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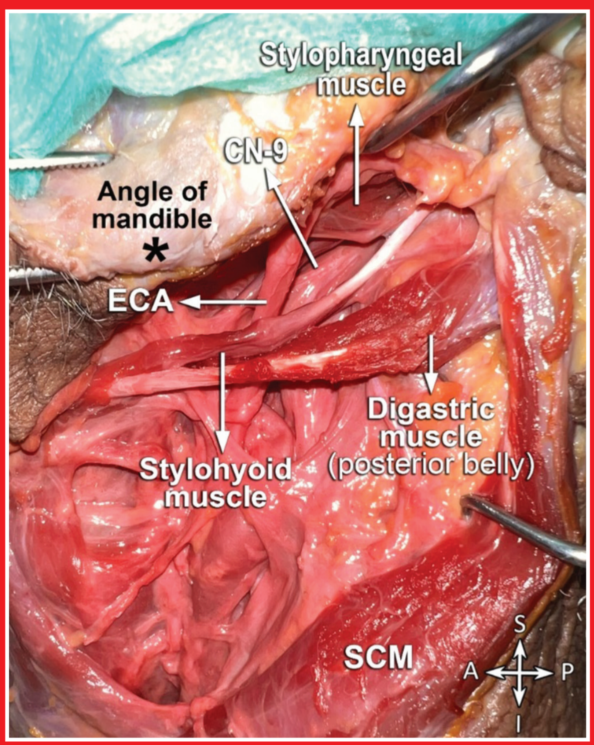

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Importance of an unclear fascial layer, stylopharyngeal fascia: an anatomical study

Pelin Samaraz Olgun[1], Aybegüm Balcı[2], Halil İbrahim Açar[2]

[1]*Department of Anatomy, Graduate School of Health Sciences, Ankara University, Ankara, Türkiye*
[2]*Department of Anatomy, Ankara University Faculty of Medicine, Ankara, Türkiye*

Abstract

Objectives: The stylopharyngeal fascia is an important anatomical structure; however, its exact location and relationship with other neighboring structures have not been clearly demonstrated. Therefore, our aim was to reveal the stylopharyngeal fascia to demonstrate its course and neurovascular relationship in the parapharyngeal space.

Methods: Ten fresh frozen cadaveric necks were dissected through a transparotideal and transcervical approach extending to the parapharyngeal region. All the neurovascular structures and muscles were preserved to demonstrate the stylopharyngeal fascia.

Results: The stylopharyngeal fascia was mostly found on the lateral aspect of the internal carotid artery and could be found by advancing into the plane between the posterior belly of the digastric and stylohyoid muscles at the parapharyngeal space borders. The stylopharyngeal fascia covered not only the parapharyngeal segment of the internal carotid artery but also the cranial nerves X–XII at the parapharyngeal space. The cranial nerve IX coursed laterally to this fascial structure, posterior to the stylopharyngeus muscle in the parapharyngeal space.

Conclusion: Although the stylopharyngeal fascia was previously shown to be related to other neurovascular structures, its anatomical course and histology remain unclear. Moreover, the stylopharyngeal fascia was defined using different nomenclatures in different studies. In this study, the stylopharyngeal fascia was shown to be an important anatomical landmark for dissection at the border of the parapharyngeal space. Further studies investigating its histological structure and defining its proper nomenclature are required. Therefore, we propose the term "parapharyngeal fascia".

Keywords: internal carotid artery; parapharyngeal space; stylopharyngeal fascia

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Introduction

The parapharyngeal space (PPS) is a fascial compartment located in the suprahyoid region of the neck and is surrounded by various important fascial spaces. It is a complex structure that resembles an inverted pyramid, with its superior base at the skull base and inferior apex at the greater horn of the hyoid bone.[1] Inside this complex anatomical compartment located laterally to the pharynx, the cranial nerves IX–XII, cervical sympathetic trunk, internal jugular vein, internal carotid artery, deep lobe of the parotid gland, and lymph nodes are situated.[2–4]

This area, which houses deep-seated and highly significant neurovascular structures, is of great importance in head and neck surgical practice for interventions related to infectious, tumoral, and trauma-related pathologies.[5] Tumors located in this area constitute approximately 0.5% to 1% of head and neck cancers and are primarily treated surgically.[6] Surgery for pathologies located in the parapharyngeal space is challenging because of the potential damage that may occur in the adjacent neurovascular structures. The risk of complications associated with neurovascular structures after surgery is reportedly between 55% and 75%.[7]

The PPS is traditionally divided into prestyloid and poststyloid compartments, and the presence of different anatomical structures within these compartments is important for approaching pathologies in this area.[3] The

This study was an oral presentation at the joint congress of EACA and ISCAA; it is the 17th Congress of the European Association of Clinical f.Anatomy and the XIV Symposium of Clinical and Applied Anatomy, 14th–17th September 2023, Prague, Czech Republic.

deep lobe of the parotid gland and adipose tissue are located in the prestyloid compartment, whereas the internal carotid artery (ICA), internal jugular vein (IJV), sympathetic trunk and cranial nerves IX–XII are present in the poststyloid compartment.[8] The division of the PPS into anterolateral (prestyloid) and posteromedial (retrostyloid) spaces by the stylopharyngeal fascia (SPF) is crucial for understanding its detailed anatomy and clinical relevance.[9]

According to an anatomical study, SPF covers the parapharyngeal segment of the ICA, IJV, and cranial nerves IX–XII. By incising this fascia, the parapharyngeal segment of the ICA was revealed.[10] Through detailed exploration, we aim to provide further insights into the anatomy of the SPF to facilitate clinical applications and surgical procedures in this challenging region.

Materials and Methods

Ten neck regions of five fresh frozen cadavers were meticulously dissected at the Anatomy Department of Ankara University Faculty of Medicine. A modified Blair incision was made extending to the midline of the neck and 3 cm below the mandible. After the skin incision, a subplatysmal flap was raised. Routine superficial parotidectomy was performed and the main trunk of the facial nerve was identified.

After the sternocleidomastoid muscle and posterior belly of the digastric muscle were identified, an incision was made through the anterior border of the investing fascia of the sternocleidomastoid muscle. The posterior belly of the digastric muscle was then seen on the same plane as the stylohyoid muscle, and the surface of the fascial plane between these two muscles was dissected. At the point where the fascial plane reached the carotid sheath, the carotid sheath was opened and structures such as IJV, vagal nerve, and ICA were identified. Hypoglossal nerve was observed on the lateral aspect of the external carotid artery (ECA). Branches of the ECA and accessory nerve located deep in the fascial plane were dissected. After following the stylohyoid muscle, the styloid process was palpated. Dissection was advanced into the PPS using the described SPF. The fascial plane was followed by to the stylopharyngeus muscle. In this area, glossopharyngeal nerve and adipose tissue was identified.

Results

After identifying the posterior belly of the digastric and stylohyoid muscles, the fascial plane was seen to continue between these two muscle (**Figure 1**). This fascia was attached to the carotid sheath inferiorly and extended superiorly to the skull base. Moreover, this fascial structure extended from the posterior aspect of the styloid process to the posterior border of the stylopharyngeus muscle. On the surface of this facial compartment, anterior to the styloid process, the fatty tissue of the parapharyngeal space was observed.

In this region, the cranial nerves X–XII originated from the skull base and the parapharyngeal segment of the ICA and IJV was covered by this fascial plane. The parapharyngeal segment of the ICA was located in the deepest position compared to the other neurovascular structures mentioned. In all cadavers, the glossopharyngeal nerve coursed lateral to the fascial plane posterior to the stylopharyngeus muscle (**Figures 2** and **3**).

In addition, the occipital artery and ascending pharyngeal artery, which are posterior branches of the ICA, were also observed to be covered by this fascia. Dissection was advanced along this fascial plane, and as we proceeded medially along the fascial plane, we demonstrated that the SPF enveloped not only the parapharyngeal segment of the ICA, but also the cranial nerves X–XII within the PPS (**Figure 4**).

Discussion

The traditional division of the PPS has been analyzed in different studies using different nomenclature. The presthyloid compartment contains the retromandibular part

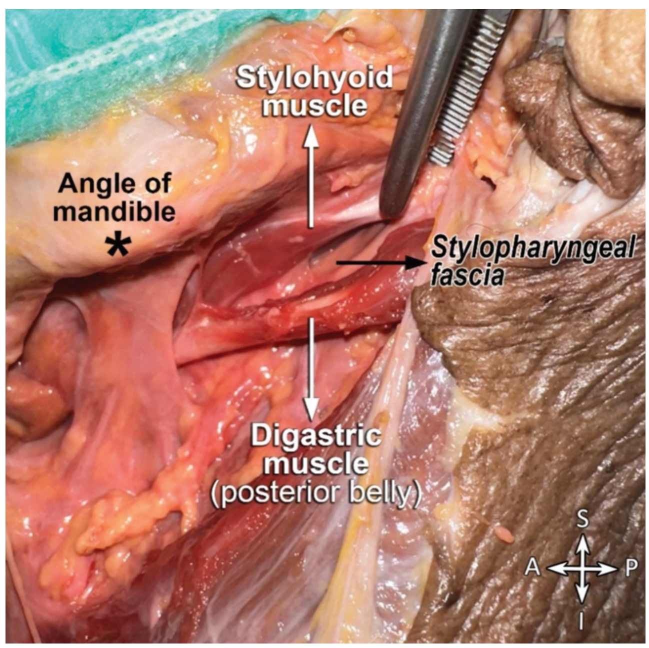

Figure 1. Stylopharyngeal fascia between stylohyoid and posterior belly of digastric.

