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ARAŞTIRMA / RESEARCH

The relationship of the digit ratio (2D:4D) with body fat distribution and handgrip strength in medical students

Tıp fakültesi öğrencilerinde 2./4. el parmak uzunluk oranının vücut yağ dağılımı parametreleri ve el kavrama kuvveti ile olan ilişkisi

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Abstract

Purpose: Digit ratio (2D:4D) is a sexually dimorphic trait, that may be a sign for prenatal testosterone level, which is significantly associated with handgrip strength (HGS) and sex-related body fat distribution. The aim of this study was to explore the association between the 2D:4D, HGS, and body fat distribution parameters in medical students.

Materials and Methods: A total of 253 participants (112 males, 141 females) were involved in this cross-sectional study. Anthropometric parameters, including height and body weight, circumferences of arm, neck, waist, hip, HGS, the length of the second and fourth finger were measured. According to 2D:4D, the volunteers were divided into three groups (>1, =1, <1).

Results: For both genders, 2D:4D>1 was associated with lower HGS, while larger arm, neck, and waist circumferences were associated with higher HGS. Pearson correlation analysis showed that 2D:4D of both hands had a strong negative correlation with height, circumferences of arm and neck, waist-to-hip ratio (WHR), and HGS, whereas it was only positively correlated with body mass index. Right and left HGS were positively correlated with WHR, height, weight, circumferences of arm, neck, and waist.

Conclusion: 2D/4D makes a substantial contribution to our prediction of body fat distribution in terms of the relationship of 2D:4D <1 to an increased HGS, WHR, arm and neck circumference depending on testosterone hormone as in males.

Keywords: Body mass index, digit ratio, body fat distribution, handgrip strength, medical student

Öz

Amaç: Cinsel dimorfik bir özellik olan el ikinci ve dördüncü parmak uzunluk oranının (2P/4P), el kavrama kuvveti (EKK) ve cinsiyete bağlı vücut yağ dağılımı ile ilişkili olan prenatal testosteron seviyesinin güçlü bir göstergesi olduğu bildirilmektedir. Bu çalışmada; tıp fakültesi öğrencilerinde el parmak uzunluk oranı, EKK ve vücut yağ dağılımı parametreleri arasındaki ilişkinin araştırılması amaçlanmıştır.

Gereç ve Yöntem: Bu kesitsel çalışmaya toplam 253 katılımcı (112 erkek, 141 kadın) dahil edildi. İkinci ve dördüncü parmak uzunluğu, boy ve vücut ağırlığı, kol, boyun, bel, kalça çevresi ve EKK gibi antropometrik parametreler ölçüldü. El parmak uzunluk oranına göre gönüllüler üç gruba ayrıldı (> 1, = 1, <1).

Bulgular: Her iki cinsiyette el parmak uzunluk oranı >1 olması, düşük EKK ile ilişkili bulunurken kol, boyun ve bel çevresi geniş olanlarda EKK'nin daha büyük olduğu görüldü. Korelasyon analizine göre her iki elin parmak uzunluk oranı ile boy, EKK, bel/kalça oranı (BKO), kol ve boyun çevresi arasında kuvvetli negatif korelasyon bulunurken, vücut kitle indeksi ile pozitif korelasyon gösterdiği tespit edildi. Sağ ve sol EKK ölçüm sonuçları ile BKO, ağırlık, boy, kol, boyun ve bel çevresi değerleri arasında pozitif korelasyon bulundu.

Sonuç: Erkeklerde testosteron hormonuna bağlı olarak el parmak uzunluk oranı <1'dir ve EKK, BKO, kol ve boyun çevresi daha büyüktür. El parmak uzunluk oranı ile bu parametreler arasındaki ilişki vücut yağ dağılımının tahmin edilmesine katkıda bulunacağını düşünmekteyiz.

Anahtar kelimeler: Vücut kitle indeksi, el parmak oranı, vücut yağ dağılımı, el kavrama kuvveti, tıp fakültesi öğrencisi

