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Research Article / Araştırma Makalesi

Evaluation of the Gender Determining Features of Upper and Lower Extremity Morphometric Measurements in the Newborn

Yenidoğanda Üst ve Alt Ekstremite Morfometrik Ölçümlerinin Cinsiyet Belirleyici Özelliklerinin Değerlendirilmesi

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Abstract: Somatometric measurements are frequently used for identification in forensic investigations. In particular, data on the extremities may be needed to determine the age and gender of the dismembered corpse remains as a result of mass disasters. In the literature, the limitations of studies on sex determination in the prepubertal period are frequently mentioned. Therefore, in our study, it was aimed to determine the morphometric measurements of the upper and lower extremities in the neonatal period and to evaluate them in terms of gender determination. The study was conducted on 399 newborns (196 females, 203 males; 326 Turkish, 73 Syrian) newborns with no external anomaly and pathology. Initially, length and width parameters were measured for the upper and lower extremities of the newborns. Subsequently, index values were determined to examine the proportional relationship between the upper and lower extremities The obtained data were evaluated statistically and compared according to gender and groups. According to the results, in the comparison of all parameter and index values obtained from the upper and lower extremities, it was observed that there was no statistically significant difference between the genders, except for the leg/thigh length index. It is thought that the newborn extremity parametric values obtained in the study will contribute to fields such as forensic sciences, fetopathology, anatomy, obstetrics and pediatrics in terms of growth-development and gender determination.

Keywords: Newborn, Gender determination, Morphometry, Upper extremity, Lower extremity.

Öz: Somatometrik ölçümler adli soruşturmalarda kimlik tespitinde sıklıkla kullanılmaktadır. Özellikle kitlesel felaketler sonucu parçalanan ceset kalıntılarının yaşını ve cinsiyetini belirlemek için ekstremitelere ilişkin verilere ihtiyaç duyulabilir. Literatürde ergenlik öncesi dönemde cinsiyet belirlemeye yönelik çalışmaların sınırlılıklarından sıklıkla bahsedilmektedir. Bu nedenle çalışmamızda yenidoğan döneminde üst ve alt ekstremite morfometrik ölçümlerinin belirlenmesi ve cinsiyet tespiti açısından değerlendirilmesi amaçlandı. Çalışma herhangi bir dış anomali ve patolojisi olmayan 399 (196 kız, 203 erkek; 326 Türk, 73 Suriyeli) yenidoğan üzerinde gerçekleştirildi. Bu kapsamda öncelikle yenidoğanın üst ve alt ekstremite uzunluk ve genişlik parametreleri ölçüldü, daha sonra üst ve alt ekstremite arasındaki orantısal ilişkinin incelenmesi amacıyla indeks değerleri belirlendi. Elde edilen veriler istatistiksel olarak değerlendirilerek cinsiyet ve gruplara göre karşılaştırıldı. Sonuçlara göre üst ve alt ekstremiteden elde edilen tüm parametre ve indeks değerleri karşılaştırıldığında bacak/uyluk uzunluğu indeksi dışında cinsiyetler arasında istatistiksel olarak anlamlı bir fark olmadığı görüldü. Çalışmada elde edilen yenidoğan ekstremite parametrik değerlerinin büyüme-gelişme ve cinsiyet tespiti açısından adli bilimler, fetopatoloji, anatomi, kadın doğum ve pediatri gibi alanlara katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Yenidoğan, Cinsiyet tespiti, Morfometri, Üst ektremite, Alt ektremite.

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Introduction

Identification of human remains with impaired body integrity or reduced to skeletal remains is an important part of forensic investigations (Krogman and İscan, 1986; Ubelaker, 2006). The process of determining the gender, age, height, and ethnic origin of a living or deceased individual is referred to as identification. In this identification process, gender, age, and height play a crucial role

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in accurate determination (Scheuer, 2002; Sing et al., 2017). In forensic investigations, the identification of intact human bodies can be easily achieved. However, difficulties arise when attempting to identify fragmented bodies or skeletal parts in mass fatalities. In such cases, anthropometric and somatometric methods are employed (Krogman and İscan, 1986; Scheuer, 2002; Sing et al., 2017).

Gender determination often relies on morphological and metric findings from the skull, pelvis, and extremity bones (Çöloğlu and İscan, 1998; Loth and Henneberg, 2001). Especially in cases of dismembered bodies, the evaluation of structural features and detailed morphometric measurements of the extremities becomes essential for identifying a limb belonging to a specific corpse (Scheuer, 2002; Sing et al., 2017). Additionally, to determine the gender and height of a dismembered body part, somatometric and anthropometric measurements obtained from the extremities of living individuals are needed.