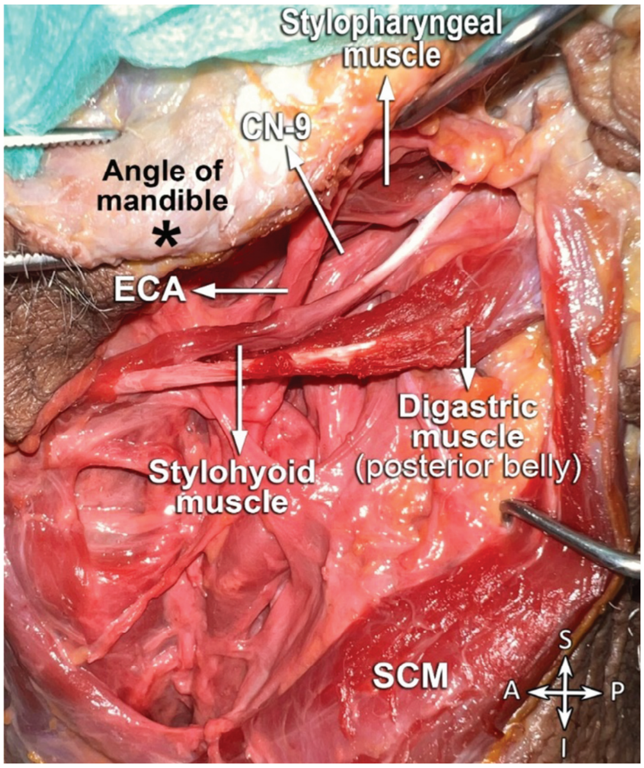

Figure 2. Glossopharyngeal nerve on the lateral aspect of the fascial plane. **CN-9**: glossopharyngeal nerve; **ECA**: external carotid artery; **SCM**: sternocleidomastoid muscle.

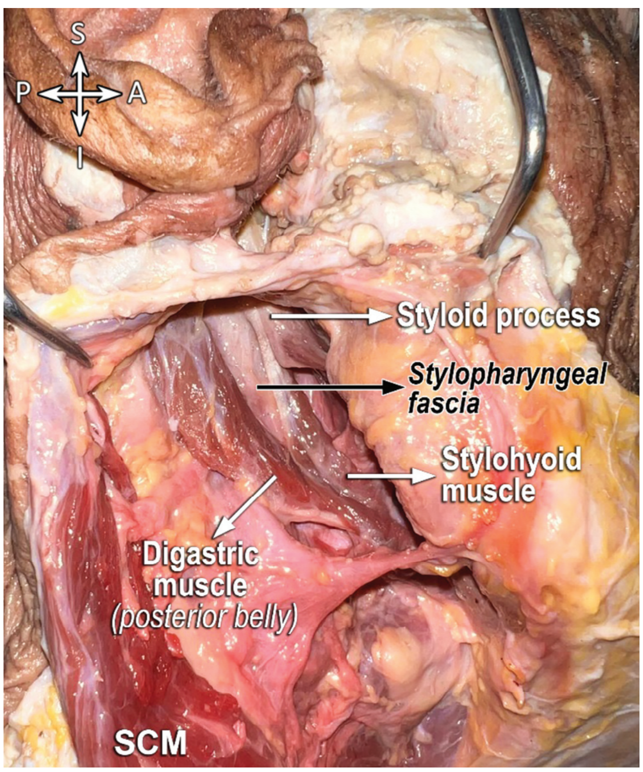

Figure 3. Stylopharyngeal fascia envelops the cranial nerves X-XII at the parapharyngeal space. **SCM**: sternocleidomastoid muscle.

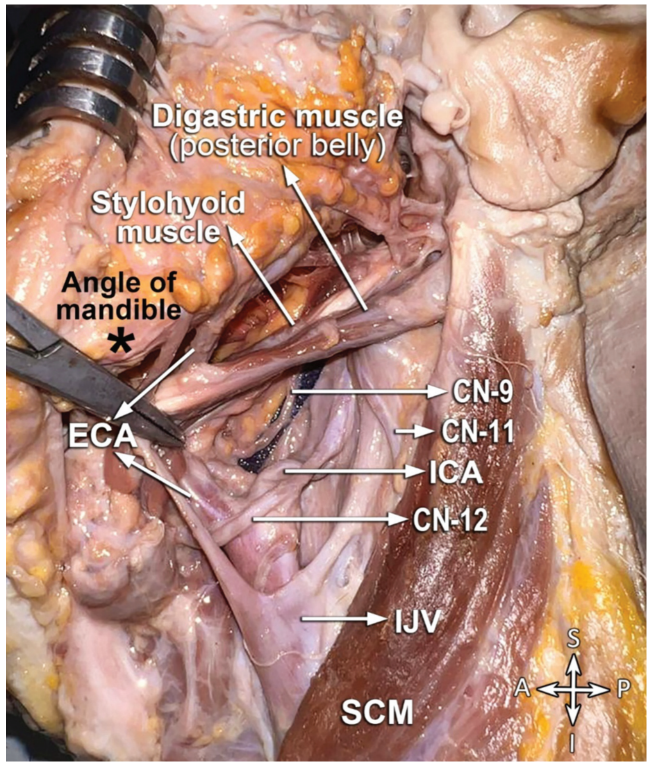

Figure 4. Anatomical structures that can be encountered when moving medially along the fascial plane. **CN-9**: glossopharyngeal nerve; **CN-11**: accessory nerve; **CN-12**: hypoglossal nerve; **ECA**: external carotid artery; **ICA**: internal carotid artery; **IJV**: internal jugular vein; **SCM**: sternocleidomastoid muscle.

of the parotid gland, adipose tissue and lymph nodes. The ICA, IJV sympathetic trunk, cranial nerves IX–XII and lymph nodes are located.[3,4]

According to Lopez et al.,[4] the fascia extending from the posterior aspect of the styloid process towards the tensor veli palatini muscle, named 'tensor vascular styloid fascia' divided the PPS into the prestyloid or anterolateral compartment and the posteromedial or retrostyloid compartment.

Kawai et al.[11] noted a structure named 'styloid diaphragm' dividing the PPS into prestyloid and poststyloid compartments. The styloid diaphragm is described as an anteroinferiorly coursing fibrous band containing the posterior belly of the digastric muscle, stylohyoid muscle, styloglossus muscle, stylopharyngeus muscle, stylohyoid ligament, and stylomandibular ligament. Additionally, it is mentioned that the styloid diaphragm covers the distal cervical part of the ICA, IJV, cranial nerves IX–XII,and the ECA and its branches pass through this structure. Therefore, it is mentioned that the structure of the styloid diaphragm is not continuous.[11]

Komune et al.[12] demonstrated a fascial plane covering the ICA from the inferior border of the tensor veli palatini muscle and including the levator veli palatini muscle, a small part of which was defined as SPF. In another study, tensor vascular styloid fascia structures, defined as layers of the carotid sheath, merged with the SPF as they covered the ICA below the skull base.[13] Varoquaux et al.[9] named the anatomical structure separating the prestyloid and retrostyloid compartments of the PPS as the 'stylopharyngeal fascia'. SPF was defined as a structure extending from the styloid process to the tensor vascular styloid fascia.

In a study by Soriano et al.,[10] excision of prestyloid adipose tissue revealed posterolateral localisation of the styloglossus and stylopharyngeus muscles. Medial to this styloid muscle group is a white-grey fibrous structure called the stylopharyngeal fascia. The styloid muscles and the stylopharyngeal fascia cover the parapharyngeal segment of the ICA, IJV and cranial nerves IX–XII in the poststyloid compartment. When this fascial structure is cut, the parapharyngeal segment of the ICA is exposed and it is seen that it is covered by this fascial structure up to the carotid canal at the skull base.

According to our study, the SPF is located between the posterior belly of the digastric muscle and the stylohyoid muscle and extends inferiorly from the carotid sheath towards the skull base. This fascial structure extends from the posterior aspect of the stylohyoid process to the posterior border of the styloopharyngeus muscle and its surface is covered with adipose tissue anterior to the stylohyoid process. As the fascial plane exits the skull base, it covers the X–XII cranial nerves and the parapharyngeal segment ICA and IJV. The parapharyngeal segment of the ICA is located in a deeper position compared to other neurovascular structures, indicating its relative depth within the anatomical space. The glossopharyngeal nerve runs continuously lateral to the facial plane, parallel to the posterior border of the stylopharyngeal muscle. Our observations also revealed that the occipital and ascending pharyngeal arteries, the posterior branches of the ECA, were covered by this fascial structure.

