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Is digit ratio a biomarker of bone mineral density? Sivas Cumhuriyet University example‡

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Abstract

This study aimed to investigate the relationship between bone mineral density (BMD) and digit ratio, with the goal of evaluating the potential of digit ratio as a marker for predicting osteoporosis-type bone diseases. The study sample included 200 patients (100 women and 100 men) who visited the Nuclear Medicine Clinic at Cumhuriyet University Research Hospital for check-ups, along with a control group of 100 healthy individuals (50 women and 50 men). Bone densitometry measurements were obtained for all participants, and the lengths of the second and fourth digits on both hands were measured using digital calipers. The results indicated a positive correlation between digit ratio and BMD, with this relationship being more pronounced in women. In men, significant positive correlations were found between the right-hand digit ratio and L BMD ($r = 0.589$), the right digit ratio and L T-score ($r = 0.544$), and the right digit ratio and L Z-score ($r = 0.454$). Similar positive associations were observed between the right digit ratio and femoral BMD ($r = 0.608$), femoral T-score ($r = 0.465$), and femoral Z-score ($r = 0.362$) ($p < 0.05$). For women, stronger positive correlations were identified between the right-hand digit ratio and L BMD ($r = 0.707$), the right digit ratio and L T-score ($r = 0.815$), and the right digit ratio and L Z-score ($r = 0.737$). Additionally, significant associations were noted between the right digit ratio and femoral BMD ($r = 0.469$), femoral T-score ($r = 0.535$), and femoral Z-score ($r = 0.495$) ($p < 0.05$). These findings suggest that the association between digit ratio and bone mineral density is stronger in women. In summary, individuals with a high digit ratio generally have higher bone density.

Key Words: Anthropometric measurements, digit ratio, bone mineral density, osteoporosis, sexual dimorphism.

Parmak oranı kemik mineral yoğunluğunun biyobelirteci midir? Sivas Cumhuriyet Üniversitesi örneği

Öz

Bu çalışmanın amacı, parmak oranı ile kemik yoğunluğu arasında bir ilişki olup olmadığını belirleyerek, parmak oranının osteoporoz ve osteopeni gibi kemik hastalıklarına duyarlılığı gösteren bir biyolojik belirteç olma potansiyelini incelemektir. Çalışma verileri, Cumhuriyet Üniversitesi Araştırma Hastanesi Nükleer Tıp Polikliniği'ne kontrol amacıyla başvuran 100 kadın, 100 erkek olmak üzere 200 hastadan ve 50 kadın, 50 erkek 100 sağlıklı bireyden toplanmıştır. Katılımcıların kemik dansitometri ölçümleri alınırken, her iki eldeki ikinci ve dördüncü parmak uzunlukları dijital kumpas kullanılarak ölçülmüştür. Araştırma sonuçları, parmak oranı ile kemik yoğunluğu arasında pozitif bir ilişki saptandığını göstermektedir. Bu ilişki her iki cinsiyette de gözlemlenmiş olsa da, kadınlarda daha belirgin bir şekilde güçlüdür. Erkeklerde sağ el parmak oranı (2P:4P) ile lumbar KMY ($r = 0.589$), sağ 2P:4P ile lumbar T- skoru ($r = 0.544$) ve sağ 2P:4P ile lumbar Z-skoru ($r = 0.454$) arasında pozitif yönlü ilişkiler tespit edilmiştir. Benzer şekilde, sağ 2P:4P ile femoral KMY ($r = 0.608$), femoral T- skoru ($r = 0.465$) ve femoral Z-skoru ($r = 0.362$) arasında da anlamlı pozitif ilişkiler bulunmuştur ($p < 0.05$). Kadınlarda ise, sağ el parmak oranı (2P:4P) ile lumbar KMY ($r = 0.707$), sağ 2P:4P ile lumbar T-skoru ($r = 0.815$) ve sağ 2P:4P ile lumbar Z-skoru ($r = 0.737$) arasında daha güçlü pozitif ilişkiler saptanmıştır. Ayrıca sağ 2P:4P ile femoral KMY ($r = 0.469$), femoral T-skoru ($r = 0.535$) ve femoral Z-skoru ($r = 0.495$) arasında da benzer şekilde anlamlı ilişkiler bulunmuştur ($p < 0.05$). Bu bulgular, parmak oranı ile kemik yoğunluğu arasındaki ilişkinin özellikle kadınlarda daha güçlü olduğunu göstermektedir. Özetle, daha yüksek parmak oranına sahip olan bireylerin kemik yoğunluğunun daha yüksek olduğu saptanmıştır.

