Received: 17 Mar 2025 | **Accepted:** 11 Aug 2025 **Genel Tıp Derg. Volume** 35/**Issue** 5 (October), 899-907
DOI: 10.54005/geneltip.1660070

ORIGINAL ARTICLE

A Cross-Sectional Study on The Relationship Between Hand Grip Strength and Digit Ratio: The Case of Hitit University

El Kavrama Gücü ile Parmak Oranı Arasındaki İlişkiye İlişkin Kesitsel Bir Çalışma: Hitit Üniversitesi Örneği

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How to cite ?

Koç F., A Cross-Sectional Study on The Relationship Between Hand Grip Strength and Digit Ratio: The Case of Hitit University, Genel Tıp Derg. 2025;35(5):899-907

ABSTRACT

Aim: This study aimed to investigate the relationship between the second-to-fourth digit ratio and handgrip strength in healthy young adults, and to determine whether this relationship differs by sex.
Methods: In this cross-sectional study, 156 university students (85 females, 71 males) aged 18–30 from Hitit University participated voluntarily. The lengths of the second and fourth digits of both hands were measured using a digital caliper, and digit ratios were calculated. Handgrip strength was assessed with a Jamar® hydraulic hand dynamometer. Statistical analyses included the Mann–Whitney U test and Spearman's rank correlation coefficient.
Results: Males had significantly higher handgrip strength values and longer digit lengths than females, but lower digit ratios. In males, moderate positive correlations were found between digit lengths and handgrip strength (r = 0.40–0.59), while in females, only a weak correlation was observed between right-hand fourth digit length and handgrip strength. No statistically significant associations were found between digit ratios and handgrip strength in either sex.
Conclusion: The findings suggest a potential link between prenatal androgen exposure and the connection between morphological traits and muscular strength. However, this relationship appears to be influenced by not only biological but also environmental, developmental, and sex-specific factors. Future studies should adopt broader age ranges and include hormonal biomarkers for a more comprehensive analysis.

Keywords: Anatomy, anthropometry, digit ratio, hand grip strength, medicine.

ÖZ

Amaç: Bu çalışma, sağlıklı genç yetişkin bireylerde ikinci ve dördüncü parmak uzunluğunun birbirine oranı ile el kavrama kuvveti arasındaki ilişkiyi incelemeyi ve bu ilişkinin cinsiyete göre farklılık gösterip göstermediğini belirlemeyi amaçlamaktadır.
Yöntem: Kesitsel tasarıma sahip bu araştırmaya, 18–30 yaş aralığında, Hitit Üniversitesi'nde öğrenim gören 156 gönüllü öğrenci (85 kadın, 71 erkek) katılmıştır. Katılımcıların her iki eline ait ikinci ve dördüncü parmak uzunlukları dijital kumpasla ölçülmüş ve parmak oranı oranları hesaplanmıştır. El kavrama kuvveti ise Jamar el dinamometresi ile ölçülmüştür. İstatistiksel analizlerde Mann–Whitney U testi ve Spearman korelasyon katsayısı kullanılmıştır.
Bulgular: Erkek bireyler, kadınlara kıyasla anlamlı şekilde daha yüksek HGS ve daha uzun parmak uzunluklarına sahiptir; ancak parmak oranı oranları daha düşüktür. Erkeklerde parmak uzunlukları ile el kavrama kuvveti arasında orta düzeyde pozitif korelasyonlar saptanırken (r = 0.40–0.59), kadınlarda yalnızca sağ el 4. parmak uzunluğu ile el kavrama kuvveti arasında zayıf bir ilişki bulunmuştur. Parmak oranı ile el kavrama kuvveti arasında ise her iki cinsiyette de istatistiksel olarak anlamlı bir ilişki belirlenmemiştir.
Sonuç: Elde edilen bulgular, prenatal androjen maruziyetinin morfolojik yapı ve kas gücü arasında potansiyel bir bağlantı kurduğunu düşündürmektedir. Ancak bu ilişkinin yalnızca biyolojik değil, aynı zamanda çevresel, gelişimsel ve cinsiyete bağlı faktörlerden de etkilendiği anlaşılmaktadır. Gelecekteki araştırmalarda daha geniş yaş grupları ve hormonal biyobelirteçleri içeren kapsamlı tasarımlar önerilmektedir.