During the lateral approach from the neck, as we proceeded anteromedially between the posterior belly of the digastric muscle and the stylohyoid muscle, we encountered a compact fascial structure extending across the parapharyngeal space that could not be dissected into separate layers. This fascial plane appeared as a fascial structure encircling the parapharyngeal segment of the internal carotid artery deep in the fatty tissue of the parapharyngeal space. Injury to the parapharyngeal segment of the internal carotid artery is among the most lethal complications that can occur during surgical procedures within the borders of the PPS.[14,15] According to previous studies, the risk of injury to the parapharyngeal segment of the internal carotid artery in open surgical approaches is between 3–8%.[16] Therefore, it is of great importance to have reliable anatomical markers that reveal the parapharyngeal segment of the internal carotid artery during surgical approaches in or around this region.

We believe that this fascial plane enables the spread of deep neck infections and the formation of abscesses in this area to be easily, quickly, and safely drained. Also, mass excisions performed in this area can be carried out more safely by considering the proximity of the described neurovascular structures to the fascia.

The diverse nomenclature and varied descriptions of the anatomical structure traditionally divided into the PPS present a challenge in anatomical studies. While previous studies have designated this structure as the stylopharyngeal fascia, tensor vascular styloid fascia, and other terms, inconsistencies in naming persist across the studies mentioned above. We propose to term as the "parapharyngeal fascia" emphasizing its consistent localization and extensions in fresh frozen cadavers, distinct from the previously described fascial layers. In our recent dissections, specifically conducted on fresh frozen cadavers, we observed a lack of clearly delineated fascial layers distinguishing this structure, reinforcing the need for a simplified designation. Given its vital role in safeguarding essential structures such as the parapharyngeal segment of the ICA, we advocate the adoption of the term "parapharyngeal fascia" to replace the complex nomenclatures utilized in prior studies.

Conclusion

We believe that this study provides valuable information about the complex anatomical arrangements within the PPS and emphasises the importance of understanding these structures for surgical intervention and diagnostic approaches targeting the PPS. The consistent presence of the SPF spanning important structures such as the parapharyngeal segment of the ICA and cranial nerves X–XII emphasises its importance as a key anatomical landmark. Further investigation of the histological aspects and standardisation of nomenclature is needed to better understand this fundamental anatomical entity for clinical applications. By proposing the term 'Parapharyngeal Fascia', we aim to improve clarity and facilitate better communication in future anatomical research and surgical practice.

Future research should focus on examining the histological composition and functional effects of the SPF within the PPS in more depth. The fascial structure extending to the skull base, which we observed in our study not to be composed of separate and distinct layers, can be examined in more detail using endoscopic approaches.

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

PSO: project development, data collection, manuscript writing; AB: data collection, manuscript writing; HİA: Project development, manuscript editing.

Ethics Approval

The ethical approval for this study has been granted on by the University of Ankara Ethical Committee (November 2021, approval number: 19-615-21).

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ORCID ID:
P. Samaraz Olgun 0000-0003-3229-8860;
A. Balcı 0000-0002-6345-1082;
H. İ. Açar 0000-0001-8739-0512

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Correspondence to: Pelin Samaraz Olgun, MD
Department of Anatomy, Graduate School of Health Sciences,
Ankara University, Ankara, Türkiye
Phone: +90 534 223 09 44
e-mail: plnsmrz@hotmail.com

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The effect of the golden ratio in facial anatomy on beauty perception

Erdi İmre , **Ali Yılmaz**

Department of Anatomy, Faculty of Medicine, Trakya University, Edirne, Türkiye

Abstract

Objectives: This study explores the influence of the golden ratio on aesthetic perception, focusing on facial features such as the nasal index, nasooral ratio, and upper-to-lower lip thickness ratio. The aim is to identify patterns in individuals' aesthetic preferences and examine correlations with demographic factors such as gender, educational background, and interest in visual arts.

Methods: Facial images, both digitally altered and hand-drawn, were manipulated to create variations in anthropometric measurements. A questionnaire featuring these images was distributed among adults in various social settings. Statistical analyses included chi-squared tests to compare aesthetic preferences across demographic groups and correlation coefficients to assess the relationships between binary aesthetic choices and demographic factors.

Results: Significant differences in aesthetic preferences were found based on respondents' educational background and interest in visual arts. Males exhibited a stronger preference for golden ratio proportions in nasal and nasooral features, while females demonstrated more variable preferences depending on the specific facial feature. Higher education levels and greater interest in visual arts were consistently associated with a stronger inclination towards selecting golden ratio proportions.

Conclusion: Education and exposure to the arts significantly influence aesthetic preferences, highlighting the impact of social factors on beauty perception. The use of digitally manipulated and hand-drawn images provided a controlled setting for testing the golden ratio and other proportions, ensuring consistency in the study. Future research incorporating real-life images may further enhance our understanding of the mechanisms behind aesthetic perception.

Keywords: aesthetic anatomy; aesthetic perception; facial features; golden ratio; visual arts

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Introduction

Throughout history, the human body has been a focal point of investigation in the study of aesthetics and beauty. Although each era has adopted its own unique approach to analyzing and interpreting the human form, fundamental anatomical principles have consistently played a key role in these assessments.[1] However, a universal standard for beauty has yet to be established. Among various aspects of human beauty, facial aesthetics are often considered more influential than the body.[1,2] One theory suggests that the beauty of the human face is largely derived from the golden ratio.[2,3]

The golden ratio, a concept long recognized in physics and mathematics, is represented by the value Φ=1.6180339887. It is defined as the ratio where the proportion of the longer segment of a line to the shorter segment is the same as the proportion of the whole line to the longer segment.[4] This ratio has been employed by numerous artists throughout history to create what are considered ideal works of art. Today, the golden ratio is increasingly being applied in plastic and reconstructive surgery to achieve aesthetically pleasing results.

In this study, we aim to investigate whether the golden ratio and other facial proportions influence individuals' perception of beauty. By exploring this relationship, we hope to provide the scientific community and the general public with more accurate and objective information on this subject. Furthermore, we anticipate that our findings will help guide individuals in making informed decisions before undergoing aesthetic procedures, reducing the risk of misconceptions regarding beauty standards.

Materials and Methods

A total of 384 volunteers participated to the study. Among the participants, 219 were female and 165 were male, with an average age of 32.5±8.7 years. The average age for males was 32.6±9.2, while for females it was 32.5±8.6 years. Participants were categorized into three groups based on their educational background: the first group consisted of individuals with a high school diploma or lower, the second group included those with a bachelor's degree, and the third group comprised individuals with master's or doctoral degrees. Of the volunteers, 87 had a high school diploma or lower, 228 held a bachelor's degree, and 69 had a master's or doctoral degree.

Participants were also asked about their interest in visual arts, such as sculpture, painting, photography, cinema, and design. Among them, 175 indicated an interest in visual arts, while 209 stated they had no interest.

To assess aesthetic perception, a facial image that represented aesthetic beauty, as judged by a professional artist, was created both digitally and freehand. This image, possessing proportions associated with beauty, was modified by altering specific anthropometric measurements related to the nose, resulting in a series of images. Throughout these images, parameters such as forehead height, forehead width, eye width (right and left), interocular distance, upper facial width, lower facial width, and lower facial height were kept constant. A total of 20 images were produced using both digital and hand-drawn techniques.

In the digital images, the nasal index (the ratio of nasal length to nasal width) and the upper-to-lower lip thickness ratio were adjusted to conform to the golden ratio and other specified proportions. For the hand-drawn images, the nasooral ratio (the ratio of mouth width to nasal width) was created by a professional artist according to the golden ratio and related proportions. These images were then incorporated into a questionnaire format, presenting multiple-choice options for participants. Volunteers were asked to select the most aesthetically pleasing option for the nasal index, nasooral index, and upper-to-lower lip thickness ratio in both male and female faces.

Additionally, demographic information such as age, gender, educational level, and interest in visual arts was collected.

For the male nasal index question, four images were created digitally, each illustrating different nasal length-to-nasal width ratios (nasal index) of 1.5, 1.618 (the golden ratio), 1.7, and 1.8 (**Figure 1**). Option A corresponded to a ratio of 1.5, Option B to 1.618 (the golden ratio), Option C to 1.7, and Option D to 1.8.

Similarly, for the female nasal index, four images were created digitally using the same ratios (**Figure 2**). Option A corresponded to a ratio of 1.5, Option B to 1.618 (the golden ratio), Option C to 1.7, and Option D to 1.8.

For the male nasooral ratio question, four freehand-drawn images were prepared, each depicting different mouth width-to-nasal width ratios of 1, 1.2, 1.618 (the golden ratio), and 1.8 (**Figure 3**). Option A represented a ratio of 1, Option B 1.2, Option C 1.618 (the golden ratio), and Option D 1.8.

Similarly, for the female nasooral ratio, four images were prepared in the same manner, using the same ratios (**Figure 4**). However, in this case, Option A had a ratio of 1.8, Option B 1.618 (the golden ratio), Option C 1.2, and Option D 1.