Anahtar Kelimeler: *Antropometrik ölçümler, parmak oranı, kemik mineral yoğunluğu, osteoporoz, seksüel dimorfizm*

Introduction

To understand human cultural and biological diversity, anthropologists have developed various tools and techniques. Anthropological research relies on both fieldwork and laboratory work, utilizing a range of methods and instruments. Contemporary methods in anthropology differ significantly from those employed by traditional anthropologists.

Physical anthropologists study areas such as human adaptation, genetics, auxology, nutrition, epidemiology, and other biological aspects of humans. In physical anthropology, specific properties are observed, measured, and tested using diverse apparatus, instruments, and scales. Anthropometric measurements serve multiple purposes, including monitoring growth and development, evaluating

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athletic performance, optimizing industrial designs for ergonomic efficiency, and improving overall quality of life.

In recent years, numerous studies have explored the relationships between specific physical traits and their associations with diseases, behaviors, and tendencies. A key focus has been the impact of prenatal androgen exposure during fetal development. Evidence from certain studies suggests that a prenatal androgen phase influences traits later in life (Xu et al., 2013).

The ratio of the lengths of the second and fourth digits (2D:4D) is widely used as an indicator of prenatal exposure to testosterone relative to estrogen. This measure reflects many variables and parameters (Manning et al., 2011). Exposure to sex hormones in the womb influences not only bodily structures but also the relative lengths of these digits. Higher prenatal testosterone exposure is associated with a longer fourth digit, while prenatal estrogen promotes the growth of the second digit. Consequently, lower 2D:4D ratios, typically observed in males, are linked to higher prenatal testosterone levels, while higher 2D:4D ratios in females suggest greater prenatal estrogen exposure (Tao et al., 2023).

The inverse relationship between prenatal testosterone levels and digit ratios has driven researchers to investigate potential links between 2D:4D and various hormonal conditions, biological traits, and behavioral patterns (Lee et al., 2021). Numerous studies have examined how digit ratios may relate to athletic performance and conditions such as type-2 diabetes, ADHD, dementia, Alzheimer's disease, cardiovascular issues, endocrine and gynecological disorders, and even COVID-19. Additionally, some studies have explored associations between digit ratios and aggression levels (Jiang et al., 2020).

The growing body of literature on digit ratios and hormone-driven conditions has prompted hypotheses about potential links between digit ratios and bone mineral density (BMD), which is also influenced by hormonal factors. BMD serves as a quantitative measure of skeletal health and is a key predictor of fracture risk (Keen, 2007).

Low BMD is a major risk factor for fractures, with an inverse relationship between BMD levels and fracture probability (Miller et al., 2011). Based on BMD levels, individuals can be categorized as osteopenic, osteoporotic, or in cases of fractures as having severe osteoporosis (Ratti et al., 2013).

Osteoporosis is a skeletal disease characterized by reduced bone mass and increased fragility, which significantly raises the risk of fractures. This condition is particularly insidious, as it often remains asymptomatic until fractures occur. It is more common in females, particularly after menopause, due to the rapid hormonal changes experienced during this period (Davis et al., 2015).

Bone fractures, one of the most serious consequences of osteoporosis, can lead to a range of health complications and even fatal outcomes (Lu et al., 2005).