Anatomically, the structure of extremities displays a complex organization. This complexity allows for the formation of individual-specific extremities. The individual-specific shaping of extremities is influenced by various factors, including genetic factors, climate, dietary habits, environmental factors, physical activity, and more. As a result, these factors can lead to differences among societies or between genders within the same society. Metrics measurements play a crucial role in identifying these differences and serve as a guide, especially in forensic investigations and gender-specific anatomical evaluations (Giles and Vallandigham, 1991; Gordon and Buikstra, 1992; Fessler et al., 2005; ; Özden et al., 2005; Kumar et al., 2015).

There are studies that evaluate the parameters of upper and lower extremities at different stages of human development. However, these studies mostly focus on post-pubertal periods, and research on the prepubertal period is limited. The importance of increasing data on prepubertal periods is emphasized in the literature. Therefore, our study aims to assess morphometric measurements of upper and lower extremities in newborns and evaluate their potential for gender determination. Specifically, we have measured general parameters, as well as width and length measurements of upper and lower extremities externally in newborns (0-1 month) and compared them based on gender. The results obtained from this study are expected to be beneficial in various fields, including forensic sciences, anatomy, anthropology, obstetrics, and pediatrics.

Materials and Methods

The research was conducted on 399 (196 female (F), 203 male (M)) newborns (aged between 0 and 1 month) born at the TC Ministry of Health Istanbul Sancaktepe Şehit Prof. Dr. İlhan Varank Education and Research Hospital, with permission obtained from their families. Prior to the research, ethical committee approval was obtained. The study included infants with no external pathology or anomalies. Newborn measurements were taken considering bone reference points that can be externally detected.

In this study, morphometric parameters of the upper and lower extremities of the newborns were measured. Subsequently, the index values mentioned below were calculated to examine the proportional relationship between the upper and lower extremities. The measurements were taken using a tape measure, plastic ruler, anthropometric set, and a digital caliper sensitive to 0.01 mm. The study involved measuring various parameters of the upper and lower extremities in newborns. The measurements and index values used in the study are as follows:

Upper Extremity Parameters:

Arm length: Distance between the shoulder (acromion) and elbow (olecranon midpoint).

Forearm length: Distance between the elbow (olecranon midpoint) and wrist (styloid process of the radius).

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Hand length: Vertical distance between the outer edges of the distal radius and ulna (styloid processes) and the tip of the middle finger.

Hand width: Transverse distance between the outer edges of the hand at the level of the second and fifth metacarpophalangeal joints.

Hand digit lengths: Distances between the midpoints of the metacarpophalangeal joints and the distal tips of 1st, 2nd, 3rd, 4th and 5th fingers.

Upper Extremity Index Values:

Forearm/Arm Index: Forearm Length/Arm Length x 100

Hand/Arm Index: Hand Length/Arm Length x 100

Hand Index: Hand Width/Hand Length x 100

Lower Extremity Parameters:

Femur length: Vertical distance between the greater trochanter and the midpoint of the knee joint.

Leg length: Distance between the midpoint of the knee joint and the lower end of the lateral malleolus of the fibula.

Foot width: Transverse distance between the outer edges of the foot at the level of the first and fifth metatarsophalangeal joints.

Plantar length: Distance between the midpoint of the digitopalmar crease and the furthest point on the back of the heel.

Foot digit lengths: Distances between the midpoints of the metatarsophalangeal joints and the distal tips of 1st, 2nd, 3rd, 4th and 5th toes.

Lower Extremity Index Values:

Leg/Femur Index: Leg Length/Femur Length x 100

Foot/Leg Index: Plantar Length/Leg Length x 100

Foot Index: Foot Width/Plantar Length x 100

Additionally, the 2D:4D, 2D:5D, 3D:4D, 3D:5D, and 4D:5D ratios were calculated for both the hands and feet. These ratios involve comparing the lengths of the second, third, fourth, and fifth fingers or toes in relation to each other.

Statistical Analysis

The data analysis was performed using the statistical package program SPSS 20.0 in the Windows environment. Mean and standard deviation of all parameters were determined for each gender. In the statistical evaluation, a significance level of $p<0.05$ was considered. For parametric data, gender-based comparisons were conducted using the Student's t-test.

Results

In the study, measurements were conducted on a total of 399 newborns, including 196 females and 203 males, who had no external pathologies or anomalies. Among the female newborns, 167 were Turkish and 30 were Syrian refugees, while among the male newborns, 159 were Turkish and 43 were Syrian refugees.

The upper and lower extremity parameter measurements were statistically evaluated based on groups and gender, and their mean and standard deviations were determined ($p>0.05$; Table 1, Table 2, Table 3). Subsequently, the mean and standard deviations of the index values related to the upper and lower extremities were determined ($p>0.05$; Table 1, 2, 3, 4 Figure 1, 2, 3, 4).

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Table 1. Mean and standard deviation of upper extremity parameters from newborns of Turkish and Syrian according to gender (mm).