To assess the ratio of upper lip thickness to lower lip thickness, four images were produced with ratios set at 1.5, 1.618 (the golden ratio), 1.7, and 1.8 (**Figure 5**). Option A was assigned a ratio of 1.7, Option B 1.8, Option C 1.5, and Option D 1.618 (the golden ratio).

The questionnaires were then duplicated in black and white to ensure consistency with the charcoal drawings. These were distributed in crowded social venues, such as shopping malls and hospitals, targeting individuals aged 18 and above. After collecting responses from participants who volunteered for the study, the data was entered into a computerized system and analyzed statistically. The results were expressed as numbers and percentages (%).

For comparing categorical data between groups, the chi-squared test was used to examine differences in aesthetic preferences based on demographic characteristics. The Phi coefficient (Cramer's V) was employed to assess the relationships between binary (yes/no) categorical variables. The point-biserial correlation coefficient (rrb) was used to evaluate the relationship between binary (yes/no) nominal data and ordinal rankings.

Statistical analysis was performed with IBM SPSS (Statistical Package for the Social Sciences) Statistics Version 22.0 (Armonk, NY, USA), with a significance level of $p<0.05$ considered statistically significant.

Results

In our study, we calculated that 384 participants would be needed based on the assumption of a 50% correct identi-

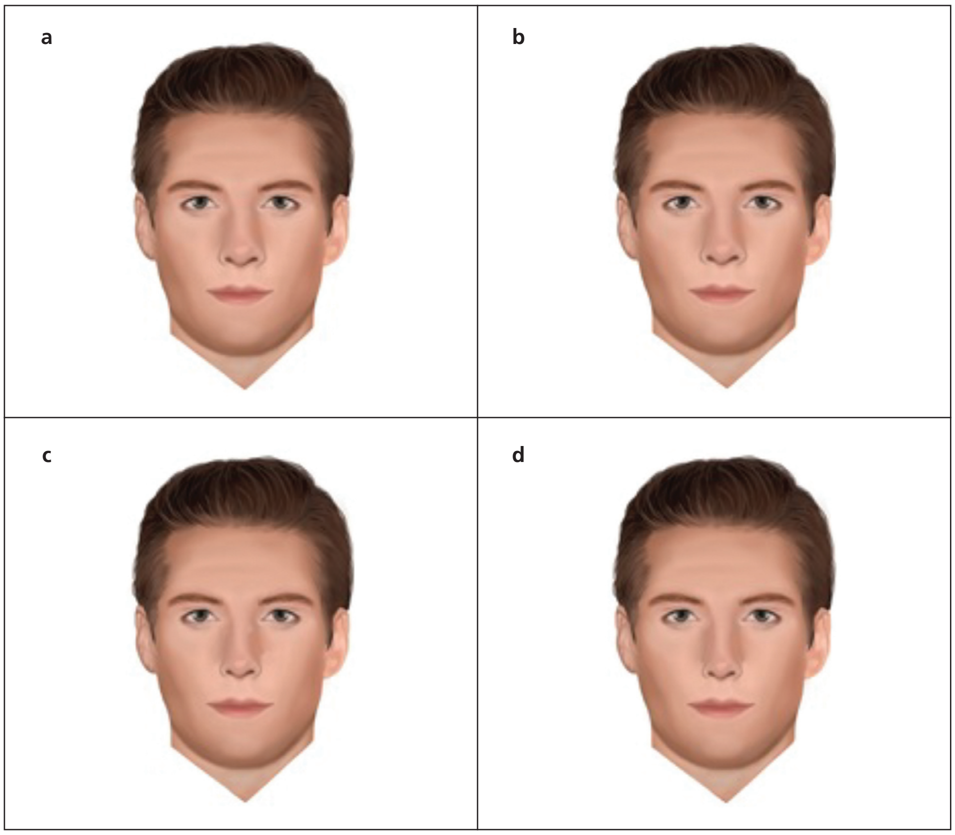

Figure 1a-d. Pictures for evaluating nasal index in men.

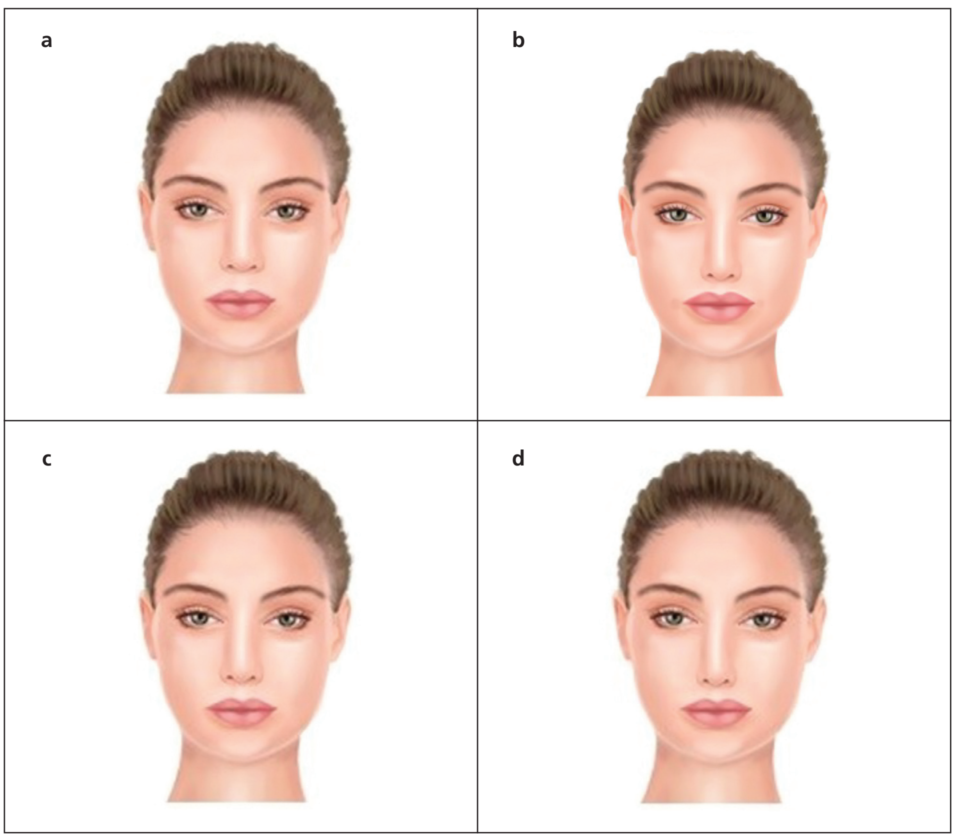

Figure 2a-d. Pictures for evaluating the nasal index in women.

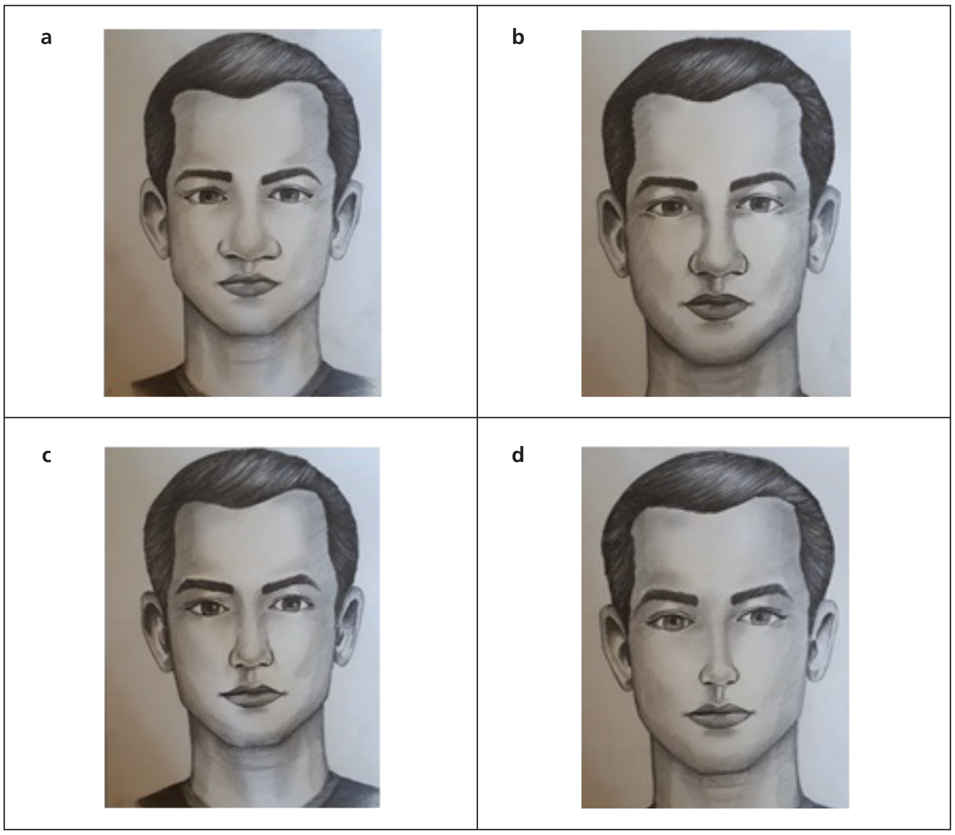

Figure 3a-d. Pictures for evaluating the nasooral index in men.

