pronation. The participant was asked to extend their wrist upward until the end point of the movement, and the angle was recorded [17](**Figure I**)

Wrist Radial Deviation Measurement:

Definition: Wrist radial deviation angle indicates the decrease in wrist angle towards the radial bone side from the midline when the wrist is in a neutral position.

Procedure: Goniometric measurements were conducted with the participant seated, forearm pronated, and palm resting on the table. The pivot point of the goniometer was placed proximal to the 3rd metacarpal joint, and participants were instructed to deviate their wrist towards the radial side until the end point of the movement, with the angle recorded (17,18) (**Figure II)**

Wrist Ulnar Deviation Measurement:

Definition: Wrist ulnar deviation angle indicates the decrease in wrist angle towards the ulnar bone side from the midline when the wrist is in a neutral position.

Procedure: Similar to radial deviation measurement, goniometric measurements were taken with the participant's forearm pronated. Participants were instructed to deviate their wrist towards the ulnar side until the end point of the movement, with the angle recorded (17,18).

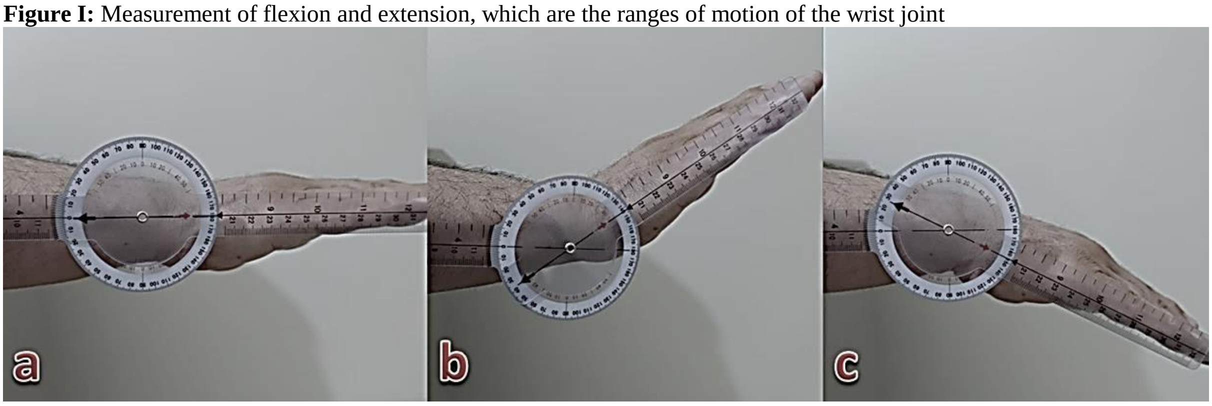
2D and 4D Finger Length Measurement:

Procedure: Digit ratios were gauged using digital calipers with 0.01 mm accuracy. Participants were asked to place their hands on a flat surface with their palms facing upwards. Measurements were taken as from the proximal pleat of the metacarpophalangeal junction to the fingertip. Measurements were obtained for both left and right hands, and 2D:4D digit ratios were calculated (19,20).

All measurements were performed thrice to minimize errors in wrist range of motion and 2D:4D digit ratio assessments (Figure III).

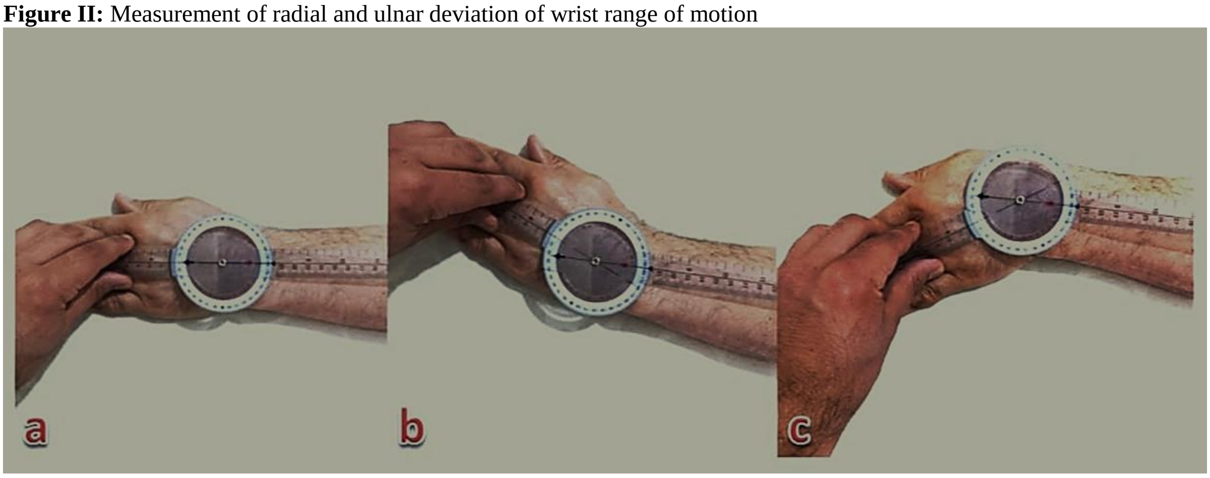
Our pictures of our measurements are given as Figure I, Figure II, Figure III.