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INTRODUCTION

Several studies reported that the relative lengths of the second finger to the fourth finger, known as the digit ratio (2D:4D ratio), is thought to be a strong indicator for testosterone exposure during the embryonic period[1,2,3]. Depending on the potency of prenatal hormones the 2D:4D ratio is sexually dimorphic, which is inversely proportional to testosterone level in males and directly proportional to estrogen level in females during embryonic period[1,2,3,4]. In general, because of the number of androgen receptors in the fourth finger is high, this finger is longer, and the 2D:4D ratio is less than one in male, while in female the second finger is longer, and this ratio is greater than one due to estrogen exposure[1,5,6]. If this ratio is equal to 1, the second and fourth finger lengths are equal, and this situation can be seen in both genders[1]. When the testosterone hormone is found sufficient levels, causing the diameter of the muscle fibers to increase, it improves muscle strength, which is an indispensable parameter for every sports branch. Therefore, there was a significant negative correlation between the 2D: 4D ratio and sportive performance and handgrip strength (HGS), which is a proxy for overall strength capacity [7,8]. In literature, a lower 2D:4D ratio (masculinized digit ratio) was repoted to be related to higher cardiovascular capacity, physical performance, and aggression, and also personal traits such as better arithmetic, spatial, and visual skills, whereas the increased risk of obesity, cardiometabolic disease, cognitive disorders was mostly attributed to higher 2D:4D ratio (feminized digit ratio)[3,9,10,11,12,13].

HGS is the maximum static force that emerges from all fingers' voluntary and strong flexion[14,15]. It has been considered a physical strength indicator used to determine athletes' sports performance, general nutrition, hand functions such as gripping and pulling, and overall health status[9,14,15]. It is a simple, non-invasive, and objective method to measure muscle strength and also easy to apply. Besides, HGS can be used to monitor sarcopenia, muscle weakness, and low muscle mass among elderly peoples and to predict mortality in different age groups. In previous studies, the associations between HGS and functional status, depression, cognitive functions, chronic, musculoskeletal, and neuromuscular diseases were investigated[15,16,17]. HGS is considered quite heritable and sexually dimorphic. Many anthropometric parameters such as height, weight, the 2D:4D ratio, body mass index (BMI), skinfold thickness (SFT), and waist-to-hip ratio (WHR) commonly affect muscle strength, and they can be used to predict HGS[1,5,12,18].

Body fat distribution parameters are BMI, circumferences of arm, neck, waist, and hip, SFT of triceps, biceps, abdomen, and pectoral region[1,5,12]. BMI is an expression of the relative body weight to the square of height[14]. It is generally known that these anthropometric parameters show sexual dimorphism with the effect of prenatal hormones and genetic factors. Although it is said that BMI and HGS are related, some studies had revealed a positive relationship, some had revealed a partial positive relationship, while others had not revealed a significant relationship due to substantial geographic and ethnic differences[9,13,14,19]. However, comprehensive investigations on the 2D:4D ratio and its' relationship with HGS and the parameters showing body fat distribution revealed a vital relationship between the 2D:4D ratio and HGS[1,2,5]. Some studies also reported that digit ratio may affect determining the dominant hand preference used in writing[9,14].

All these parameters were widely studied separately in many kinds of research, but some conflicted with each other[5,6,8]. Therefore, besides the importance of these parameters, more research is needed to show the relationship of HGS to the 2D:4D ratio and body fat distribution parameters in both genders and different age groups. In response to this need, the objectives of the current study were two; the first aim was to analyze the association between the 2D:4D ratio, HGS, and body fat distribution parameters, and the second aim was to determine how the resistance training affects HGS. Our results would contribute to the literature with a new database and provide additional evidence of this relationship.

MATERIALS AND METHODS

This study was accomplished as a cross-sectional analytic research model from the quantitative research methods. The Ethics Committee of Necmettin Erbakan University Meram Medical Faculty approved this study (2020/2313). For all measurements, a written informed consent form was acquired from all participants, and all parts of the study was conducted according to the principles expressed in the Declaration of Helsinki.

We conducted this study on 253 volunteers, including

112 males and 141 females (aged 18 to 22 years) from Necmettin Erbakan University Meram Faculty of Medicine. The criteria for inclusion; being a student in the 2019-2020 academic year, having Turkish as a native language. Students with right or left-hand disability, finger deficiency, and surgical intervention on their hands, and plastic surgery on their bodies were not included in the study.

Data collection

The lengths of the second and fourth fingers of both hands of the students were measured with a digital caliper with a precision of 0.01 mm from the proximal fold on the volar face of the metacarpophalangeal joint to the fingertip in the direction suggested in previous studies[1,2,3]. Each 2D:4D ratio was calculated by dividing the second by fourth finger length for both hands. The students' dominant hand was also determined according to whether they preferred the right or left hand when writing.

As a characteristic of body fat distribution, some anthropometric measurements, such as the circumferences of arm, neck, waist, hip, body weight, and height, were measured. Using these measurement values, BMI (kg/m^2), and WHR of all participants were calculated. A skinfold caliper was used to measure SFT of the triceps, biceps, abdominal, and pectoral region. The study group was divided into four groups according to BMI scores as follows: less than 20 (BMI-1=risk for malnutrition), between 20-25 (BMI-2=normal), between 25-30 (BMI-3=risk for obesity), and more than 30 (BMI-4=obese).