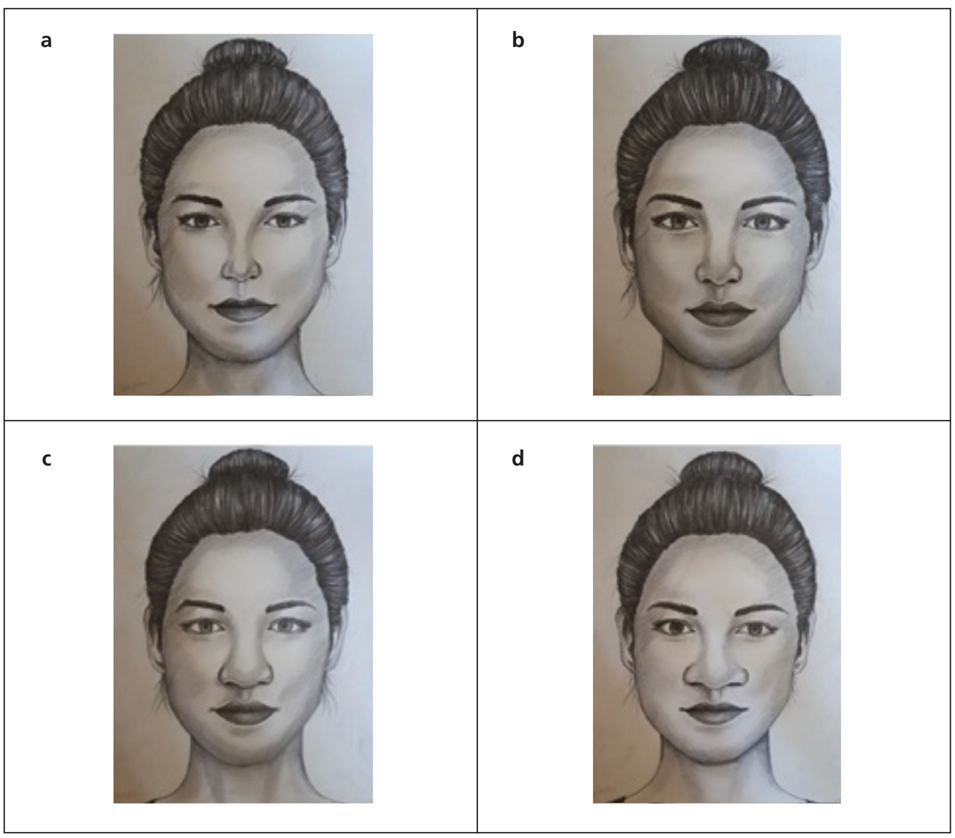

Figure 4a-d. Pictures for evaluating the nasooral index in women.

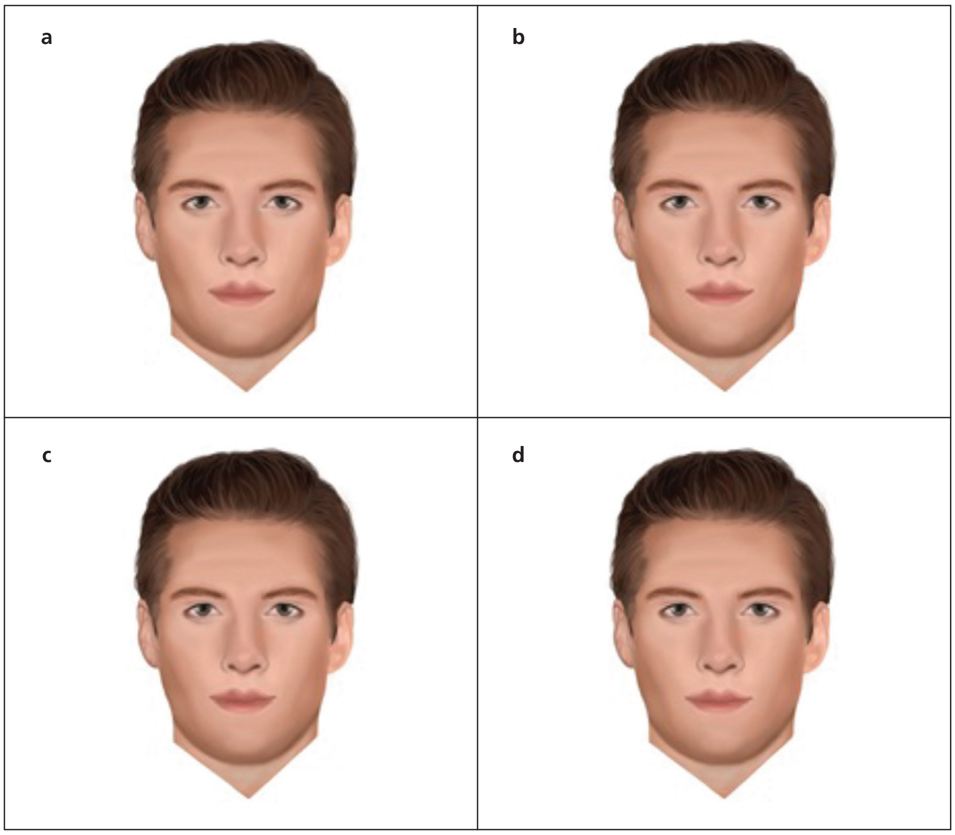

Figure 5a-d. Pictures for evaluating the ratio of upper lip thickness to lower lip thickness is questioned.

fication rate for the golden ratio (1.618), with a tolerance value (d) of 0.10 and a significance level (α) of 0.05. These 384 individuals were selected from the population using a simple random sampling method.

The questions and responses were statistically analyzed based on gender, educational level, and interest in visual arts, with the results presented in tables (**Figure 6**) (**Tables 1**, **2** and **3**). Educational level was found to be significantly correlated with the ability to identify the golden ratio in the nasal index for males (p=0.011, r=0.130), indicating that higher education levels were associated with a greater likelihood of identifying the golden ratio. Similarly, interest in visual arts was significantly correlated with identifying the golden ratio in the nasal index for females (p<0.001, r=0.197).

A negative correlation was observed between age and the ability to predict the golden ratio for the upper lip-to-lower lip ratio (p=0.021, r=-0.118), suggesting that the ability to identify the golden ratio decreased with age. However, no significant correlation was found between interest in visual arts and the ability to identify the golden ratio for the upper lip-to-lower lip ratio (φ=0.141).

Discussion

Among the volunteers in our study, 77.4% had a bachelor's degree or higher educational attainment. This percentage was higher than the 65% reported in the study by Ünver et al.[5] However, according to 2020 data from the Turkish Statistical Institute (TUIK), only 13% of the Turkish population has attained education at the bachelor's level or higher.[6] This suggests that the educational distribution of our sample diverges significantly from the general population. Conducting the study in high-population areas such as shopping malls may have resulted in a more heterogeneous group of volunteers, as individuals with higher education are often more active in public life.

In our study, 60% of the participants indicated no interest in visual arts. Given that not all participants associated the golden ratio with beauty, this result was anticipated. However, with technological advancements, visual arts have diversified and evolved.[7,8] Since we did not query the specific type of visual art participants were interested in, it remains unclear how the type of visual art might have influenced their responses.

In response to the male nasal index question, the golden ratio (114 of 384) was the most frequently select-