Low BMD in premenopausal females may result from a low peak BMD, a loss of bone content following the peak, or a combination of both factors. For most females, BMD remains stable until menopause, after which it begins to decline due to decreased estrogen levels (Davis et al., 2015).

Material and Method

The study sample was obtained from Bone Densitometry (DEXA) tests performed on patients who visited the Cumhuriyet University Research Hospital Nuclear Medicine Clinic for routine check-ups. Bone mineral density (BMD) measurements were extracted from DEXA reports generated using the Hologic QDR 4500 densitometer (Figure 1). Hormone levels were retrieved from laboratory analyses available in the hospital's database, while digit ratios were calculated based on the measurements of digit lengths from both hands.

Digit lengths were measured with the palms facing upwards and the digits held in a tense position. The first digit was kept slightly apart to avoid stretching, while the remaining four digits were held in full contact with one another. The digit length was defined as the distance between the digittip and the midpoint of the proximal line where the palmar region meets the digit (dactylion point) (Figure 2).

Figure 1: *Hologic QDR 4500 W DEXA machine (original image)*

The lengths of each participant's second digit on the right hand, followed by the second digit on the left hand, were measured. Similarly, the lengths of the fourth digits on both the right and left hands were recorded. In addition, height and weight measurements were taken to calculate each participant's body mass index (BMI).

The relationships between digit ratios and bone mineral density (BMD) were analyzed using various statistical methods. Anthropometric measurement data and DEXA scan results were processed using IBM SPSS Statistics (v.20). To compare the data of two independent groups, an independent samples t-test was conducted to evaluate the significance of differences between group means. Correlation analyses were also performed to assess the relationships between variables, with the level of significance set at 0.05.

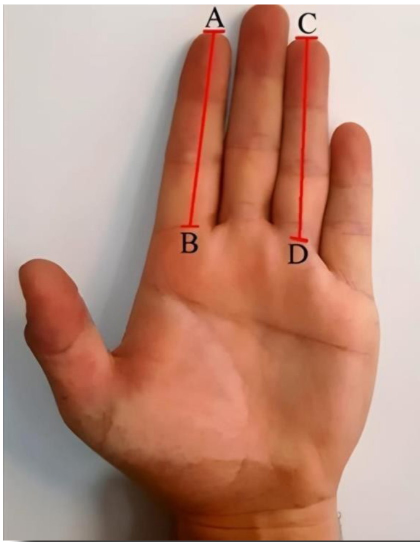

Figure 2: *Digit Length Measurement (original image)* *{[AB]=2.digit length, [CD]=4. digit length ; 2D:4D=[AB]/[CD]}*

Results

When the measurements between the groups were compared, a significant difference was found in both hand digit ratios and second digit lengths ($p < 0.05$). However, the differences in fourth digit lengths between the groups were not statistically significant ($p > 0.05$). Additionally, no significant difference was observed when comparing the ages of individuals in the two groups ($p > 0.05$) (Table 1).

When the digit lengths and digit ratios of men in both groups were compared, significant differences were observed, with the control group showing higher values than the experimental group ($p < 0.05$). Similarly, significant differences were found in digit length measurements and digit ratios among women ($p < 0.05$). However, no significant difference was observed in second digit length measurements between the groups in women (Table 2).

In males, positive correlations were observed between R_2D and L BMD ($r = 0.270$) as well as between R_2D and F BMD ($r = 0.198$). These correlations were statistically significant ($p < 0.05$). Accordingly, as the R_2D measurement increases, the L BMD measurement also increases. However, despite being statistically significant, the strength of these relationships is weak. Similarly, a statistically significant positive correlation ($r = 0.211$) was found between R_2D and L T-score in males ($p < 0.05$) (Table 5).