The left and right HGS of the participants were measured with a Jamar hydraulic hand dynamometer. Resistance training with dumbbells exercise (one set of 15-20 repetitions in 30 seconds) for females 2.5 kg and males 3.5 kg was performed, and HGS was measured again. The HGS values before and after the activity were recorded as HGS-1 and HGS-2.

Statistical analysis

For statistical analysis, the IBM SPSS Version 25.0 (SPSS, IBM Corporation, New York, USA) program was used. Number and percentage were used to express categorical variables, while metric measurements were done using mean and standard deviation. Descriptive statistics were generated for all variables. Continuous variables (not in normal distribution) were compared using Mann-Whitney U test, while for variables with normal distribution Independent sample t-test was used. The mean values of right and left hands were compared with the Paired t-test. Correlations between selected variables were analyzed by the Pearson correlation coefficient and linear regression analysis. Comparisons of average HGS among BMI and the 2D:4D ratio groups were performed by using One Way ANOVA. Statistical significance level was accepted as $p < 0.05$.

RESULTS

A total of 253 participants with a mean age of 19.91±2.8 years, 44.3% (n=112) male and 55.7% (n=141) female students volunteered for this study. We reported that 90.9% of subjects (103 male, 127 female) were found to be right-handed, and 9.1% (9 male, 14 female) were left-handed, respectively. Statistically, there was no significant difference between gender and dominant hand (p>0,05). The 2D:4D ratio and HGS scores for both hands according to hand preference were shown in Table 1.

In left-handed subjects, the length of the right second and fourth finger and arm circumference were significantly higher in males than in females, whereas the right 2D:4D ratio was higher in females than in males (p<0.001). Although other measurements' mean values were higher in males than in females, no significant differences were found (p>0.05). We highlighted that the mean 2D:4D ratio of the left hand was found as 1.002±0.03 in left-handed males (Table 1). Also, there was no significant relationship between the 2D:4D ratio and measured variables.

In right-handed subjects, significant sex differences (higher in males than in females) were assessed by an Independent sample t-test, which was described for each measurement (p<0.001), except for hip circumference, triceps, and biceps SFT (p>0.05). The weight, height, BMI, and the length of the second and fourth fingers were significantly higher in males than females, whereas the mean 2D:4D ratio was lower in males than females (0.987 ± 0.029 for males and 1.011 ± 0.032 for females) (p<0.001). Also, the value of the 2D:4D ratio for right and left hands in 42.2% and 40% of the subjects (n=97, n=92) were <1, in 17% and 19.2% of the subjects (n=39, n=44) were 1, in 40.8% and 40.8% of the subjects (n=94, n=94) were >1, respectively (Table 2 and 3).

Table 1. The distribution of the 2D:4D ratio and HGS scores according to hand preference and gender

	Male		Female	
Hand preference (Mean ±SD)	**Right-handed (n=103)**	**Left-handed(n=9)**	**Right-handed (n=127)**	**Left-handed (n=14)**
Right 2D:4D	0.98±0.03	0.94±0.02	1.02±0.03	1.002±0.03
Left 2D:4D	0.99±0.03	1.002±0.03	1.01±0.03	1.005±0.03
Right HGS	43.49±8.13	32.27±6.93	26.61±5.01	30.42±6.13
Left HGS	40.99±7.77	33.37±7.03	25.00±4.57	31.32±6.41

Descriptive statistic, SD: standard deviation, 2D:4D: digit ratio, HGS: handgrip strength

The distribution of the percentages of all participants according to 2D:4D <1, =1 and >1 groups were 23% (70 male, 24 female), 36% (10 male, 32 female), and 41% (23 male, 71 female), respectively. According to digit ratio groups, the comparison of all measurements' mean values was done and the results were shown in Table 2 for both hands in right-handed subjects. As seen in this table, the effect of the 2D:4D ratio on the mean measurement values except triceps and biceps SFT was found to be significant ($p<0.001$). Also, a weak correlation was foun between the right 2D:4D ratio and BMI, as shown in Table 2.