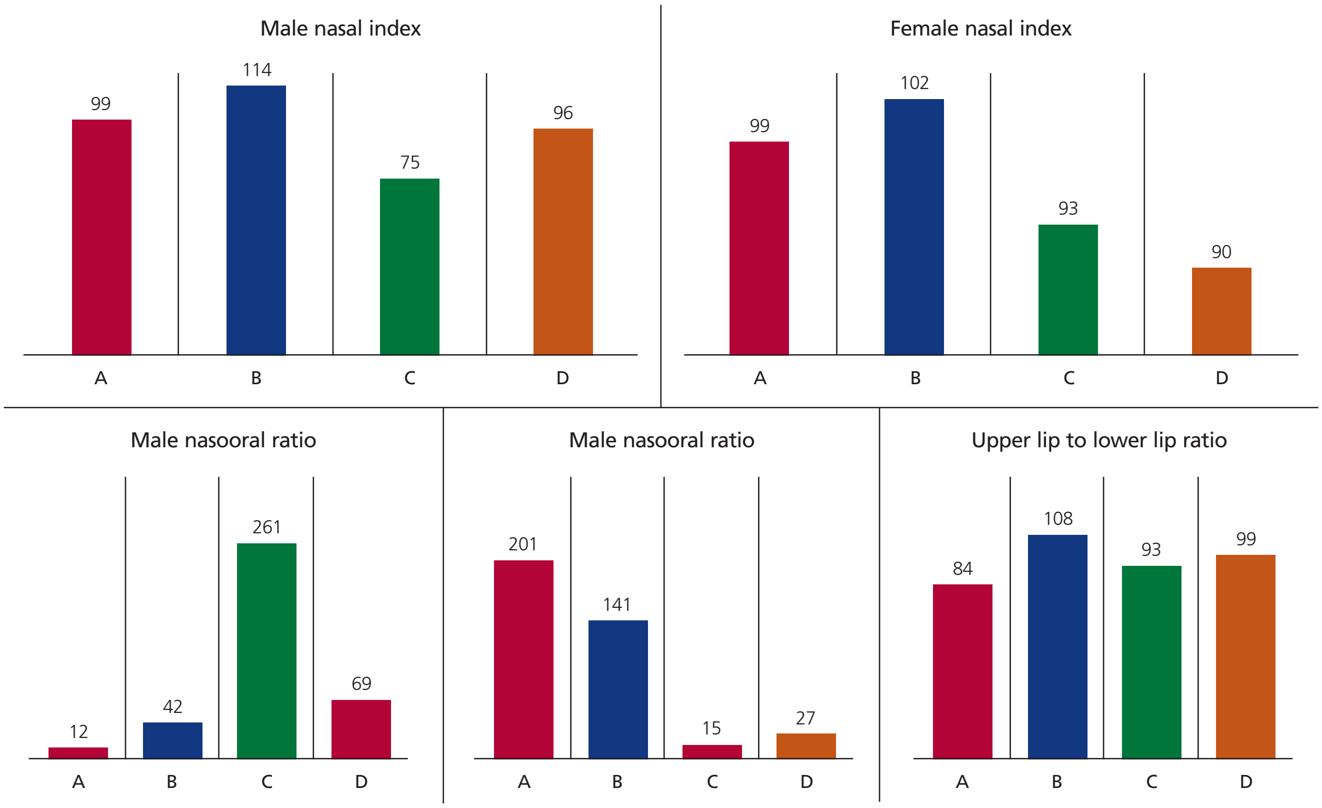

Figure 6. Bar chart representation of the answers given by the volunteers. A, B, C and D: answer options provided in the pictures.

ed option. While males were more likely to choose the golden ratio, responses for other options were also closely distributed. The significant relationship between gender and the nasal index question for males suggests that aesthetic perception differs between males and females. Educational level had a statistically significant effect on the selection of the golden ratio option, particularly among participants with a bachelor's degree or higher and those with an interest in visual arts. Correlation and regression analyses confirmed that higher education levels were associated with a greater likelihood of selecting the golden ratio for the male nasal index, consistent with findings in the literature.[5] Since the golden ratio is often employed in visual arts such as painting and sculpture, individuals interested in these areas may be more familiar with the ratio and therefore more likely to prefer it.[9,10] Additionally, the positive correlation between higher education and preference for the golden ratio aligns with studies suggesting that education influences artistic perception.[11,12]

In the study by Ünver et al.,[5] the golden ratio was the most frequently chosen option (55.2%) for the nasal index question. Although our study showed similar results, the proportion of participants selecting the golden ratio was significantly lower. We believe this discrepancy could be due to the degradation of image quality when producing black-and-white outputs of the drawings.

In the female nasal index question, the golden ratio (91 of 384) was again the most frequently chosen option. Higher education levels and interest in visual arts were associated with a stronger preference for the golden ratio, and these results were statistically significant. Correlation and regression analyses further confirmed a significant relationship between interest in visual arts and the preference for the golden ratio in female faces. These findings were consistent with the results of the male nasal index question and the findings of Ünver et al.[5]

Although both male and female participants tended to prefer the golden ratio for the nasal index, this preference was not statistically significant in either case. Based on our results, the golden ratio does not appear to have a clear superiority in determining nasal beauty for males or females. We believe that future studies using real human images and more refined nasal index measurements could provide more definitive conclusions.

Table 1
Comparison of answers and gender.

	Answer options	Female (n=219)	Male (n=165)	p-value
Male nasal index	A	42 (19.2%)	57 (34.5%)	**p<0.001**
	B	60 (27.4%)	54 (32.7%)	
	C	60 (27.4%)	15 (9.1%)	
	D	57 (26%)	39 (23.6%)	
Female nasal index	A	57 (26%)	42 (25%)	p=0.312
	B	51 (23%)	51 (31%)	
	C	54 (25%)	39 (24%)	
	D	57 (26%)	33 (20%)	
Male nasooral ratio	A	3 (1.4%)	9 (5.5%)	**p=0.026**
	B	30 (13.7%)	12 (7.3%)	
	C	150 (68.5%)	111 (67.3%)	
	D	36 (16.4%)	33 (20%)	
Female nasooral ratio	A	129 (58.9%)	72 (43.6%)	**p=0.021**
	B	69 (31.5%)	72 (43.6%)	
	C	9 (4.1%)	6 (3.6%)	
	D	12 (5.5%)	15 (9.1%)	
Upper lip to lower lip thickness ratio	A	54 (24.7%)	30 (18.2%)	p=0.506
	B	60 (27.4%)	48 (29.1%)	
	C	51 (23.2%)	42 (25.5%)	
	D	54 (24.7%)	45 (27.2%)	

The nasal index is the ratio of nasal width to nasal length. In the literature, both numerator and denominator values have been used to calculate the nasal index.[5,13] In this study, we used nasal width as the numerator to apply the golden ratio. A concept known as the "Thomson nasal rule" suggests that wider noses are more common in warmer equatorial regions, as they help transport larger volumes of warm air to the lungs. Conversely, longer and narrower noses are more common in regions closer to the poles, where they help warm cold air before it reaches the lungs.[14] Consequently, the average nasal index can vary across geographical regions.

For example, a 2019 study in Nepal reported average nasal index values of 1.18 for males and 1.23 for females.[15] A study by Nasir et al.[16] in India in 2021, measured nasal indices across four states, reporting values ranging from 1.24 to 1.58 for females and 1.26 to 1.60 for males. In a study conducted in Türkiye, nasal indices for Anatolian males across different age groups were found to be approximately 1.3 for young adults (20–40 years), and around 1.23 for adults (40–60 years) and the elderly (60 years and above). A significant difference was observed between young adults and older individuals, although no data on females were provided.[17]

A study in Nigeria examining nasal indices across different ethnic groups living in the same region found no clear link between climate conditions and nasal structure, indicating that climate might not be the sole determinant of nasal morphology.[18] These studies show that average nasal index values can vary based on several factors, even within the same ethnic group.[19,20]

In our study, the values exceeded the national average, as we included individuals with longer and narrower noses. However, the absence of options for more commonly observed nasal index values in Turkey limits our ability to draw definitive conclusions about their impact on nasal aesthetic perception.

In the question assessing the nasooral ratio in males, option C, representing the golden ratio, was the most preferred choice (68%). While preferences for other options varied by gender, knowledge of the golden ratio, belief in its association with beauty, and interest in visual arts, option C consistently remained the most favored across these factors. However, an increase in educational level was correlated with a higher preference for this ratio. Similarly, in the question about the nasooral ratio in females, the most selected option was A, representing

Table 2
Comparison of answers and level of education.

	Answer options	Highschool and below (n=87)	Bachelor's degree (n=228)	Postgraduate and above (n=69)	p-value
Male nasal index	A	24 (27.6%)	57 (25%)	18 (26.1%)	p=0.008
	B	15 (17.2%)	75 (32.9%)	24 (34.8%)	
	C	21 (24.1%)	51 (22.4%)	3 (4.3%)	
	D	27 (31%)	45 (19.7%)	24 (34.8%)	
Female nasal index	A	9 (10.3%)	72 (31.6%)	18 (26.1%)	p<0.001
	B	21 (24.1%)	54 (23.7%)	27 (39.1%)	
	C	24 (27.6%)	54 (23.7%)	15 (21.7%)	
	D	33 (37.9%)	48 (21.1%)	9 (13%)	
Male nasooral ratio	A	0 (0%)	12 (5.3%)	0 (0%)	p<0.001
	B	9 (10.3%)	33 (14.5%)	0 (0%)	
	C	54 (62.1%)	150 (65.8%)	57 (82.6%)	
	D	24 (27.6%)	33 (14.5%)	12 (17.4%)	
Female nasooral ratio	A	30 (34.5%)	129 (56.6%)	42 (60.9%)	p<0.001
	B	39 (44.8%)	78 (34.2%)	24 (34.8%)	
	C	3 (3.4%)	12 (5.3%)	0 (0%)	
	D	15(17.2%)	9 (3.9%)	3 (4.3%)	
Upper lip to lower lip thickness ratio	A	15 (17.2%)	36 (15.8%)	9 (13%)	p=0.036
	B	39 (44.8%)	135 (59.2%)	30 (43.5%)	
	C	18 (20.7%)	36 (15.8%)	15 (21.7%)	
	D	15 (17.2%)	21 (9.2%)	15 (21.7%)	
Total number	384	87	228	69	

a ratio of 1.8 (52.3%), followed by option B, representing the golden ratio (1.618) with 36.7% of selections. The most frequently chosen option for males in the nasooral ratio closely aligned with the Turkish population's average (1.45 for males, 1.53 for females).[21,22]

Reviewing the literature reveals variations in nasooral index values among populations. For example, in a 1997 study by Wang et al.,[23] Chinese populations had nasooral values below 1.5, while North American populations exceeded 1.6. While the neoclassical canon considers the nasooral proportion to be 1.5, the golden ratio is often perceived as the most aesthetically pleasing in the nasooral context.[24,25] However, a study by Burusapat and Lekdaeng[26] Thai and international beauty pageant winners suggested that the golden ratio may no longer hold as much significance in contemporary beauty standards.[26] In our study, for the nasooral ratio in females, the preference for a 1.8 ratio over the mean and the golden ratio suggests a tendency towards slightly wider lips in female beauty.