In females, statistically significant positive correlations were found between R_2D and L BMD ($r = 0.336$), R_2D and L T-score ($r = 0.275$), and R_2D and L Z-score ($r = 0.331$). These relationships indicate that as the R_2D measurement increases, L

Table 1: *Comparison of both groups in terms of age, digit lengths and ratios*

	Groups	N	Mean	s.d.	result
Age	Experimental group	200	55,72	11,17	t=0,95
	Control group	100	54,47	9,68	P=0,343
Right 2D	Experimental group	200	70,7541	4,64280	t=3,04
	Control group	100	72,5154	4,88503	p=0,003*
Left 2D	Experimental group	200	71,1713	4,70172	t=2,13
	Control group	100	72,4267	4,98018	P=0,033*
Right 4D	Experimental group	200	72,4029	4,39380	t=1,40
	Control group	100	73,2298	5,53507	P=0,161
Left 4D	Experimental group	200	72,8848	4,41200	t=0,59
	Control group	100	73,2372	5,68840	P=0,555
Right 2D:4D	Experimental group	200	,9773	,02585	t=4,68
	Control group	100	,9910	,01985	P=0,001*
Left 2D:4D	Experimental group	200	,9765	,02520	t=4,57
	Control group	100	,9898	,02070	P=0,001*

Table 2: *Comparison of both groups in terms of digit lengths and ratios.*

Sex		Group	N	Mean	s.d.	Result
Male	**Right 2D**	Experimental group	100	72,3868	4,28839	t=3,53
		Control group	50	74,9296	3,84814	P=0,001*
	Left 2D	Experimental group	100	72,8521	4,42797	t=2,57
		Control group	50	74,9012	3,93172	P=0,006*
	Right 4D	Experimental group	100	73,5442	4,27142	t=4,77
		Control group	50	76,8952	3,56280	P=0,001*
	Left 4D	Experimental group	100	74,1020	4,34305	t=4,04
		Control group	50	77,0278	3,69752	P=0,001*
	Right 2D:4D	Experimental group	100	,9843	,01793	t=3,69
		Control group	50	,9742	,01018	P=0,001*
	Left 2D:4D	Experimental group	100	,9832	,01850	t=3,81
		Control group	50	,9722	,01161	P=0,001*
Female	**Right 2D**	Experimental group	100	69,1214	4,42192	t=1,25
		Control group	50	70,1012	4,63802	P=0,210
	Left 2D	Experimental group	100	69,4906	4,37285	t=0,59
		Control group	50	69,9522	4,70701	P=0,554
	Right 4D	Experimental group	100	71,2616	4,23431	t=2,23
		Control group	50	69,5644	4,66766	P=0,027*
	Left 4D	Experimental group	100	71,6676	4,15608	t=2,94
		Control group	50	69,4466	4,73083	P=0,004*
	Right 2D:4D	Experimental group	100	,9702	,03034	t=8,50
		Control group	50	1,0078	,01082	P=0,001*
	Left 2D:4D	Experimental group	100	,9698	,02904	t=8,88
		Control group	50	,9722	,01161	P=0,001*

BMD, L T-score, and L Z-score values also increase. However, while these correlations are statistically significant, they remain weak in terms of their strength ($p < 0.05$) (Table 3).

In males, significant positive correlations were identified between L_2D and L BMD ($r = 0.295$), L_2D and L BMD T-score ($r = 0.217$), L_2D and L BMD Z-score ($r = 0.261$), and L_2D and femoral BMD ($r = 0.218$) ($p < 0.05$). These findings indicate that as the L_2D measurement increases, corresponding values for L BMD, femoral BMD, L BMD T-score, and L BMD Z-score also increase. However, despite their statistical significance, these correlations are relatively weak.

Similarly, in females, positive correlations were observed between L_2D and L BMD ($r = 0.352$), L_2D and L T-score ($r = 0.263$), and L_2D and L Z-score ($r = 0.327$), all of which were statistically significant ($p < 0.05$). These results suggest that higher L_2D measurements are associated with increases in L BMD, L T-score, and L Z-score values. As with the males, these correlations, while significant, are considered weak (Table 3).