Table 2. Comparison of morphometric parameters according to right and left 2D:4D ratio subgroups in right-handed students (n=230)

Right 2D:4D ratio (Mean ±SD)	**<1 (n=97)**	**=1 (n=39)**	**>1 (n=94)**	**p**
Right HGS1	39.66±9.78	32.32±9.17	29.27±9.21	0.000
Right HGS2	40.32±9.95	32.29±8.63	29.86±8.99	0.000
AC	28.34±3.82	25.59±4.12	25.85±3.77	0.000
NC	37.28±3.69	33.27±3.95	33.28±3.57	0.000
WHR	0.88±0.07	0.80±0.10	0.79±0.08	0.000
TSFT	19.28±4.44	18.93±5.38	20.35±4.63	0.165
BSFT	11.40±2.95	11.24±3.61	11.91±3.52	0.437
BMI	23.68±3.55	22.18±4.59	22.42±3.44	0.028
Left 2D:4D ratio (n=230)	<1 (n=92)	=1 (n=44)	>1 (n=94)	p
	Mean ±SD	Mean ±SD	Mean ±SD	
Left HGS1	37.71±10.21	26.65±6.68	29.32±8.99	0.000
Left HGS2	38.65±10.74	26.97±6.87	29.60±8.90	0.000
AC	28.05±3.72	24.93±3.54	26.59±4.20	0.000
NC	36.99±3.89	32.40±2.87	34.18±4.06	0.000
WHR	.88±.07	.78±.07	.81±.10	0.000
TSFT	18.51±4.25	19.51±4.71	20.84±4.87	0.003
BSFT	11.06±2.85	11.22±3.28	12.26±3.63	0.033
BMI	23.26±3.46	21.77±3.50	23.11±4.05	0.076

ANOVA test. SD: standard deviation, 2D:4D: digit ratio, HGS: handgrip strength, AC: arm circumference, NC: neck circumference, WHR: waist-to-hip ratio, TSFT: triceps skinfold thickness, BSFT: biceps skinfold thickness, BMI: body mass index

Considering all the participants, the numbers of the male and female subjects were 12 (4.8 %) and 42 (16.7%) in BMI-1, 53 (20.9 %) and 73 (28.9%) in BMI-2, 36 (14.2 %) and 20 (7.9%) in BMI-3, and 11 (4.3%) and 6 (2.3%) in BMI-4, respectively. The number of subjects with the 2D:4D ratio >1 was the highest in the BMI-1 group, while the BMI-3 group mostly consisted of subjects with the 2D:4D ratio <1 (Table 3). In right-handed participants, right HGS scores ranged from 17.2 to 61.2 kg, and the mean value was 34.17±10.57 kg, whereas left HGS scores ranged from 15 to 63.9 kg, and the mean value was 32.16±10.21 kg, respectively. In right-handed participants, there was a significant difference between right and left HGS scores, while no significant difference was found in left-handed students (HGS scores ranged from 10.5 to 50 kg, and the mean value was 31.58±10.24 kg).

Table 3. Distribution of genders and body mass index groups according to right and left 2D:4D ratio subgroups in right-handed students

Right 2D:4D ratio (n=230)			
	<1 (n=97)	=1 (n=39)	>1 (n=94)
BMI	n (%)	n (%)	n (%)
<20	13 (5.7)	16 (7.0)	23 (10)
20-25	48 (20.9)	13 (5.7)	51 (22.2)
25-30	31 (13.5)	7 (3.0)	14 (6.0)
>30	5 (2.1)	3 (1.3)	6 (2.6)
Gender	n (%)	n (%)	n (%)
Male	74 (71.8)	12 (11.7)	17 (16.5)
Female	23 (18.1)	27 (21.3)	77 (60.6)
Left 2D:4D ratio (n=230)			
	<1 (n=92)	=1 (n=44)	>1 (n=94)
BMI	n (%)	n (%)	n (%)
<20	14 (6.1)	14 (6.1)	24 (10.5)
20-25	47 (20.4)	21 (9.1)	44 (19.2)
25-30	27 (11.7)	6 (2.6)	19 (8.3)
>30	4 (1.7)	3 (1.3)	7 (3.0)
Gender	n (%)	n (%)	n (%)
Male	68 (66.0)	7 (6.8)	28 (27.2)
Female	24 (18.9)	37 (29.1)	66 (52.0)

Pearson correlation results between the measured parameters of right-handed subjects (n=230) were listed in Table 4. According to Pearson correlation, a weak negative correlation was found between BMI and the right 2D:4D ratio (r=- 0.141, p = 0.032), whereas there were a strong negative correlation between the right HGS and 2D:4D ratio, and the left HGS and 2D:4D ratio (r = - 0.477, p = 0.000; r = - 0.369, p = 0.000), respectively. WHR, arm, and neck circumferences showed a negative correlation with the 2D:4D ratio of both hands (p=0.000), while they showed a positive correlation significantly with BMI, right and left HGS (p=0.000), respectively. The mean triceps and biceps SFT were seemed to be not affected by the right 2D:4D ratio, WHR, right and left HGS (p>0.05).