Gender	Case (N)	Arm length	Forearm length	Hand length	Hand width	Forearm/Arm ındex	Hand/Arm ındex	Hand ındex
Turkish F (Mean±SD)	167	79,66±1,17	67,29±1,29	63,65±1,12	30,84±1,28	84,49±1,98	79,92±1,80	48,47±2,13
Syrian F (Mean±SD)	30	79,73±0,94	66,87±1,28	63,40±1,13	31,07±1,05	83,87±1,82	79,52±1,57	49,02±1,87
Total F (Mean±SD)	196	79,66±1,14	67,25±1,26	63,61±1,12	30,88±1,25	84,43±1,91	79,87±1,77	48,55±2,10
Turkish M (Mean±SD)	159	79,78±1,14	67,22±1,32	63,74±1,08	30,94±1,16	84,27±2,03	79,90±1,66	48,56±2,08
Syrian M (Mean±SD)	43	79,74±1,14	67,26±1,16	63,51±1,14	31,02±1,14	84,36±1,89	79,66±1,75	48,86±1,95
Total M (Mean±SD)	203	79,78±1,14	67,21±1,32	63,69±1,09	30,96±1,15	84,26±2,04	79,85±1,68	48,62±1,04
Total F+M (Mean±SD)	399	79,72±1,14	67,23±1,29	63,65±1,11	30,92±1,20	84,35±1,98	79,86±1,72	48,59±2,07

There were no significant difference between genders in totaly and within groups (p>0.05). F: female, M: male.

Table 2. Mean and standard deviation of lower extremity parameters from newborns of Turkish and Syrian according to gender (mm).

Gender	Case (N)	Femur length	Leg length	Plantar length	Foot width	Leg/Femur ındex	Foot/Leg ındex	Foot ındex
Turkish F (Mean±SD)	167	99,30±1,57	94,31±1,27	59,95±1,33	30,13±1,03	95,00±1,90	60,39±162	50,28±1,95
Syrian F (Mean±SD)	30	99,47±1,53	94,73±0,91	60,17±1,12	29,87±0,86	95,26±1,55	60,50±1,32	49,65±1,54
Total F (Mean±SD)	196	99,30±1,52	94,39±1,22	59,99±1,30	30,10±1,01	95,07±1,80	60,43±156	50,18±1,90
Turkish M (Mean±SD)	159	99,01±1,40	94,60±1,22	59,97±1,29	30,12±1,25	95,57±1,82	60,58±1,53	50,24±2,24
Syrian M (Mean±SD)	43	99,19±1,01	94,53±1,12	60,26±1,31	30,02±1,44	95,32±1,43	60,76±156	49,86±2,79
Total M (Mean±SD)	203	99,07±1,37	94,58±1,21	60,02±1,30	30,09±1,29	95,48±1,81	60,60±1,55	50,17±2,14
Total F+M (Mean±SD)	399	99,18±1,45	94,48±1,22	60,01±1,30	30,10±1,16	95,28±1,81	60,51±1,56	50,17±2,15

There were no significant difference between genders in totaly and within groups, (p>0.05) (except for Leg/Femur ındex, differences between genders in totally, p=0,24) F: female, M: male.

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Table 3. Mean and standard deviation of finger and toe length parameters from newborns of Turkish and Syrian according to gender (mm).

Gender	Case (N)	1st digit length	2nd digit length	3rd digit length	4th digit length	5th digit length
Hand						
Turkish F (Mean±SD)	167	27,65±1,14	29,38±1,14	30,13±1,03	31,98±1,34	28,10±1,44
Syrian F (Mean±SD)	30	27,53±1,17	29,10±1,12	29,87±0,86	31,80±0,61	28,03±1,94
Total F (Mean±SD)	196	27,64±1,14	29,33±1,14	30,10±1,01	31,95±1,26	28,09±1,52
Turkish M (Mean±SD)	159	27,56±1,14	29,28±1,20	30,12±1,25	31,97±1,07	28,02±1,37
Syrian M (Mean±SD)	43	27,51±1,20	29,09±1,11	30,02±1,44	31,70±1,12	27,72±0,83
Total M (Mean±SD)	203	27,54±1,15	29,25±1,18	30,09±1,29	31,91±1,08	27,96±1,27
Total F+M (Mean±SD)	399	27,59±1,15	29,29±1,16	30,10±1,16	31,93±1,17	28,02±1,40
Foot						
Turkish F (Mean±SD)	167	17,44±0,61	14,57±0,58	14,40±0,59	13,76±0,38	13,70±0,32
Syrian F (Mean±SD)	30	17,56±0,67	14,57±0,57	14,61±0,51	13,80±0,37	13,65±0,26
Total F (Mean±SD)	196	17,46±0,62	14,57±0,58	14,44±0,58	13,77±0,38	13,69±0,31
Turkish M (Mean±SD)	159	17,46±0,59	14,55±0,57	14,36±0,59	13,77±0,37	13,66±0,32
Syrian M (Mean±SD)	43	17,35±0,57	14,52±0,57	14,38±0,56	13,79±0,32	13,65±0,30
Total M (Mean±SD)	203	17,43±0,59	14,54±0,57	14,36±0,59	13,77±0,36	13,65±0,31
Total F+M (Mean±SD)	399	17,45±0,61	14,55±0,57	14,40±0,58	13,77±0,37	13,67±0,31

There were no significat difference between genders in totaly and within groups (p>0,05). F: female, M: male.