In the question evaluating the upper lip-to-lower lip thickness ratio, the most preferred option was B, representing a ratio of 1.8 (28.1%), followed by D, representing the golden ratio (25.8%). Volunteers with a master's degree or higher and those interested in visual arts tended to prefer option D. Additionally, correlation and regression analyses indicated a significant relationship between interest in visual arts and the preference for the golden ratio in the upper lip-to-lower lip thickness ratio.

In the question evaluating the lower lip-to-upper lip thickness ratio, the most selected option was D, representing a ratio of 1.5 (35.2%), followed by B, representing a ratio of 1.7 (29.7%). Option C, representing the golden ratio, was the least preferred (17.2%). Volunteers with higher educational attainment favored option D, while those knowledgeable about the golden ratio were less likely to select option C. The literature suggests that the ideal upper lip-to-lower lip ratio is 1:1.618.[27,28] However, average values reported for Caucasian women are 1:1.42 and for men 1:1.25.[29] In our study, the golden ratio was the least preferred option, with participants favoring a ratio of 1.5, which aligns more closely with population averages. This suggests that a thicker lower lip might not be as favored in male aesthetic preferences within Turkish society.

Table 3
Comparison of answers and interest in visual arts.

	Answer options	Interested in visual arts (n=153)	Not interested in visual arts (n=231)	Total (n=384)	p-value
Male nasal index	A	51 (33.3%)	48 (20.8%)	99 (25.8%)	p=0.001
	B	51 (33.3%)	63 (27.3%)	114 (29.7%)	
	C	27 %17.6%)	48 (20.8%)	75 (19.5%)	
	D	24 (15.7%)	72 (31.2%)	96 (25%)	
Female nasal index	A	27 (17.6%)	72 (31.2%)	99 (25.8%)	p<0.001
	B	57 (37.3%)	45 (19.5%)	102 (26.6%)	
	C	27 (17.6%)	66 (28.6%)	93 (24.2%)	
	D	42 (27.5%)	48 (20.8%)	90 (23.4%)	
Male nasooral ratio	A	0 (0%)	12 (5.2%)	12 (3.1%)	p=0.003
	B	24 (15.7%)	18 (7.8%)	42 (10.9%)	
	C	105(68.6%)	156(67.5%)	261 (68%)	
	D	24 (15.7%)	45 (19.5%)	69 (18%)	
Female nasooral ratio	A	93 (60.8%)	108 (46.8%)	201 (52.3%)	p=0.001
	B	54 (35.3%)	87 (37.7%)	141 (36.7%)	
	C	0 (0%)	15 (6.5%)	15 (3.9%)	
	D	6 (3.9%)	21 (9.1%)	27 (7%)	
Upper lip to lower lip thickness ratio	A	39 (25.5%)	45 (19.5%)	84 (21.9%)	p=0.001
	B	39 (25.5%)	69 (29.9%)	108 (28.1%)	
	C	24 (15.7%)	69 (29.9%)	93 (24.2%)	
	D	51 (33.3%)	48 (20.8%)	99 (25.8%)	

The assessment of the upper lip-to-lower lip ratio was based on a male character, while the lower lip-to-upper lip ratio was based on a female character. The use of virtual drawings in this study, rather than real-life photographs, and the potential degradation of image quality during black-and-white printing, may have influenced the results. We believe future studies utilizing real-person photographs with high-quality image processing could yield more accurate findings.

This study found significant gender differences in the preferences for male nasal indices, male nasooral indices, and female nasooral indices. Literature reviews indicate that aesthetic perceptions differ by gender.[30,31] However, a 2018 study by Lewandowski and Danel did not find significant gender differences in vermilion assessments.[32] While vermillion was not assessed in our study, the gender-based differences observed in facial indices represent novel findings that have not been previously reported. These results could provide a valuable guide for future research.

This study had several limitations. First, the use of both digital and hand-drawn images to manipulate facial proportions, rather than real photographs, may have affected participants' aesthetic evaluations, potentially limiting the external validity of the findings. However, this approach also allowed for the control of other morphometric variables, which could be advantageous for statistical analysis. Additionally, the transition from color to black-and-white images may have compromised image quality, affecting participants' responses. The study also only assessed the upper lip-to-lower lip thickness ratio in males, so future studies investigating both genders are needed for more accurate results. The sampling method, which targeted specific social venues, may have introduced selection bias, as the sample had a higher educational level compared to the general population. Furthermore, the assessment of interest in visual arts lacked specificity, as different forms of visual art were not differentiated, which could have influenced aesthetic preferences. The exclusive focus on facial features and the limited demographic diversity further constrain the generalizability of the results. Future research should address these limitations by incorporating real-life images, expanding the sample diversity, and exploring the influence of various forms of art and education on aesthetic perception.

Conclusion

The results of our study suggested that the education and interest in the fine arts were the most influential social parameters on beauty perception. These two factors had a significant impact across all measurements. Given the relationship between an interest in fine arts and education, it is likely that education plays a more pronounced role in shaping artistic understanding. While our study focused on facial beauty assessment, it did not account for specific fields of education or provide a detailed analysis of visual arts. Future studies in these areas will be valuable for gaining a deeper understanding of how social factors shape aesthetic perspectives.

Conflict of Interest

There is no conflict of interest to declare.

Author Contributions

Eİ: data collection, data analysis, literature review, writing the manuscript, critical review; AY: conception and design of the study, obtaining data, critical review, supervision.

Ethics Approval

Ethical approval is obtained from Local Ethics Committee of Trakya University Faculty of Medicine (TÜTF-BAEK 2019/158)

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ORCID ID:
E. İmre 0000-0003-2893-721X;
A. Yılmaz 0000-0003-2277-8772

Correspondence to: Erdi İmre, MD, PhD
Department of Anatomy, Faculty of Medicine,
Trakya University, Edirne, Türkiye
Phone: +90 555 717 12 36
e-mail: erdiimre@gmail.com

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Correlation between morphometry of fetal foot and gestational age: a cadaver study

Abdurrahim Eyüp Canbaloğlu[1], Ahmet Dursun[2], Kenan Öztürk[3], Yadigar Kastamoni[3]

[1]*Department of Physiotheraphy and Rehabilitation, Faculty of Health Sciences, İstinye University, Istanbul, Türkiye*
[2]*Department of Anatomy, Faculty of Medicine, Karamanoğlu Mehmetbey University, Karaman, Türkiye*
[3]*Department of Anatomy, Faculty of Medicine, Süleyman Demirel University, Isparta, Türkiye*

Abstract

Objectives: This study was conducted on a collection of fetal cadavers to describe the relationship between gestational age and foot parameters specifically in the Turkish population.

Methods: The study involved 83 fetal cadavers (45 males, 38 females) ranging from 13 to 40 weeks of gestation, without external anomalies or pathologies. Various foot parameters were measured, including foot width (FW), heel width (HW), foot length (FL), heel-metatarsophalangeal fold (HMF), bimalleolar width (BW), foot dorsum length (FDL), ankle-metatarsophalangeal fold (AMF), malleolus medialis height (MMH), malleolus lateralis height (MLH), and finger length (FiL). These parameters were measured using a digital caliper with a precision of 0.01 mm. The fetuses were grouped by gestational month, and morphometric measurements were taken.

Results: A strong and positive correlation was found between all foot parameters and gestational age (months). All parameters increased consistently throughout the fetal period. No significant differences were observed based on gender or side comparisons for any of the parameters. Linear regression equations were developed to estimate gestational age using fetal foot parameters. These parameters explained 72% to 90% of the variation in gestational age.

Conclusion: Fetal foot length and related foot parameters can reliably be used to estimate gestational age. Due to the simplicity of these measurements, fetal foot parameters can be utilized to estimate age for babies born outside a hospital setting without the need for specialist equipment. Additionally, for premature babies receiving treatment in neonatal units, foot measurements offer a practical and easily accessible method for age estimation.