Table 3: *Comparison of right and left hand second digit lengths and DEXA values of both gender groups.*

Sex			Right 2D	Left 2D
Male	L_BMD	Pearson Correlation	,270*	,295**
		Sig. (2-tailed)	,006	,003
	L_Tscore	Pearson Correlation	,211*	,217*
		Sig. (2-tailed)	,036	,030
	L_Zscore	Pearson Correlation	,254*	,261**
		Sig. (2-tailed)	,011	,009
	F_BMD	Pearson Correlation	,198*	,218*
		Sig. (2-tailed)	,049	,029
	F_Tscore	Pearson Correlation	,077	,112
		Sig. (2-tailed)	,445	,267
	F_Zscore	Pearson Correlation	,091	,130
		Sig. (2-tailed)	,368	,199
Female	L_BMD	Pearson Correlation	,336**	,352**
		Sig. (2-tailed)	,001	,000
	L_Tscore	Pearson Correlation	,275**	,263**
		Sig. (2-tailed)	,006	,008
	L_Zscore	Pearson Correlation	,331**	,327**
		Sig. (2-tailed)	,001	,001
	F_BMD	Pearson Correlation	,124	,150
		Sig. (2-tailed)	,218	,135
	F_Tscore	Pearson Correlation	,065	,074
		Sig. (2-tailed)	,522	,463
	F_Zscore	Pearson Correlation	,086	,100
		Sig. (2-tailed)	,397	,321

No statistically significant relationship was observed between the lengths and ratios of the fourth digits on both the right and left hands and bone mineral density values in both men and women (Table 4).

In males, significant positive correlations were observed between the right-hand digit ratio (R_2D:4D) and bone health indicators, including bone mineral density (BMD), T-scores, and Z-scores in both the lumbar and femoral regions. Specifically, the correlation between R_2D:4D and L BMD was moderate and statistically significant (r = 0.589, $p < 0.05$). Similar significant relationships were found between R_2D:4D and L T-score (r = 0.544, $p < 0.05$) as well as L Z-score (r = 0.454, $p < 0.05$).

Table 4: *Comparison of right and left hand fourth digit lengths and DEXA values of both gender groups*

Sex			Right 4D	Left 4D
Male	L_BMD	Pearson Correlation	,092	,117
		Sig. (2-tailed)	,360	,248
	L_Tscore	Pearson Correlation	,043	,040
		Sig. (2-tailed)	,668	,696
	L_Zscore	Pearson Correlation	,115	,115
		Sig. (2-tailed)	,254	,255
	F_BMD	Pearson Correlation	,012	,022
		Sig. (2-tailed)	,907	,832
	F_Tscore	Pearson Correlation	-,069	-,052
		Sig. (2-tailed)	,496	,607
	F_Zscore	Pearson Correlation	-,023	,001
		Sig. (2-tailed)	,823	,996
Female	L_BMD	Pearson Correlation	-,008	,015
		Sig. (2-tailed)	,935	,881
	L_Tscore	Pearson Correlation	-,129	-,124
		Sig. (2-tailed)	,200	,218
	L_Zscore	Pearson Correlation	-,034	-,025
		Sig. (2-tailed)	,735	,801
	F_BMD	Pearson Correlation	-,110	-,083
		Sig. (2-tailed)	,275	,412
	F_Tscore	Pearson Correlation	-,209*	-,192*
		Sig. (2-tailed)	,037	,051
	F_Zscore	Pearson Correlation	-,170	-,150
		Sig. (2-tailed)	,091	,137

Positive correlations were also observed between R_2D:4D and femoral BMD (r = 0.608, $p < 0.05$), femoral T-score (r = 0.465, $p < 0.05$), and femoral Z-score (r = 0.362, $p < 0.05$). These findings suggest that higher R_2D:4D values in males are associated with increased BMD, T-scores, and Z-scores in both the lumbar and femoral regions, with moderate correlation strength.