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Table 4. Mean and standard deviation of finger and toe ratios from newborns of Turkish and Syrian according to gender.

Gender	Case (N)	2D:4D ratio	2D:5D ratio	3D:4D ratio	3D:5D ratio	4D:5D ratio
Hand						
Turkish F (Mean±SD)	167	0,92±0,05	1,05±0,07	0,95±0,05	1,07±0,06	1,14±0,07
Syrian F (Mean±SD)	30	0,92±0,04	1,04±0,07	0,94±0,03	1,07±0,07	1,14±0,06
Total F (Mean±SD)	196	0,92±0,04	1,04±0,04	0,94±0,04	1,07±0,06	1,14±0,05
Turkish M (Mean±SD)	159	0,92±0,04	1,05±0,06	0,94±0,05	1,08±0,06	1,14±0,06
Syrian M (Mean±SD)	43	0,92±0,05	1,05±0,05	0,95±0,06	1,08±0,06	1,14±0,05
Total M (Mean±SD)	203	0,91±0,04	1,04±0,05	0,94±0,05	1,07±0,06	1,14±0,05
Total F+M (Mean±SD)	399	0,92±0,05	1,05±0,06	0,95±0,05	1,08±0,06	1,14±0,06
Foot						
Turkish F (Mean±SD)	167	1,06±0,05	1,06±0,05	1,05±0,05	1,05±0,05	1,01±0,04
Syrian F (Mean±SD)	30	1,06±0,05	1,07±0,05	1,06±0,05	1,07±0,04	1,01±0,03
Total F (Mean±SD)	196	1,06±0,04	1,06±0,04	1,04±0,05	1,05±0,05	1,00±0,03
Turkish M (Mean±SD)	159	1,06±0,05	1,07±0,05	1,04±0,05	1,05±0,05	1,01±0,04
Syrian M (Mean±SD)	43	1,05±0,05	1,06±0,05	1,04±0,05	1,05±0,05	1,01±0,03
Total M (Mean±SD)	203	1,05±0,05	1,06±0,04	1,04±0,04	1,05±0,04	1,00±0,03
Total F+M (Mean±SD)	399	1,06±0,05	1,07±0,05	1,05±0,05	1,05±0,05	1,01±0,04

There were no significant difference between in totally and within the groups with respect to genders (p>0,05). F: female, M: male.

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Discussion

The structure of the extremities is a complex organization formed by the ideal alignment of bones, muscles, and joints from an anatomical perspective. This structure enables the formation of unique hand and foot shapes specific to individuals. Anthropometric or somatometric measurements are taken to reveal these differences and determine the intersexual variations within the community. Moreover, these measurements are essential for obtaining population-specific data and identifying differences between populations. This is particularly significant for forensic sciences in guiding forensic identification (Giles and Vallandigham, 1991; Fessler et al., 2005; Özden et al., 2005; Kumar et al., 2015).

The most critical elements in identity determination are age, gender, race, and height (Krogman and İscan, 1986; Ubelaker, 2006). Gender determination is a crucial and foremost criterion in identifying an individual. In forensic applications, rapid identification of the probable gender of a decomposed body or body part is expected (Mall et al., 2001). Gender determination is often considered one of the simplest tasks in forensic analysis because external and internal genital organs can directly determine an individual's gender. However, in intersex cases, highly decomposed bodies, mutilated, fragmented, and skeletal remains, gender differentiation becomes complex (Kanchan and Krishan, 2011). Therefore, in cases where gender cannot be determined from primary anatomical structures, anthropometric or somatometric methods are employed (Krogman and İscan, 1986; Gupta et al., 2017).

The emergence of DNA technology in forensic investigations has significantly simplified gender determination. However, this technology may not be a reasonable option for identifying the identity of bodies that have been fragmented or whose body integrity has been compromised in mass disaster incidents like natural disasters, transportation accidents, wars, terrorism, and bombings. DNA technology, especially in developing countries and cases where DNA analysis is not feasible, may have limitations concerning qualified human resources, time, and financial resources. Therefore, the development of alternative methods is essential (Scheuer, 2002; Kanchan and Krishan, 2011; Sing et al., 2017).