Figure I: Measurement of flexion and extension, which are the ranges of motion of the wrist joint



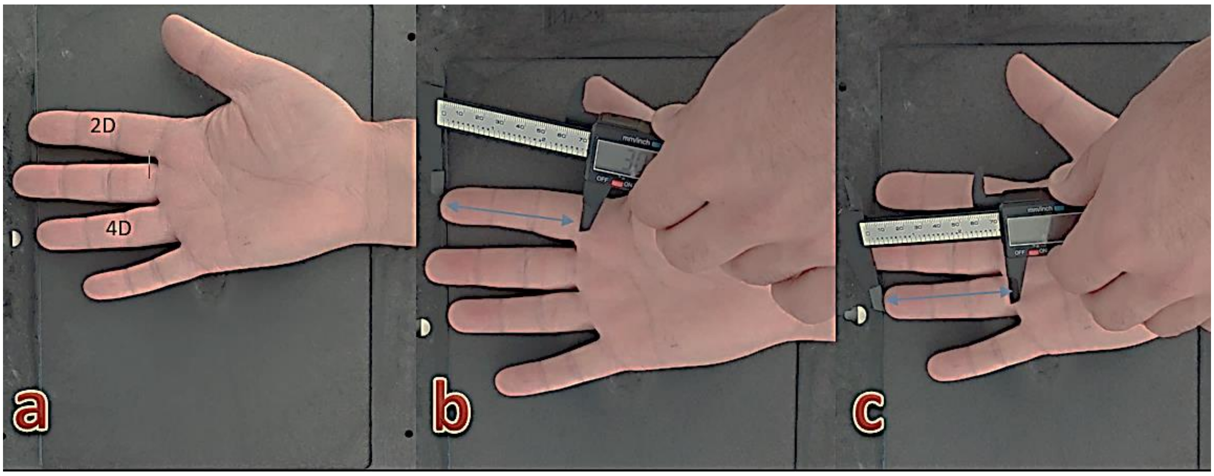
a: For flexion and extension measurement, which are the ranges of motion of the wrist joint, the hand is suspended from the table with the palm of the hand facing downward and the hand is positioned in the neutral position for measurement, **b:** For the extension measurement, the participant is asked to perform an upward extension for the hand previously positioned on the table and joint motion measurement is taken at the end point. **c:** For flexion measurement, the participant is asked to flexion downward for the hand previously positioned on the table and joint movement measurement is taken at the end point.

Figure II: Measurement of radial and ulnar deviation of wrist range of motion



a: For the measurement of radial and ulnar deviation, which are the ranges of motion of the wrist joint, the hand is adjusted with the palm facing the table and the hand is positioned in the neutral position, **b:** For the radial deviation measurement, the participant is asked to deviate the hand to the radial side for the hand previously positioned on the table and the joint motion measurement is taken at the end point, **c:** For the ulnar deviation measurement, the participant is asked to deviate the hand to the ulnar side for the hand previously positioned on the table and joint motion measurement is taken at the end point.

Figure III: 2D:4D measurement of finger lengths



a: To measure 2D:4D finger length, the hand is placed on a hard surface with the palm facing upwards, **b:** 2D measurement of finger length, **c:** 4D measurement of finger length.