On the other hand, there was a positive correlation between the SFT of triceps and biceps and BMI, arm, and neck circumferences (p=0.000). Also, a weak positive correlation between the left 2D:4D ratio and the SFT of triceps and biceps was found (Table 4). As seen in Table 5, correlation analysis revealed a strong association between the left 2D:4D ratio and left HGS, whereas the relationship was not found between the 2D:4D ratio and BMI and HGS, in left-handed subjects. Like right-handed subjects, a positive correlation between the parameters that showed body fat distribution (BMI, WHR, circumferences of arm and neck) was found in left-handed students (Table 5). Linear regression analysis revealed that gender, the 2D:4D ratio, WHR, and circumferences of arm and neck were significant predictors of HGS in right-handed subjects. In Figures 1 and 2, the mean HGS, WHR, and neck circumference values were significantly negatively correlated with the 2D:4D ratio in right-handed subjects. The mean HGS values recorded on the second occasion (after dumbbell exercise) were substantially higher than the first occasion in males and females. They showed a positive correlation significantly with each other in right-handed subjects (r = 0.917, p = 0.000) (Figure 2C). As seen in Figure 3A and B there was a positive correlation between the mean biceps and pectoral SFT and BMI in males, whereas, in females, BMI was positively correlated with the mean triceps and abdominal SFT (for males r = 0.312, p<0.05; for females r = 0.278, p<0.05). In Figure 3C, there was a weak association between HGS and BMI in males.

Table 4. Correlation between the 2D:4D ratio and anthropometric parameters in right-handed students (n=230)

		Right 2D:4D	Left 2D:4D	BMI	Right HGS	Left HGS	AC	NC	WHR	TSFT	BSFT
Right 2D:4D	r	1									
	p										
Left 2D:4D	r	.594**	1								
	p	.000									
BMI	r	-.141*	.005	1							
	p	.032	.940								
Right HGS	r	-.477**	-.376**	.403**	1						
	p	.000	.000	.000							
Left HGS	r	-.494**	-.369**	.389**	.951**	1					
	p	.000	.000	.000	.000						
AC	r	-.291**	-.167	.817**	.590**	.579**	1				
	p	.000	.011	.000	.000	.000					
NC	r	-.460**	-.282**	.641**	.776**	.758**	.780**	1			
	p	.000	.000	.000	.000	.000	.000				
WHR	r	-.434**	-.309**	.500**	.738**	.713**	.631**	.838**	1		
	p	.000	.000	.000	.000	.000	.000	.000			
TSFT	r	.116	.211**	.674**	-.031	-.026	.463**	.182**	.038	1	
	p	.080	.001	.000	.644	.699	.000	.006	.569		
BSFT	r	.061	.170*	.634**	.075	.080	.473**	.256**	.104	.856**	1
	p	.359	.010	.000	.257	.227	.000	.000	.117	.000	

Pearson correlation coefficient was used. r: Correlation coefficient, p: Sig. (2-tailed), * p<0.05, ** p<0.000 2D:4D: digit ratio, BMI: body mass index, HGS: handgrip strength, AC: arm circumference, NC: neck circumference, WHR: waist-to-hip ratio, TSFT: triceps skinfold thickness, BSFT: biceps skinfold thickness.

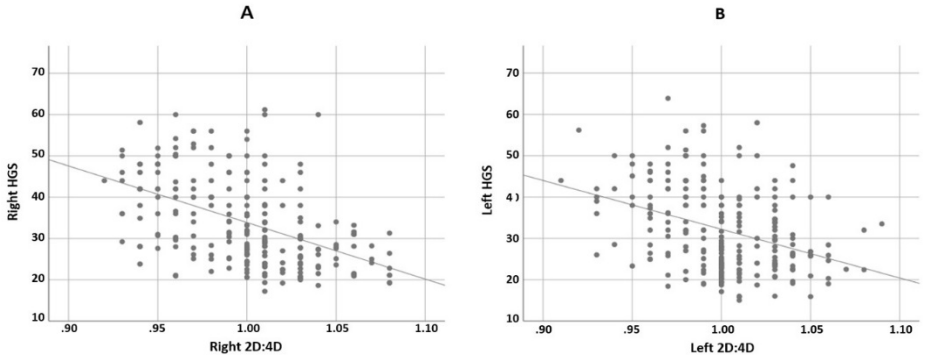

Figure 1. Scatter plots showing the correlation of the digit ratio (2D:4D) A. with the right handgrip strength (HGS), B. with the left HGS in right-handed subjects.