In forensic investigations, gender determination is sometimes made using extremity bones if necessary (Çöloğlu and İscan, 1998; Loth and Henneberg, 2001). Additionally, alternative studies have been conducted to determine the gender of a fragmented body based on the available parts in cases of mass deaths. These studies utilize hand measurements, arm length, leg length, and foot measurement data obtained from living individuals to identify the gender of the body (İris and Celbiş, 2003; Jasuja and Singh, 2004; Sanlı et al., 2005; Krishan and Sharma, 2007; Sahni et al., 2010; Agnihorti et al., 2011).

There are studies evaluating upper and lower extremity parameters at different stages of human development. However, studies specifically focusing on morphometric parameters of both upper and lower extremities in the newborn period are relatively rare. In this study, unlike previous research, a wide range of newborns was included, and both upper and lower extremity parameters were evaluated morphometrically together. Additionally, the fact that the measurement series consisted of newborns from both Turkish and Syrian backgrounds allowed for the comparison of different ethnic groups.

In previous studies, it has been suggested that the development of the urogenital system and external genitalia, as well as extremity development, may reflect differences in prenatal androgen exposure (Kondo et al., 1997; Ernsten et al., 2021; Goodman, 2002; McIntyre, 2006). Sex hormones such as androgens and estrogens at a genetic level support the phenotypic differentiation of males and females secondarily. However, it is worth noting that these studies have mainly focused on either the prenatal period or the postnatal period after puberty. Studies covering the prenatal period emphasize the significance of prenatal androgen exposure in determining gender-specific outcomes, while studies covering the postnatal

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period after puberty highlight the role of activated gonadal hormones in gender differentiation (Ernsten et al., 2021). It is particularly emphasized that reliable observations of gender differences can be made during adolescence when puberty starts. However, there are very few studies focused on the prepubertal period.

One of the phenotypic differences between males and females is related to the hands. Generally, males have longer fingers and broader and longer hands compared to females (Amirsheybani et al., 2001). Therefore, hands and fingers tend to show sexual dimorphism as a reflection of prenatal androgen exposure (Ernsten et al., 2021). There are studies covering the prenatal period related to this assumption (Malas et al., 2006, 2008). However, no significant gender differences in hand length, hand width, and hand index values have been observed during the fetal period (Malas et al., 2006, 2008). Even in prepubertal children, no differences in hand size between genders have been observed (Raziye et al., 2016; Ernsten et al., 2021).

However, it is noted that most of the studies in the literature related to hand and finger measurements are conducted on adult samples, and there are very few studies that include preadolescent individuals (Cohen-Bendahan et al., 2005; Arnold, 2009; Kanchan and Rastogi, 2009; Hönekopp and Watson, 2010; Krishan et al., 2011; Jowaheer and Agnihotri, 2011; Manning, 2012).

Kanchan and Rastogi, (2006) conducted evaluations on hand length and width measurements in an adult population and reported gender classification accuracy rates ranging from 81.7% to 91.9%. They especially emphasized that hand width is generally the strongest dimorphic measurement (Kanchan and Rastogi, 2009). Jowaheer and Agnihotri, (2011) used multiple regression models to investigate the gender identification potential of hand length and found that 91.2% of adult individuals were correctly classified by gender for both their right and left hands (Jowaheer and Agnihotri, 2011). Krishan et al., (2011) determined gender biases at rates of 79.5% for hand width and 86.0% for hand length using hand width and length measurements, and they mentioned that hand width is more dimorphic than hand length (Krishan et al., 2011).

One of the phenotypic differences between genders is the feet. A literature review indicates that fetal feet have a characteristic normal growth pattern and show gradual length increase relative to the embryo's length, which can be used to estimate gestational age (Kumar and Kumar, 1993). Besides determining gestational age, foot length parameter also appears as an alternative parameter in detecting fetal pathologies. Kumar and colleagues have shown that fetal hands and feet also have a characteristic normal growth model, and they propose that fetal hand and foot length can be used to estimate gestational age (Kumar and Kumar, 1993).

In our study, the mean and standard deviations of length and width parameters of upper and lower extremities of newborns were determined according to gender (Table 1, 2). According to the results obtained in our study, there were no significant differences between genders in the length and width parameters of all newborn upper extremities ($p>0.05$; Table 1). Similarly, when evaluated according to gender within the same nationality (male-female), no significant gender differences were found, and when comparing the same genders in both nationalities (female-female, male-male), there were no significant differences in terms of nationality ($p>0.05$; Table 1).

Regarding the evaluation of lower extremity length and width parameters, there was only a significant gender difference in foot length ($p=0.04$) among all newborns, while no other lower extremity parameters showed significant differences ($p>0.05$; Table 2). In the comparison of Turkish and Syrian newborns' lower extremity parameters (female-female, male-male), no significant differences were found between Turkish female and male newborns, except for leg length ($p=0.03$), and no differences were found in any

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lower extremity parameter between Syrian female and male newborns (p>0.05; Table 2). Moreover, there were no statistically significant differences in any lower extremity parameter between male and female newborns of different nationalities (p>0.05; Table 2).