Anahtar Kelimeler: anatomi, antropometri, el kavrama gücü, parmak oranı, tıp.

Peer-Review: Double anonymized - Two External
Plagiarism Checks: Yes - intihal.net
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Selcuk University Press
Genel Tıp Dergisi | e-ISSN: 2602-3741
https://dergipark.org.tr/tr/pub/geneltip
https://yayinevi.selcuk.edu.tr/

INTRODUCTION

The second-to-fourth digit ratio (2D:4D) is a sexually dimorphic anthropometric index that reflects the balance of prenatal androgen and estrogen exposure. This ratio is calculated by dividing the length of the index finger (2D) by the length of the ring finger (4D), and is generally lower in males and higher in females (1,2). The underlying biological mechanism is linked to the organizational effects of sex hormones during early fetal development, making the 2D:4D ratio a widely used morphological marker of prenatal hormonal influence (3).

In addition to its association with biological sex differences, the 2D:4D ratio has also been linked to physical traits such as muscular strength, sports performance, and motor coordination (4–6). For example, lower 2D:4D values have been associated with higher handgrip strength (HGS), particularly among male participants, suggesting a potential link between prenatal androgen exposure and muscle development (5,6). Several studies have also examined the relationship between absolute finger lengths (i.e., digit anthropometry) and handgrip strength, reporting moderate to strong correlations that highlight the mechanical role of hand dimensions in force production (4,7,8). However, inconsistencies remain in the literature, due to methodological differences, varying measurement protocols, and heterogeneous sample characteristics (7–9). Notably, most existing studies either focus solely on digit ratios or do not assess the combined impact of digit length and sex-based differences in strength performance.

Similarly, another study conducted among Tuvan individuals living in Siberia found a negative association between 2D:4D and handgrip strength in both hands among females and in the right hand among males (8). These findings suggest that the 2D:4D ratio may be related to muscle strength and that this relationship may vary according to biological sex.

However, inconsistencies exist in the current literature due to methodological variations, differences in measurement techniques, and sample heterogeneity. It has been noted that contextual factors, such as exercise, may influence the strength of this association. For instance, some findings suggest that increases in handgrip strength following intense physical activity may vary depending on the individual's 2D:4D ratio (9).

Although the 2D:4D ratio has also been linked to behavioral tendencies such as aggression, impulsivity, and risk-taking in the health sciences, this study focuses specifically on its association with physical performance. Handgrip strength, in turn, is considered a simple, inexpensive, and valid indicator of physical fitness, and is widely used as an indirect marker of muscular strength among young adults (10).

While some studies have discussed potential associations between HGS and cardiovascular or neurological disorders, such variables were intentionally excluded from the scope of the present research. Accordingly, the present study focuses strictly on physical parameters and sex-based comparisons, in alignment with its target population.

In this context, the aim of the current study is to investigate the relationship between the 2D:4D digit ratio and handgrip strength among healthy young adults studying at Hitit University, and to contribute original, sample-specific insights to the existing body of literature.

METHODS

This cross-sectional study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Non-Interventional Research Ethics Committee of Hitit University (protocol number: 2022-28; date: January 3, 2023). The research was carried out at Hitit University between March and May 2023. A total of 156 university students, selected based on voluntary participation, were included in the study. Inclusion criteria required participants to be between 18 and 30 years of age, to have no known history of musculoskeletal, neurological, or cardiovascular diseases, and not to be using any medications that could affect muscle strength. Individuals with a history of hand or digit injuries, those reporting fatigue or chronic illness on the day of measurement, and those who had engaged in resistance training within 48 hours prior to testing were excluded from the study. The hand grip strength data used in this study were also included in a separate publication that investigated the relationship between grip strength and aggression (11). However, that study had an independent research design, hypothesis, and methodological framework, and it addressed a different research question.

A non-probability convenience sampling method was employed. The required sample size was calculated using G*Power 3.1.9.7 software, based on a significance level of 5%, a statistical power of 80%, and an effect size of 0.25, referencing similar studies in the literature. While a minimum of 128 participants was deemed sufficient, 156 individuals were included to account for potential data loss. In previous studies investigating the relationship between digit ratio and handgrip strength, sample sizes have ranged from approximately 50 to 150 participants. For example, Butovskaya et al. (2018) included 122 Russian adolescents (4), while Zhao et al. (2012) analyzed 142 Han Chinese adults (18). Similarly, Bäck et al. (2022) conducted their study with 87 healthy females (7). The sample size used in the present study is thus consistent with or larger than those in comparable research.