Statistical Analysis

IBM SPSS Statistics for Windows (version 22.0; IBM, Armonk, NY) was employed for data analysis.The initial examination of the variables involved the use of analytical procedures (Kolmogorov-Simirnov/Shapiro-Wilk test) as well as visual methods (histograms, probability plots) to determine normalcy. Data that was regularly dispersed was subjected to parametric analysis. Ratios (%) were utilized to display categorical data, whereas mean±standard deviation, standard error of mean, and 95% confidence intervals were used to represent continuous variables. Pearson product-moment correlation coefficients were employed to investigate relationships among 2D:4D digit ratios for the right and left hands and other variables (wrist flexion-extension-radial deviation-ulnar deviation; height, 0weight, age, and body mass index). Strong correlation was denoted by correlation coefficients larger than 0.5, moderate correlation by coefficients among 0.3 and 0.5, and weak correlation by coefficients between 0.2 and 0.3. A significant threshold of $p<.05$. A stepwise multiple linear regression analysis was employed to define which variables had the biggest effects on the left and right hands' 2D:4D digit ratios. Regression model variables that showed significant correlations with 2D:4D digit ratios were included. To find and deal with outliers, Cook's distance and the centered leverage value were also applied.

RESULTS

Participating in the study were 120 asymptomatic persons (37.50% female), whose average age was 33.73±14.12 years and their average body mass index was 24.66±4.60 kg/m^2. In Table 1, descriptive statistics were displayed.

The 2D:4D digit ratio for the right hand did not significantly correlate with any other variables (p=0.127-0.902). As a result, Table 2's regression equation lacked any variables.

The left hand's 2D:4D digit ratio did, however, showed a significant connection with weight (r=-0.288; p=0.001) and body mass index (r=-0.282; p=0.002, Table 2). Weight and body mass index were included as independent variables in the regression model to examine potential factors impacting the 2D:4D digit ratio in the evaluation of the left hand's 2D:4D digit ratio. Weight was found to be a significant and independent predictor of the left hand's 2D:4D digit ratio by stepwise multiple regression analysis, explaining 4.9% of the variance (Table 3).

The explanatory variable (weight) and coefficients were used to create the regression equation formula for the dependent variable (2D:4D digit ratio for the left hand). The following is the regression equation formula for the left hand's 2D:4D digit ratio:

2D:4D digit ratio for left hand: 1.021 + (-0.001 * Weight)

Table 1. Descriptive statistic of variables

	Minimum	Maximum	Mean	Std. Error	Std. Deviation
2D:4D digit ratio					
for right hand	0.79	1.10	0.93	0.004	0.053
for left hand	0.75	1.10	0.95	0.006	0.075
Right hand					
Flexion	74.00	86.00	79.54	0.219	2.407
Extension	64.00	74.00	68.81	0.214	2.345
Radial deviation	14.00	84.00	21.30	0.761	8.339
Ulnar deviation	24.00	71.00	31.13	0.542	5.947
Left hand					
Flexion	8.00	85.00	77.34	1.030	10.614
Extension	34.00	76.00	67.98	0.457	5.012
Radial deviation	14.00	34.00	20.05	0.251	2.752
Ulnar deviation	23.00	36.00	29.90	0.287	3.152
Height	149.00	196.00	172.48	0.945	10.360
Weight	50.00	130.00	73.19	1.613	17.676
Age	20.00	75.00	33.73	1.289	14.128
Body mass index	16.02	41.50	24.66	0.420	4.606

Table 2. Relationship among 2D:4D digit ratios for right and left hands and other variables

	Flexion	Extension	Radial deviation	Ulnar deviation	Height	Weight	Age	Body mass index
Right	p=0.342 r=0.087	p=0.127 r=0.140	p=0.902 r=0.011	p=0.871 r=0.015	p=0.776 r=-0.026	p=0.224 r=-0.112	p=0.752 r=0.029	p=0.239 r=-0.108
Left	p=0.119 r=-0.152	p=0.188 r=0.121	p=0.282 r=0.099	p=0.830 r=0.020	p=0.053 r=-0.177	p=0.001* r=-0.288	p=0.058 r=-0.173	p=0.002* r=-0.282

*: Correlation is significant at the 0.05 level (2-tailed).