In the literature, hand and foot index values are frequently mentioned as potential indicators for determining gender. Studies conducted on postpubertal individuals in different age groups suggest that the index values obtained from hand and foot length and width measurements can be effective in determining gender. Gupta et al., (2017) conducted a study on 300 adults (150 females, 150 males) and performed hand and foot measurements and index calculations. They found that hand length and width were larger in males compared to females. Similarly, they noted that hand index values were also greater in males than in females. Moreover, they reported that foot length and width were greater in males than in females, and the foot index was also larger in males. Therefore, it was emphasized that both hand and foot length, width, and index values can be used as gender determinants (Gupta et al., 2017; Ernsten et al., 2021).

In studies conducted during the prepubertal period, similar results were not observed. Ernstein et al., (2021) measured hand width, length, and index in 6-month-old infants (364 females, 399 males). According to the results obtained, average hand width and length values were reported to be larger in males. Additionally, hand index values were compared between genders, and no significant difference was found between the hand indices of boys and girls (Ernsten et al., 2021). Malas et al., (2008) conducted a study on newborns, including 60 infants (30 females, 30 males), and reported that average hand length and width did not show statistically significant differences between boys and girls (Malas et al., 2008).

In the current study, the mean values of extremity parameters were obtained from newborns. When comparing these values, a significant gender difference was found in the leg/thigh index in all newborns (p=0.24) and in Turkish newborns (p=0.06). However, no statistically significant differences were observed in other index values between the same genders within the same nationality and between the same genders of different nationalities (female-female, male-male) (p>0.05; Table 1, 2; Figure 1, 2). The results of the hand index in our study are consistent with other studies that cover the prepubertal period. According to the obtained results, hand and foot length, width, and index values were not determinative for gender identification in the newborn period. However, it is suggested that leg/thigh index values may be decisive for gender determination during the prepubertal period and should be supported by new studies with larger sample sizes.

The second to fourth digit ratio (2D:4D) is one of the most debated indicators in the literature, known to differ between males and females. In these studies, it has been proposed that males have a lower 2D:4D ratio compared to females (Gordon et al., 1991; Patriquin et al., 2005; Krishan et al., 2011). It has been emphasized that this gender difference in the ratio can be detected from the 14th week of pregnancy, but may vary over time (Knickmeyer et al., 2011; Wong and Hines, 2016). Besides the 2D:4D ratio, the proportional evaluation of the fingers, including the fifth finger, has also been suggested to be an alternative for gender determination (McIntyre et al., 2006; Dressler and Voracek, 2011; Kumar et al., 2017). On the other hand, a study on children between the ages of 2 and 18 has stated that evaluations other than the 2D:4D ratio may not be reliable indicators (Manning, 2012). However, it is crucial to consider the variations in study designs and measurement techniques in these studies while comparing and interpreting the results (Aboul-Hagag et al., 2011; Kanchan and Krishan, 2011). Research on sexual dimorphism in finger lengths has revealed that males tend to have longer fourth and fifth fingers, while females have longer second and third fingers (Loehlin et al., 2009; Stenstrom

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et al., 2011). As evident from the literature, there are numerous studies supporting the assumption that hand and finger measurements reflect sexual dimorphism. The literature contains limited studies specifically focusing on hand and finger lengths as well as foot and toe lengths in prepubertal individuals (Malas et al., 2008; Ernsten et al., 2021). Hence, comparing the data obtained in our study poses some challenges.

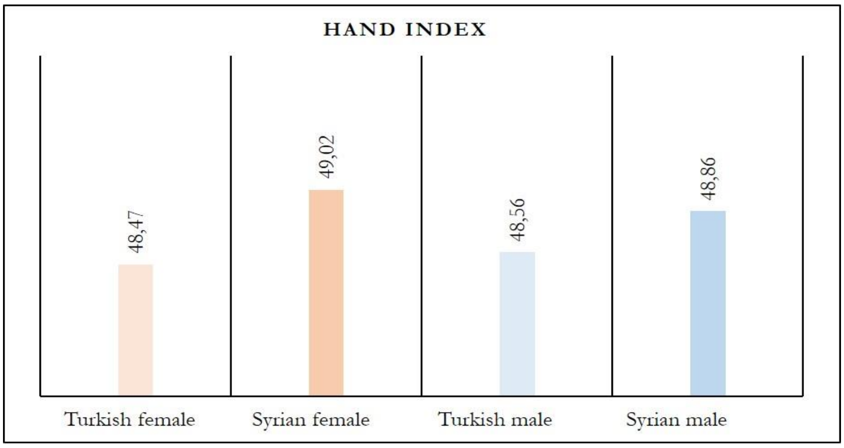

Figure 1. Hand index values in Turkish female and male newborns and Syrian female and male newborns.