In females, similar positive correlations were found between the right-hand 2D:4D ratio and BMD, T-scores, and Z-scores in both the lumbar and femoral regions. The relationship between R_2D:4D and L BMD was particularly strong (r = 0.707, $p < 0.05$), as were the correlations between R_2D:4D and L T-score (r = 0.815, $p < 0.05$) and L Z-score (r = 0.737, $p < 0.05$). Additionally, R_2D:4D was positively correlated with femoral BMD (r = 0.469, $p < 0.05$), femoral T-score (r = 0.535, $p < 0.05$), and femoral Z-score (r = 0.495, $p < 0.05$). These results suggest that higher R_2D:4D values in females are associated with increased BMD, T-scores, and Z-scores in both regions. While statistically significant, these correlations demonstrate moderate strength, consistent with the pattern observed in males.

In conclusion, both male and female participants exhibited significant positive correlations between R_2D:4D ratios and bone health indicators (BMD, T-scores, and Z-scores) across the lumbar and femoral regions. This indicates that higher R_2D:4D values are generally associated with improved bone health markers. While these relationships are statistically significant, the strength of the association remains moderate ($p < 0.05$) (Table 5).

In males, positive correlations were also found between left-hand digit ratios and bone health indicators: L BMD (r = 0.590), L T-score (r = 0.578), L Z-score (r = 0.482), femoral BMD (r = 0.641), femoral T-score (r = 0.521), and femoral Z-score (r = 0.416). All these correlation coefficients indicate that as L_2D:4D values increase, the corresponding values for L BMD, femoral BMD, L T-score, L Z-score, femoral T-score, and femoral Z-score also increase significantly ($p < 0.05$). While statistically significant, these correlations are moderate in strength.

In females, similar positive relationships were observed. Right-hand digit ratios showed significant correlations with L BMD (r = 0.715), L T-score (r = 0.800), and L Z-score (r = 0.733). Additionally, positive associations were noted between L_2D:4D and femoral BMD (r = 0.480), femoral T-score (r = 0.545), and femoral Z-score (r = 0.498). These correlations are also statistically significant ($p < 0.05$), indicating that higher L_2D:4D values are associated with increased values for left and femoral BMD, T-scores, and Z-scores. These relationships show statistical significance and are considered strong in strength (Table 5).

Table 5: *Comparison of right and left hand digit ratios and DEXA values of both gender groups*

Sex			Right 2D:4D	Left 2D:4D
Male	L_BMD	Pearson Correlation	,589*	,590*
		Sig. (2-tailed)	,001	,001
	L_Tscore	Pearson Correlation	,544*	,578*
		Sig. (2-tailed)	,001	,001
	L_Zscore	Pearson Correlation	,454*	,482*
		Sig. (2-tailed)	,001	,001
	F_BMD	Pearson Correlation	,608*	,641*
		Sig. (2-tailed)	,001	,001
	F_Tscore	Pearson Correlation	,465*	,521*
		Sig. (2-tailed)	,001	,001
	F_Zscore	Pearson Correlation	,362*	,416*
		Sig. (2-tailed)	,001	,001
Female	L_BMD	Pearson Correlation	,707*	,715*
		Sig. (2-tailed)	,001	,001
	L_Tscore	Pearson Correlation	,815*	,800*
		Sig. (2-tailed)	,001	,001
	L_Zscore	Pearson Correlation	,737*	,733*
		Sig. (2-tailed)	,001	,001
	F_BMD	Pearson Correlation	,469*	,480*
		Sig. (2-tailed)	,001	,001
	F_Tscore	Pearson Correlation	,535*	,545*
		Sig. (2-tailed)	,001	,001
	F_Zscore	Pearson Correlation	,495*	,498*
		Sig. (2-tailed)	,001	,001

Discussion

Understanding prenatal conditions not only helps predict an individual's physical characteristics but also allows for speculation about potential diseases and behaviors that may manifest later in life (Lee et al., 2021).

One of the primary goals of studies in physical anthropology is to reveal current conditions and interpret them within the framework of causality. Using collected data, physical anthropologists are also tasked with making inferences and predictions about changes that may occur in individuals and/or populations over time. In this context, biomarkers like digit ratios serve as an ideal field of study for modern anthropology (Manning et al., 2021).