Table 3. Stepwise multiple linear regression model of 2D:4D digit ratio for left hand and weight

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	p
		B	Std. Error	Beta		
1	(Constant)	1.021	0.032		31.875	<0.001
	Weight	-0.001	0.000	-0.242	-2.541	0.013
a. Dependent variable: 2D:4D digit ratio for left hand						

DISCUSSION

The aim of this study was to evaluate any possible among range of motion (ROM) and 2D:4D digit ratios. A cohort of 120 people was included, with 62.5% male and 37.5% female. The cohort's average age was 33.73±14.12 years, and its average body mass index (BMI) was 24.66±4.60 kg/m². Goniometers and calipers were employed to measure the ROM and finger lengths, respectively. Although 2D:4D digit ratios have been the subject of much investigation in the past , (12,21–26). no study has looked at how they relate to ROM. This gap was filled by our study, which emphasized the originality and importance of our findings.

Demirel et al. found no significant gender or BMI-related differences in ROM, a conclusion supported by our findings (18). For the right hand, no substantial connections was found among 2D:4D digit ratios and other variables (p=0.127-0.902). However, for the left hand, a significant correlation was found among 2D:4D digit ratios and weight (r=-0.288; p=0.001) and BMI (r=-0.282; p=0.002). Pasanen et al. highlighted a weak correlation (r = -0.15) between hand grip strength and 2D:4D digit ratios, suggesting an association with muscle fitness (27). Although our work did not establish a direct link among ROM and 2D:4D ratios, it could have implications for muscle fitness if such a relationship existed.

Akbulut et al. indicated that ROM is influenced by various factors including age, gender, obesity, and certain medical conditions. They emphasized the role of sports in enhancing ROM, thus promoting quality of life and reducing the risk of injury (28). Ceylan et al. realised that no substantial association among 2D:4D ratios and shooting performance in basketball players, contrasting with Adamczyk et al.'s findings regarding combat sports (29). These discrepancies underscore the complexity of the relationship among 2D:4D ratios and sports performance.

CONCLUSION

In conclusion, our study identified an important correlation among left hand 2D:4D ratios and BMI but found no association with wrist ROM. Future research could explore this relationship further, particularly in patient populations. Our findings have implications for various disciplines, including anthropology and anatomy.

Limitations and Suggestions for Future Research

Despite its contributions, our work has limitations. ROM data were limited to the wrist, warranting exploration in other body parts. Future studies could diversify samples and streamline measurement processes to enhance applicability.

DESCRIPTIONS

No financial support.

No conflict of interest.

Acknowledgments: We extend our gratitude to all study participants.

Ethical Approval: Ethical approval was obtained from the Malatya Turgut Özal University Non-Invasive Clinical Research Ethics Committee (Decision No: 2023/26).

REFERENCES

1. Tubiana R. Examination of the hand and wrist [Internet]. London : Martin Dunitz ; St. Louis : Mosby; 1996 [cited 2024 Apr 1]. 416 p. Available from: http://archive.org/details/examinationofhan0000tubi

2. Paker N, Alp M, Bardak An, Buğdaycı D, Sabırlı F, Ersoy S. Evaluation of Wrist Range of Motion and Hand Grip Strength in Women with the Diagnosis of Carpal Tunnel Syndrome: A Controlled Study. J Phys Med Rehabil Sci [Internet]. 2020 [cited 2024 Apr 1];23(2).

3. Tubiana R, Thomine JM, Mackin E. Examination of the hand and wrist. CRC Press; 1998.

4. Eichler A, Kaufmann F, Titzmann A, et al. 2D:4D biomarker reliability and validity in a within-subject pregnancy-childhood-adolescence cohort. Early Hum Dev. 2023 Jun;181:105776.

5. Karaoğlu N, Gülay A. Tıp fakültesi öğrencilerinin 2P: 4P el parmak uzunluk oranları ile kişilik özellikleri arasındaki ilişkinin incelenmesi. Antropoloji. 2021;(41):1–10.

6. Uzun GB. In the Anatomic Studies, Is It Correct to Add an Artificial Intelligence Such as Chatgpt as a Co-Author? Eur J Ther. 2024;30(1):89–90.

7. Manning JT, Stewart A, Bundred PE, Trivers RL. Sex and ethnic differences in 2nd to 4th digit ratio of children. Early Hum Dev. 2004 Nov;80(2):161–8.

8. Phelps VR. Relative index finger length as a sex-influenced trait in man. Am J Hum Genet. 1952;4(2):72.

9. Ertuğrul B, Özener B, Pawłowski B. Prenatal exposure to oestrogens estimated by digit ratio (2d/4d) and breast size in young nulliparous women. Ann Hum Biol. 2020 Jan 2;47(1):81–4.