Data collection was performed in a controlled laboratory setting between 09:00 and 12:00 to minimize the potential effects of circadian variation on handgrip strength. All measurements were conducted by the same research team. Participants were verbally and in writing informed about the study procedures prior to the assessments.

Digit Ratio (2D:4D)

The lengths of the second (index) and fourth (ring) digits of both hands were measured using a digital caliper (accuracy ±0.01 mm), from the basal crease to the digittip. Measurements were conducted with participants in a seated position, hands flat, digits extended, and kept closely together. The measurement order was standardized: the right hand was measured first, followed by the left. Each measurement was taken twice by two independent researchers, and the average of the values was used in the analysis.

The 2D:4D ratio was calculated by dividing the length of the second digit by the length of the fourth digit. Prior to data collection, an inter-rater reliability analysis was performed, and inter-observer agreement was found to be high (Intraclass Correlation Coefficient, ICC = 0.92), supporting the reliability of the measurements.

Handgrip Strength Measurement

Handgrip strength was assessed using a Jamar® hydraulic hand dynamometer (Lafayette Instrument, USA) following the protocol recommended by the American Society of Hand Therapists (ASHT). The dynamometer handle was adjusted to the standard second position. Participants were seated upright, with the shoulder adducted and in neutral rotation, the elbow flexed at 90°, the forearm in a neutral position, and the wrist positioned between 0°–30° extension.

Three measurements were taken for each hand, with a 30-second rest interval between trials. The highest value recorded from the dominant hand was used for analysis. Participants were instructed to refrain from engaging in strenuous physical activity for at least 24 hours before testing. No participant reported fatigue or discomfort during the measurements; therefore, no data loss occurred.

Assessment of Hand Preference

Handedness was determined via self-report. Participants were asked which hand they predominantly used in daily activities. Based on their responses, individuals were categorized into two groups: "right-handed" and "left-handed." This variable was considered important due to potential developmental and size differences in the dominant hand. Self-report is a widely accepted and practical method for assessing handedness in research settings. In clinical and experimental contexts requiring more detailed analysis, standardized tools such as the Edinburgh Handedness Inventory (EHI) may be utilized. In this study, the self-report method was preferred, as it offered practical advantages for sex-based comparative analysis (12, 13).

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 25.0 (Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as mean ± standard deviation, median (minimum–maximum), and percentages.

In this study, the dependent variables were the 2D:4D ratios of the right and left hands and the handgrip strength of the dominant hand. Independent variables included sex, hand preference, and digit lengths. Relationships between continuous variables were analyzed using Spearman's rank correlation coefficient. For data not following a normal distribution, differences between two independent groups were assessed using the Mann–Whitney U test, while differences among three or more groups were evaluated using the Kruskal–Wallis test. A p-value of less than 0.05 was considered statistically significant in all analyses.

RESULTS

A total of 156 individuals participated in the study. Of these, 85 (54.49%) were female and 71 (45.51%) were male. The participants had a mean age of 21.97 ± 2.28 years, with an age range of 18 to 30. Regarding hand preference, 134 individuals (85.90%) reported right-hand dominance, 10 (6.41%) reported left-hand dominance, and 12 (7.69%) stated they used both hands equally.

Table 1. Descriptive Characteristics of Participants

Variable	Category	n	%
Sex	Female	85	54.49%
	Male	71	45.51%
Age	Mean ± SD	21.97 ± 2.28	—
	Range (Min–Max)	18–30	—
Hand Preference	Right	134	85.90%
	Left	10	6.41%
	Both	12	7.69%

Descriptive statistics for digit lengths and 2D:4D ratios according to sex are presented in Table 2. Males had longer digit lengths than females for both hands. However, the 2D:4D ratios were slightly lower in females, although the difference between sexes was marginal. Mean digit lengths were higher on the dominant hand across both groups.

Descriptive statistics for hand grip strength (HGS) are presented in Table 3. Males demonstrated significantly higher grip strength values than females for both hands. The average grip strength of the right hand was higher than that of the left hand in both sexs. Standard deviations were notably larger among males, reflecting greater variability in strength capacity.