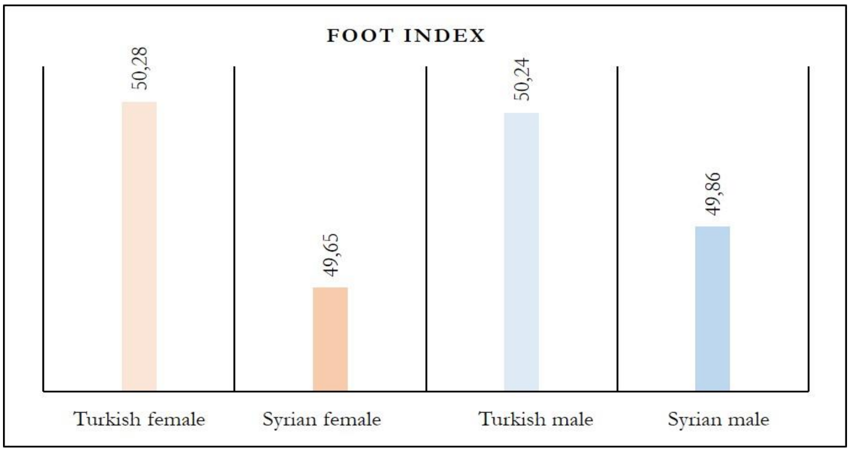

Figure 2. Foot index values in Turkish female and male newborns and Syrian female and male newborns.

In the present study, hand and foot finger lengths were evaluated. A thorough review of the literature indicates that finger lengths, and even the proportional relationships between fingers, have been frequently emphasized as indicators for gender determination. Studies suggest that phalangeal lengths grow faster in boys (Butovskaya et al., 2021). Particularly in prepubertal children, finger lengths tend to be longer in girls compared to boys, while the 2D:4D ratio shows the expected sexual dimorphism (men < women) (Manning and Fink, 2018). However, after the age of 13, sexual dimorphism in finger lengths becomes more pronounced, with boys having longer finger lengths than girls. In another study, it was observed that initially girls tend to have longer phalanges than boys, but around the age of 13, both sexes reach approximately equal phalangeal lengths (Butovskaya et al., 2021).

In the literature, it has been indicated that finger growth in males continues even after the age of 18.

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Therefore, finger length values between the ages of 20 to 30 are considered to be important in terms of gender differences. However, despite the periodic variations in phalangeal lengths in terms of gender, the ratio of phalangeal lengths to each other remains relatively constant. Studies suggest that gender differences in 2D:4D are not related to finger lengths, and the sexual dimorphism in 2D:4D remains stable (Butovskaya et al., 2021). In the study conducted by Malas et al., (2008), it was reported that 2nd and 4th finger length measurements did not show gender differences, but the 2D:4D finger ratio exhibited sexual dimorphism (men < women) (Malas et al., 2008).

In our study, first, finger lengths of hands and feet were statistically evaluated, and no significant differences were found between male and female genders in all newborns ($p>0.05$; Table 3,4). Comparisons were made between same-gender newborns within the same ethnicity and between different genders within different ethnic groups, and similarly, no statistically significant differences were found ($p>0.05$; Table 3,4).

Studies in the literature have not only focused on the 2D:4D finger ratio but also explored the ratios of other fingers. Particularly, the relationship of the 5th finger with other fingers has been suggested to be effective in gender determination. In the study conducted by Ernsten et al. (2021), the ratios of all fingers except the thumb were examined, and they found that males had larger finger ratios compared to females. Additionally, besides the 2D:4D ratio, significant differences were observed in other finger ratios, such as 2D:3D, 2D:5D, 3D:4D, 3D:5D, and 4D:5D, between male and female infants. In the same study, relative finger lengths were emphasized as potential gender determinants (Ernsten et al., 2021). In our study, we measured finger ratios and for both hands and feet as defined in the literature. However, no statistically significant differences were found in finger ratios between male and female newborns and between Turkish and Syrian groups ($p>0.05$; Table 3,4; Figure 3, 4).