Table 5. Correlation between the 2D:4D ratio and anthropometric parameters in left-handed students (n=23)

		Right 2D:4D	Left 2D:4D	BMI	Right HGS	Left HGS	AC	NC	WHR	TSFT	BSFT
Right 2D:4D	r	1									
	p										
Left 2D:4D	r	.440*	1								
	p	.036									
BMI	r	-.175*	-.152	1							
	p	.438	.490								
Right HGS	r	-.244	-.162	.260	1						
	p	.236	.460	.232							
Left HGS	r	-.231	-.222*	.356	.936**	1					
	p	.290	.312	.096	.000						
AC	r	-.291*	-.308	.658**	.173	.244*	1				
	p	.035	.053	.001	.431	.034					
NC	r	-.108	-.206	.690**	.533**	.552**	.415*	1			
	p	.399	.346	.000	.009	.006	.049				
WHR	r	-.224	-.039	.645**	.703**	.725**	.428*	.814**	1		
	p	.261	.570	.001	.000	.000	.042	.000			
TSFT	r	.030	.073	.658**	.162	.160	.586**	.535**	.228	1	
	p	.891	.740	.001	.459	.299	.001	.006	.052		
BSFT	r	.079	.116	.689**	.221	.211	.642**	.540**	.403*	.656**	1
	p	.721	.598	.000	.312	.333	.001	.008	.034	.001	

Pearson correlation coefficient was used. r: Correlation coefficient, p: Sig. (2-tailed), * p<0.05, ** p<0.000 2D:4D: digit ratio, BMI: body mass index, HGS: handgrip strength, AC: arm circumference, NC: neck circumference, WHR: waist-to-hip ratio, TSFT: triceps skinfold thickness, BSFT: biceps skinfold thickness.

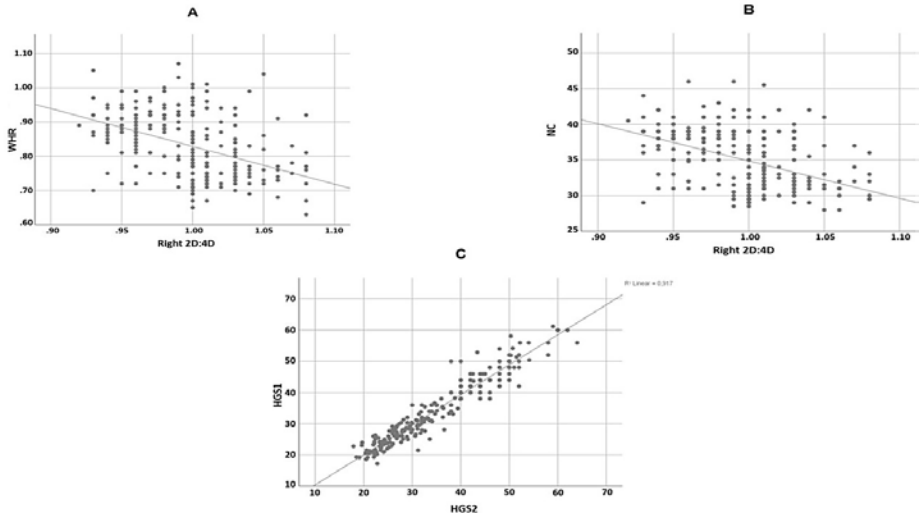

Figure 2. Scatter plots showing the correlation of the digit ratio (2D:4D) A. with waist-to-hip ratio (WHR), B. with neck circumference (NC) in right-handed subjects, C. a positive correlation between handgrip strength-1 (HGS-1) and handgrip strength-2 (HGS-2).