In female participants, significant positive correlations were observed between right hand grip strength and the lengths of both the right fourth digit ($r = 0.322$, $p = 0.003$) and the left fourth digit ($r = 0.319$, $p = 0.003$) (Table 4). A moderate correlation was also found between right hand grip strength and left second digit length ($r = 0.260$, $p = 0.016$). No statistically significant associations were found between 2D:4D and hand grip strength on either hand.

Table 2. Descriptive statistics of digit lengths (mm) and 2D:4D ratios by sex

Measurement	Sex	Mean	SD	Median	Min	Max
Right 2D Length (mm)	Female	68.90	±3.99	69.10	60.50	78.30
	Male	72.93	±4.27	73.00	64.70	82.00
Right 4D Length (mm)	Female	69.83	±3.88	69.70	60.30	77.00
	Male	73.81	±4.91	73.00	65.00	84.00
Left 2D Length (mm)	Female	68.06	±3.56	68.00	59.90	76.60
	Male	72.44	±4.53	72.60	59.90	82.00
Left 4D Length (mm)	Female	69.63	±3.89	69.90	59.20	77.20
	Male	74.07	±4.87	74.00	63.10	84.40
Right 2D:4D Ratio	Female	0.9872	±0.03	0.98	0.93	1.07
	Male	0.9893	±0.04	0.99	0.92	1.07
Left 2D:4D Ratio	Female	0.9782	±0.03	0.98	0.92	1.08
	Male	0.9791	±0.04	0.98	0.90	1.07

Table 3. Descriptive statistics of hand grip strength (HGS) by sex (kg)

Measurement	Sex	Mean	SD	Median	Min	Max
Right Hand HGS (kg)	Female	25.90	±5.70	26.00	12.00	43.50
	Male	44.37	±10.23	45.90	26.00	61.90
Left Hand HGS (kg)	Female	23.90	±6.06	22.80	11.00	45.90
	Male	41.80	±8.76	43.00	22.00	60.70

In female participants, significant positive correlations were observed between right hand grip strength and the lengths of both the right fourth digit (r = 0.322, p = 0.003) and the left fourth digit (r = 0.319, p = 0.003) (Table 4). A moderate correlation was also found between right hand grip strength and left second digit length (r = 0.260, p = 0.016). No statistically significant associations were found between 2D:4D and hand grip strength on either hand.

DISCUSSION

This study examined the relationship between the second-to-fourth digit length ratio (2D:4D) and handgrip strength (HGS) in healthy young adults and revealed how this relationship differs based on sex. The findings show that male participants had significantly lower 2D:4D ratios and higher HGS values compared to females. This is largely consistent with the literature suggesting that sex-specific prenatal hormonal effects result in both morphological (2D:4D) and functional (HGS) outcomes (14-16). These findings contribute to the growing body of evidence on sex-specific biological influences on physical performance traits such as grip strength.

Moderate positive correlations (r = 0.40–0.59) observed between the lengths of the second and fourth digits and HGS in males support the regulatory role of prenatal testosterone in muscle development. In contrast, in female participants, a weaker correlation was observed between the length of the right-hand fourth digit and HGS (r = 0.20–0.39). However, no statistically significant relationship was found between the 2D:4D ratio and HGS in general. This

Table 4. Spearman correlation coefficients between digit lengths, digit ratios, and hand grip strength in female participants (n = 85)

Variable	Right HGS (r)	p-value	Left HGS (r)	p-value
Right 2D (mm)	0.212	0.052	0.084	0.447
Right 4D (mm)	**0.322**	**0.003**	0.141	0.199
Left 2D (mm)	**0.260**	**0.016**	0.154	0.159
Left 4D (mm)	**0.319**	**0.003**	0.191	0.080
Right 2D:4D	−0.201	0.065	−0.104	0.341
Left 2D:4D	−0.094	0.391	−0.057	0.606

r = Spearman's rho correlation coefficient. Significant p-values ($p < 0.05$) are bolded.