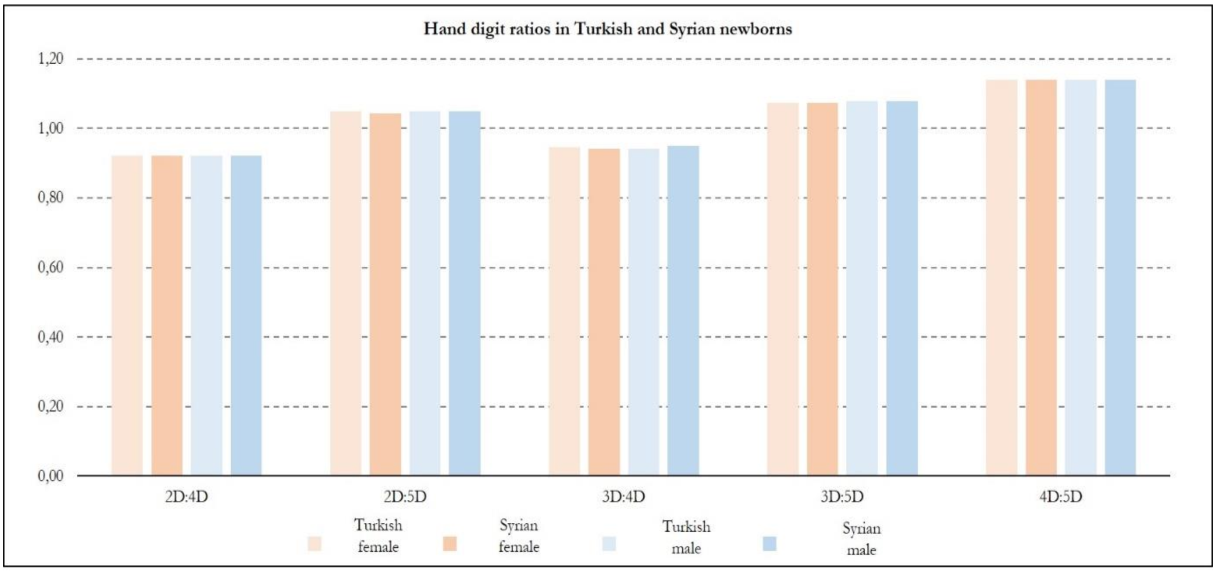

Figure 3. Hand digit ratios in Turkish female and male newborns and Syrian female and male newborns.

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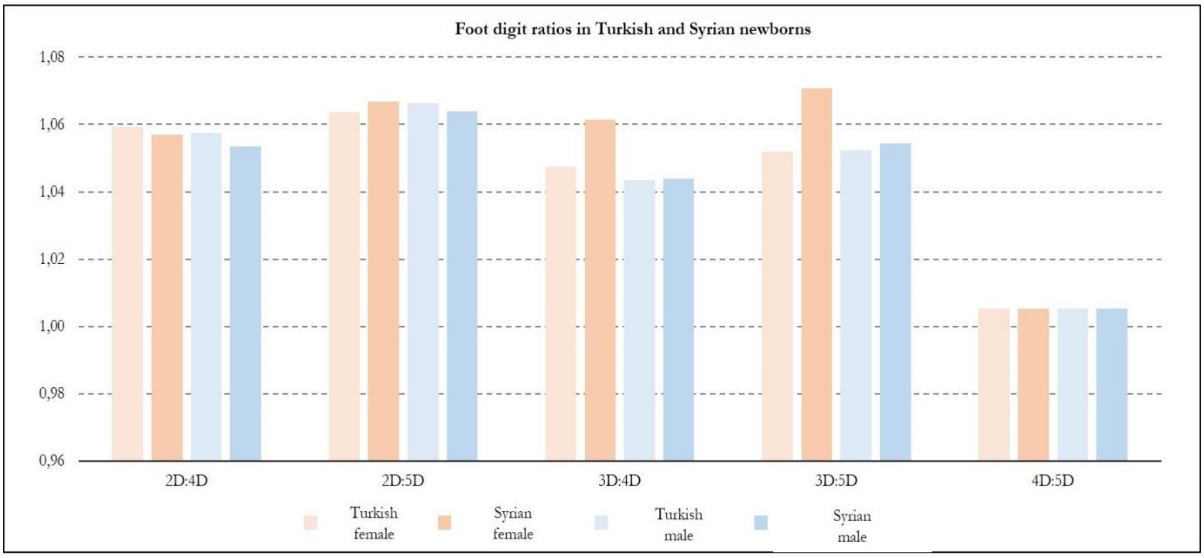

Figure 4. Foot digit ratios in Turkish female and male newborns and Syrian female and male newborns.

As a result, there are several studies evaluating upper and lower extremity parameters at different stages of human development. In these studies, somatometric or radiological methods were used to examine the upper and lower extremities of adults. In addition, finger, hand and foot measurements were evaluated in different age groups according to gender. However, studies focusing on newborns (0-1 months) in this developmental period are insufficient. İn our study upper and lower extremities, especially hand and foot region measurements on 399 newborns were examined according to gender. In particular, the fact that the sample group consisted of both Turkish and Syrian newborns enabled the comparison of ethnic groups. Although our findings partially overlap with previous studies, they also reveal some differences. These differences can be attributed to variation in sample size or differences in measurement techniques. We believe that the results obtained in our study will contribute to forensic sciences as well as anatomy, gynecology and pediatric sciences and will be a guiding reference for future research. Further work in this area is necessary to improve our understanding of limb development in newborns and its implications in different fields of medicine and science.

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