10. Çay M, Gürel S. The relationship between mothers' second and fourth finger lengths (2D: 4D) and anthropometric measurements (height, weight, head circumference, and 2D: 4D) of the newborns. Am J Hum Biol. 2022;34(5):e23700.

11. Malas MA, Dogan S, Evcil EH, Desdicioglu K. Fetal development of the hand, digits and digit ratio (2D: 4D). Early Hum Dev. 2006;82(7):469–75.

12. Manning JT. Resolving the role of prenatal sex steroids in the development of digit ratio. Proc Natl Acad Sci. 2011 Sep 27;108(39):16143–4.

13. Putz DA, Gaulin SJ, Sporter RJ, McBurney DH. Sex hormones and finger length: What does 2D: 4D indicate? Evol Hum Behav. 2004;25(3):182–99.

14. Keith-Barnett N, Campbell A. Sporting achievement: what is the contribution of digit ratio? J Pers. 2007;75(4):663–78.

15. Boone DC, Azen SP. Normal range of motion of joints in male subjects. JBJS. 1979;61(5):756–9.

16. Macedo LG, Magee DJ. Differences in range of motion between dominant and nondominant sides of upper and lower extremities. J Manipulative Physiol Ther. 2008;31(8):577–82.

17. Otman AS. Tedavi hareketlerinde temel değerlendirme prensipleri [Internet]. Pelikan yayıncılık; 2014 [cited 2024 Mar 10]. Available from: https://scholar.google.com/scholar?cluster=4454540470653614825&hl=en&oi=scholarr

18. Demirel E, İnceoğlu F, Uzun Gb, Anıl K, Pekmez H. The Effect of Computer Usage Time on Radial and Ulnar Deviation in University Students. Harran Üniversitesi Tıp Fakültesi Derg. 2023;20(1):111–21.

19. İnceoğlu F, Uzun GB. Evli Çiftlerde 2d:4d Parmak Uzunluk Oranının Kişilik Özellikleri, Evlilikte Doyum Ve Uyum Özellikleri Arasındaki İlişkiye Etkisinin İncelenmesi. İnönü Üniversitesi Sağlık Hizmetleri Mesl Üksek Okulu Derg. 2023 Jun 10;11(2):1507–23.

20. Uzun GB, Tok Y. Investigating the correlation between 2D:4D finger digit ratios and attention gathering skills of 60-72 month-old children. Early Hum Dev. 2023 Jan 10;176:105712.

21. Evcen R, Çölkesen F, Saygın DA, et al. High digit ratio (2D:4D) is associated with attack frequency and severity in hereditary angioedema patients. Early Hum Dev. 2023 Mar 1;177–178:105724.

22. Fink B, Manning JT, Neave N. Second to fourth digit ratio and the 'big five'personality factors. Personal Individ Differ. 2004;37(3):495–503.

23. 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. 2014;5:9.

24. Manning JT, Fink B, Trivers R. Digit Ratio (2D:4D; Right-Left 2D:4D) and Multiple Phenotypes for Same-Sex Attraction: The BBC Internet Study Revisited. Arch Sex Behav. 2024 Jan;53(1):213–22.

25. Sorokowski P, Kowal M. Relationship between the 2D:4D and prenatal testosterone, adult level testosterone, and testosterone change: Meta-analysis of 54 studies. Am J Biol Anthropol. 2024 Jan;183(1):20–38.

26. Ying Y, Madathil S, Nicolau B. Association between the second- and fourth-digit ratio and oral squamous cell carcinoma. Oral Dis. 2023;29(8):3173–82.

27. Pasanen BE, Tomkinson JM, Dufner TJ, Park CW, Fitzgerald JS, Tomkinson GR. The relationship between digit ratio (2D:4D) and muscular fitness: A systematic review and meta-analysis. Am J Hum Biol Off J Hum Biol Counc. 2022 Mar;34(3):e23657.

28. Akbulut T, AydemiR İ, Karaman ME. Eklem Hareket Açıklığı, Sağlık ve Sportif Performans. Gaziantep Üniversitesi Spor Bilim Derg. 2023 Sep 25;8(3):174–91.

29. Ceylan L, Küçük H, Ceylan T, Eliöz M. The 2nd:4th digit ratio and shooting skill performance in Basketball Players. Akdeniz Spor Bilim Derg. 2022 Sep 28;5(3):537–49.