Table 5. Spearman correlation coefficients between digit lengths, digit ratios, and hand grip strength in male participants (n = 71)

Variable	Right HGS (r)	p-value	Left HGS (r)	p-value
Right 2D (mm)	**0.348**	**0.003**	**0.386**	**0.001**
Right 4D (mm)	**0.467**	**0.000**	**0.472**	**0.000**
Left 2D (mm)	**0.444**	**0.000**	**0.466**	**0.000**
Left 4D (mm)	**0.327**	**0.005**	**0.416**	**0.000**
Right 2D:4D	−0.223	0.062	−0.211	0.078
Left 2D:4D	0.056	0.643	−0.023	0.836

suggests that HGS may be more closely related to absolute digit lengths rather than the ratio between them.

The obtained results confirm the negative 2D:4D–HGS correlation reported by Butovskaya et al. (17) in male Tuvan individuals, while also aligning with the lack of association found in the study by Zhao et al. (18) conducted on a Han ethnic group. The weak correlations found in females raise the possibility of sex-specific differences in biological sensitivity to prenatal hormones. Similarly, Bäck et al. (2022) reported that the negative correlation between 2D:4D and HGS remained significant in female participants even when controlling for variables such as BMI and exercise levels (7). In the study conducted by Shen et al. (2016) on Han ethnicity individuals in Ningxia, China, no significant correlation was found between 2D:4D and handgrip strength in males, whereas a significant negative correlation was observed in females for both hands. This finding is consistent with the weak associations found among females in our study and underscores the importance of sex-specific biological sensitivity in interpreting the 2D:4D–HGS relationship (19).

In the literature, a study conducted by Aydık et al. (2024) examining how facial morphology changes based on HGS and 2D:4D ratio found that these two variables explained significant variance in facial shape only among male individuals (20). Similarly, male participants differed significantly from females in both HGS level and 2D:4D. In females, the relationship remained weak. This pattern may reflect greater phenotypic sensitivity to prenatal androgen exposure in males compared to females. The absence of a direct relationship between 2D:4D and HGS suggests that the association between these variables may be shaped by contextual, environmental, and genetic factors.

The lack of a statistically significant association in our study suggests that the 2D:4D–HGS relationship may be context-dependent rather than universal. However, moderate correlations between digit lengths and grip strength, particularly in males, support the idea that prenatal hormonal influences may shape morphological and functional traits in a sex-specific manner (4, 18, 19).

These findings are consistent with previous studies reporting sex-specific or population-dependent variation in the 2D:4D–HGS association. For example, Lu et al. (2017) found a significant negative correlation between right-hand 2D:4D and HGS only in females, while Zhao et al. (2012) reported no significant association among Han Chinese males (22, 23).

Taken together, these results suggest that contextual factors such as ethnicity, physical activity level, and measurement protocols may influence how digit ratios relate to handgrip strength. Future studies should include broader demographic samples and hormonal biomarkers to clarify the multifactorial nature of this association.

This study has several limitations. First, due to its cross-sectional design, it is not possible to establish causality regarding the relationship between 2D:4D and HGS. Second, since the sample consisted solely of young adults studying at a single university, the generalizability of the findings to other age groups or socioeconomic levels is limited. Additionally, the exclusion of variables such as hormone levels, genetic variations, and

psychosocial factors makes it difficult to fully explain the relationship between 2D:4D and HGS. Furthermore, since inter-rater reliability for digit length measurements was not formally tested, certain limitations in measurement reliability are present.

CONCLUSION

This study examined the association between the 2D:4D and HGS in a sample of healthy young adults from a non-Western university context. The findings revealed that digit length, particularly in males, was moderately associated with handgrip strength, supporting the influence of prenatal androgen exposure on physical performance. However, no direct association was observed between the 2D:4D ratio and grip strength overall.

These results suggest that the 2D:4D–HGS relationship is multifactorial and shaped by biological, genetic, and contextual factors. Future research should incorporate broader demographic groups, hormonal biomarkers, and functional measures to build more comprehensive explanatory models.

Funding: This research received no external funding.

Institutional Review Board Statement: The study data were obtained in accordance with the principles of the Declaration of Helsinki and under the approval of the Hitit University Non-Interventional Research Ethics Committee (dated 03/01/2023, protocol number 2022-28).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Declaration of Interest: I hereby declare that there was no conflict of interest with any institution or individual at any stage of this research.

Author Contribution Statement: I hereby declare that I am the sole contributor to the conceptualization, design, execution, and interpretation of the reported study.

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