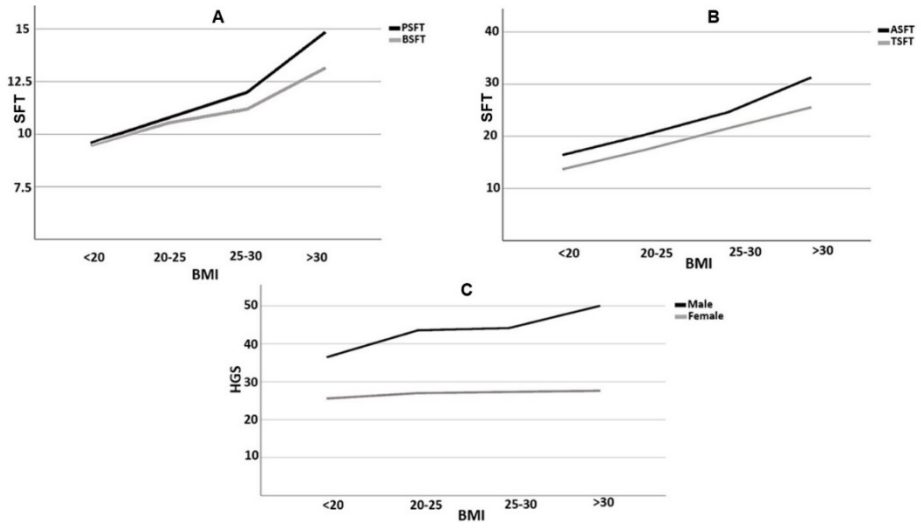

Figure 3. Line diagrams showing the correlation between A. the mean biceps (BSFT) and pectoral (PSFT) skinfold thickness and body mass index (BMI) in males, B. the mean triceps (TSFT) and abdominal (ASFT) skinfold thickness and body mass index (BMI) in females, C. the association between handgrip strength (HGS) and body mass index (BMI) in right handed students.

DISCUSSION

It is well known that HGS and circumferences of arm, neck, and waist have been highlighted and accepted as a significant predictor of the upper extremity performance, which plays a vital role in the forecast for overall health and physical activity of professional athletes. Also, It was reported that a low 2D:4D ratio is ensued from prenatal testosterone hormone and closely related to sexually dimorphic morphological traits[1,2,8,13]. The results in previous studies expressed that there was a strong association between the 2D:4D ratio and HGS, which is in relation to catching and throwing activity required for different branches of sports, Also, HGS can be increased with resistance training and also an aggressive stimulus[3,6,14,18]. In the literature, the parameters helping to predict body fat distribution such as BMI, circumferences of arm, neck, waist, hip, SFT of triceps, biceps, abdomen, and pectoral regions were identified, and they were found to be in a strong association with the 2D:4D ratio, HGS, and also gender[12,17,19,20]. This investigation assessed the relationship of the 2D:4D ratio to HGS and body fat distribution by objective and quantitative methods in medical students in Turkey. In particular, increasing HGS value in response to dumbbell exercise (15-20 repetitions) suggested that resistance training plays an active role in the upgrade of muscular strength.

We enrolled 253 participants, and the difference in the variables between the groups in terms of gender was found significant. The weight, height, BMI, HGS, the length of the fourth and second fingers, WHR, circumferences of arm, waist, and neck were significantly higher in males than females, whereas the 2D:4D ratio, TSF, and BSF were markedly higher in females than males. However, there was no significant difference between the 2D:4D ratio of right and left hands and SFT values. This study revealed a predictive association (negative correlation) between the 2D:4D ratio and HGS, which is consistent with previous findings. Also, we highlighted that the mean 2D:4D ratio of the left hand was found as 1.002±0.03 in left-handed males as seen in Table 1. Eler et al. performed a study on 123 (72 females and 51 males, 10–12 years old) swimmers to examine HGS, which is a valuable index of physical strength, along with the 2D:4D ratio. Males with lower 2D:4D ratio have been notified to show significantly higher HGS scores than their 2D:4D ratio≥1 peers. Especially in female athletes, the right 2D:4D ratio showed a positive correlation with BMI parameters[8]. In another study with 108 healthy university students (73 male and 35 female,

aged 18-20 years), for both hands, the 2D:4D ratio was significantly lower in males than females. A moderately significant positive correlation was observed between the handball throwing distances and weight and BMI. Still, no significant association was reported between the 2D:4D ratio and the speed and power performance in both genders[7]. In the study (57 boys aged 13–18 years) by Tomkinson et al., they reported moderately inverse correlation between the 2D:4D ratio and HGS[19]. In agreement with the literature, our study showed that digit ratio was negatively correlated with HGS and BMI in males and females. Also, an inverse relationship was found between the 2D:4D ratio and WHR, circumferences of arm, waist, and neck. Similar to other studies, we did not report a significant difference in HGS between right and left hands in left-handed participants. In contrast to Acar's study[9], we reported that no significant difference was observed between the right and left 2D:4D ratios and HGS in left-handed students, whereas the right-handed ones showed a statistically significant difference.