Anthropologists make invaluable contributions to the scientific community through their multidisciplinary research, which spans from the past to the present and projects into the future, all grounded in the principle of causality (Manning et al., 2020).

The effects of prenatal conditions on an individual's development and their future life outcomes have long been a subject of curiosity (Galis et al., 2010). While morphological characteristics and anthropometric measurements can be easily obtained during life, new approaches have been proposed to better understand the lasting effects of the prenatal period. These approaches highlight how prenatal influences can shape an individual's traits and health outcomes later in life. One such influence is the effect of prenatal sex steroids, which not only cause various gender-specific differences but also directly impact the development of certain limbs. One of the most extensively studied parameters related to prenatal sex steroids is digit ratios (Hönekopp et al., 2010).

The ratio between the lengths of the 2nd and 4th digits is influenced by prenatal exposure to sex hormones. The length of the 4th digit, which is regulated by testosterone, and the 2nd digit, which is shaped by estrogen, determine the direction in which the digit ratio develops. A low digit ratio is associated with high prenatal testosterone exposure, while a high digit ratio indicates lower prenatal testosterone exposure (Tao et al., 2023).

Osteoporosis is a disease that can occur at any age and carries a significant risk of bone fractures. Fractures caused by osteoporosis can lead to various health complications and, in severe cases, death. Generally, bone mass in women remains stable until menopause. After menopause, however, bone mineral density decreases with age, primarily due to the loss of estrogen. Factors such as family history, gender, and ethnicity also play a role in the structure of bone mass. Additionally, socioeconomic status, diet, and exercise have been shown to influence the development of osteoporosis (Davis et al., 2015).

Given these factors, it has been hypothesized that there may be a relationship between digit ratios—considered an indicator of prenatal androgen exposure—and osteoporosis, a hormonal and metabolic bone disease (Manning et al., 2007). Numerous studies have examined digit ratios in fields like clinical medical sciences, sports sciences, and health sciences.

Digit ratios are influenced by the balance between androgens and estrogens. Low estrogen levels can lead to a reduction in bone mineral density, inducing detrimental changes in bone microarchitecture, which increases the risk of osteoporosis and potentially life-threatening fractures.

When we initially proposed investigating whether digit ratios could serve as an indicator of bone mineral density, there were very few scientific studies addressing this specific topic. However, two years after completing our doctoral thesis on this subject, a study was published examining the relationship between bone mineral density and anthropometric measurements in postmenopausal women. Although some anthropometric parameters showed relationships with bone mineral density, the study found no strong correlation between digit ratio and bone mineral density (Yaman et al., 2024).

The findings of our study present some contradictory results compared to the aforementioned research. It is important to note that these discrepancies may be influenced by factors such as sample size, the exclusion of certain digit measurements, potential measurement errors, and the criteria used for sample selection. We concur with the researchers' suggestion that further studies are necessary to explore the relationships between digit ratios, anthropometric measurements, and bone mineral density.

Conclusion

This research article, derived from the doctoral thesis developed around this approach, aims to expand the role of anthropometric variables beyond traditional functions such as determining age and identity, analyzing variations, and assessing pathologies and to provide additional insights into the contribution of anthropometric characteristics to human health.

Digit ratios are considered a gender-specific trait influenced by both modifiable and non-modifiable factors. The widespread interest in this topic today is not coincidental; digit measurements are a simple, low-cost technique that yields quick, easily analyzable results. With further comprehensive and in depth research on the 2D:4D ratio, digit ratios may become a recognized health parameter in the future, potentially gaining validity as a diagnostic tool.

Similar to studies linking digit ratios with certain metabolic diseases, this study also explores the relationship between digit ratios and bone mineral density. Such studies could help minimize disease risks and contribute to public health by enabling early diagnosis for individuals predisposed to certain conditions.

Contributors

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