When Bakholdina et al. conducted a study in 106 students including, 48 females and 58 males, from Mordovian, an association between HGS, BMI, WHR, and the 2D:4D ratio was not found for both genders by using partial and Pearson correlations. They reported that all measurements were higher in males than females, while the 2D:4D ratio was lower in males than females in relation to a high degree of sexual dimorphism [5]. Eighty participants (50 females, 30 males) from 3 European universities were included in a study conducted in Europe. Digit ratio was lower in males than females, and a significant negative correlation was observed between females' left and right 2D:4D ratio and WHR ($p= 0.0001$). Also, the left 2D:4D ratio was positively correlated with BMI[1]. In a study with 168 adolescents (67 males and 101 females), no significant correlation was found between neck circumference and the 2D:4D ratio in the overweight (BMI-3) and obese (BMI-4) participants, while a negative correlation was observed between them in the normal group (BMI-2)[12]. Similar to this study, we found a weak negative correlation between the 2D:4D ratio and WHR, arm, and neck circumferences in BMI-1 and 2 groups in the present study. Also, we found a positive correlation between HGS (especially right) and BMI, WHR, circumferences of arm, waist, and neck. At the same time, we found an association between BMI and triceps and abdominal SFT among females, and also between BMI and biceps and pectoral SFT among males ($p<0.05$), respectively. As seen in Figure 3A and B there was a weak association between BMI and SFT values in BMI-1 and 2 groups, whereas a moderate correlation in BMI-3 and 4 groups. Incredibly, a significant correlation can be found between BMI and HGS among males ($p<0.001$). But, the 2D:4D ratio did not show a significant difference according to BMI groups for both hands in right handed males and females (Table 3).

In a study of 1835 college students by Garcia-Hermoso et al., body fat distribution was measured by using tetrapolar whole-body impedance (Tanita). A significant positive association was found between HGS and muscle mass and cardiovascular health indicators[21]. Bagepally et al. conducted a study on 1217 male subjects (range 13 to 40 years). They reported that there was a significant association between higher BMI and blood pressure values and higher right 2D:4D ratio. Still, there was no strong association between the 2D:4D ratio of both hands and body fat distribution[22]. In contrast, another study from Turkey reported that no significant relationship was observed between the 2D:4D ratio and BMI, and also cardiovascular capacity in 82 university students[11]. In the study performed by Hidese et al., HGS scores were compared between healthy controls and patients with schizophrenia (significantly lower HGS). The relationships between HGS and HGS/BMI ratio and cognitive functions were investigated in the patient group, and a significant positive correlation was found. When BMI was compared with cognitive function scores, a significant negative correlation was found. They reported that the HGS/BMI ratio could be used as a predictive indicator for cognitive performance in schizophrenia[16]. In a study of 493 medical students by Karaoğlu et al. a negative correlation was found between the right hand 2D:4D ratio and positive and negative emotions and they reported that there was no significant relationship between the 2D:4D ratio and BMI[23]. In the present study, a weak negative correlation was found between the right 2D:4D ratio and BMI, but we did not found an association between the 2D:4D ratio and BMI groups. Tegin et al. reported that there was no direct association between impulsivity scores and digit ratio, while the right digit ratio was lower in control group compared to the bipolar patients[10].

The meta-analytical systematic review performed by Labott et al. demonstrated an inductive effect of

different exercise training on older adults' physical performance; for example, more significant changes in handgrip strength can be seen in participants trained with dumbbells[15]. Also, Holubıac et al. conducted a study including exercise (resistance training on HGS) and control groups of postmenopausal women and used HGS to identify the degree of sarcopenia and malnourishment. They reported that HGS increased 12% for the dominant hand and 10.53% for the nondominant hand in older women trained with dumbbells[24]. In our study, we applied a dumbbell exercise with 15-25 repetitions for 30 seconds to train the arms and found an increase in HGS as 5% for right and 4% for left hands, respectively. Moreover, we found that triceps and abdominal SFT in females and biceps and pectoral SFT in males were associated with a moderate increase in BMI, which revealed the influence of prenatal sex hormone levels to predict body fat distribution in university students.

Our study had some limitations. First, all of the participants were first-year medical students, and second, this study did not include any information about athletes' physical fitness. We could not enlarge the study group because of the protective rules that were started to be applied to avoid the spread of COVID-19. Moreover, extensive research with a larger sample size conducted on athletes and control groups from different ethnicities may be more helpful and play a key role in determining the relationship between digit ratio, HGS, and sexual dimorphism of physical traits.

In conclusion, we revealed that the 2D:4D digit ratio had a significant effect on HGS and body fat distribution parameters such as WHR, circumferences of arm and neck. Furthermore, we revealed the minor impact of exercise training on HGS scores. In this sense, we can say that the data we have obtained will contribute to the literature in the interest of understanding the relationship of digit ratio to HGS and body fat distribution in medical students.

Yazar Katkıları: Çalışma konsepti/Tasarımı: GA, AEÇ; Veri toplama: GA, BD, AS; Veri analizi ve yorumlama: GA, BD, AS; Yazı taslağı: GA, AEÇ; İçeriğin eleştirel incelenmesi: GA, AEÇ; Son onay ve sorumluluk: GA, BD, AS, AEÇ; Teknik ve malzeme desteği: GA, AEÇ, BD, AS; Süpervizyon: GA, BD, AS; Fon sağlama (mevcut ise): yok.
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