Keywords: fetus; foot length; gestational age; morphometry

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Introduction

Accurate assessment of gestational age is essential for the effective management of any obstetric case. The most precise fetal age estimates are typically obtained from measurements of crown-rump length (CRL) in early pregnancy. In later stages of pregnancy, gestational age estimates tend to be less accurate; however, using multiple body measurements can provide an overall estimate that is approximately 93% accurate in determining the true gestational age.[1] Multiple anatomical parameters, such as fetal biparietal diameter, head circumference, crown-rump length, abdominal circumference, foot length, and femur length, are commonly used to assess gestational age. Historically, pathologists and obstetricians have relied on fetal foot length measurements following spontaneous abortion to estimate gestational age and assist in diagnosing certain fetal anomalies. Today, the combination of ultrasound assessment and the date of the last menstrual period is considered the most accurate method for pregnancy dating.[2] In areas where prenatal ultrasound is not routinely available, measuring fetal foot length after delivery is a viable method for estimating gestational age.[3] Assessing gestational age can also be challenging in fetuses with conditions such as anencephaly, hydrocephalus, and short limb dysplasia. A review of the literature shows that the fetal foot has a characteristic normal growth pattern, making it an easily measurable parameter that can be used to estimate gestational age.[4]

Over the past 90 years, several studies have reported reference intervals for fetal foot length in relation to gestational age.[5,6] While all studies indicated a linear relationship between fetal foot length and gestational age, none confirmed the generalizability of their models to the populations studied. Some studies reported differences in data collection methods, such as measurements from fresh versus formalin-fixed specimens, while others suggested that racial and population variances may affect fetal size measurements.[7]

Accurate assessment of gestational maturity in newborns, especially those requiring intensive care, can be challenging. However, the foot is usually easily accessible for measurement, even in an incubator. Measuring foot length has proven particularly valuable in premature infants who are too ill for traditional anthropometric measurements due to the constraints of intensive care apparatus. Clinicians typically rely on a combination of prenatal and postnatal indicators—such as ultrasound and the last menstrual period—to determine gestational age. There are also scoring systems that use various neurological and physical criteria for this purpose. While these scoring methods are convenient for physicians, they can be cumbersome for allied health personnel to use. In contrast, measuring foot length is simple and requires minimal expertise.[8]

This study was conducted to explore the relationship between gestational age and fetal foot length, as well as other foot-related parameters such as foot dorsum length, foot width, heel width, toe lengths, bimalleolar width, and the heights of the medial and lateral malleoli. Additionally, the study aimed to establish reference ranges for these fetal foot parameters in our population.

Materials and Methods

The study was a clinical investigation conducted in the Laboratory of the Department of Anatomy, Faculty of Medicine, involving 83 fetuses (45 males, 38 females) aged between 13 and 40 weeks of gestation, without external anomalies or pathologies. The fetuses were obtained from the Obstetrics and Gynaecology Hospital, with the consent of their families. The causes of death of the fetal cadavers were unknown.

All fetal cadavers were preserved using arterial injections of 10% formaldehyde solution and stored in pools containing the same solution. For fetal embalming, the common carotid and femoral arteries were used for arterial injection. In cases where arterial injection was not feasible or insufficient, partial embalming was performed.

Gestational age of the fetuses was determined using crown-rump length, biparietal diameter, head circumference, and femur length.[9–12] The fetuses were then grouped by gestational month as; fetuses between 13 and 16 weeks were categorized as being in the 4th month, 17 to 20 weeks in the 5th month, 21 to 24 weeks in the 6th month, 25 to 28 weeks in the 7th month, 29 to 32 weeks in the 8th month, 33 to 36 weeks in the 9th month, and 37 to 40 weeks in the 10th month.

Morphometric measurements were performed using a digital caliper with a precision of 0.01 mm. The following parameters were analyzed for each foot.[13–16] (**Figures 1** and **2**). Marked parameters indicate measurements unique to this study.

- **Foot width (FW):** The distance between the medial endpoint of the first metatarsophalangeal joint and the lateral endpoint of the fifth metatarsophalangeal joint.
- **Heel width (HW):** The distance between the widest points of the heel.
- **Foot length (FL):** The distance from the pternion (heel endpoint, Pte) to the longest toe's endpoint.
- **Heel-metatarsophalangeal fold (HMF)*:** The distance between the pte and the anterior endpoint of the metatarsophalangeal fold between the second and third digits.
- **Bimalleolar width (BW):** The distance between the endpoints of the malleolus medialis and malleolus lateralis.
- **Foot dorsum length (FDL)*:** The distance between the midpoint of the ankle and the tip of the longest toe.
- **Ankle-metatarsophalangeal fold (AMF)*:** The distance between the midpoint of the ankle and the anterior endpoint of the metatarsophalangeal fold between the second and third toes.
- **Malleolus medialis height (MMH)*:** The distance between the apex of the malleolus medialis and the heel.
- **Malleolus lateralis height (MLH)*:** The distance between the apex of the malleolus lateralis and the heel.
- **Finger length (FiL):** The distance from the metatarsophalangeal joint to the distal end of the toe.

Statistical analysis was conducted using SPSS for Windows, version 20.0 (IBM, Armonk, NY, USA). For each parameter, the minimum, maximum, mean, and standard deviations were calculated according to gestational age (in months), gender, and sides. The data were normally distributed for gender and side comparisons, so an inde-

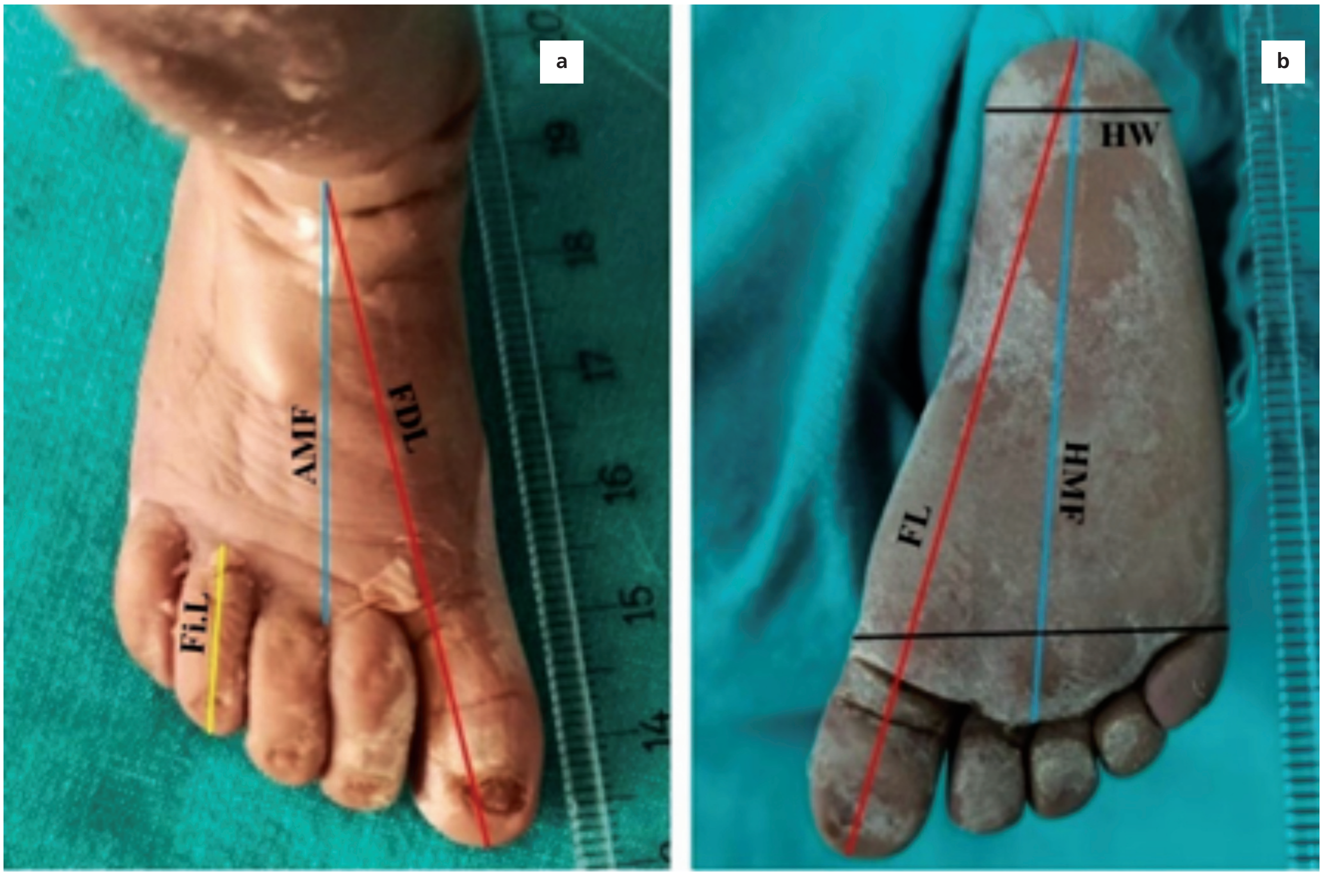

Figure 1. Fetal foot measurement parameters on a 40-week-old male fetus. (**a**) dorsal view; (**b**) plantar view. **AMF:** distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the second and third toes; **FDL:** distance between the midpoint of the ankle and the tip of the longest toe; **FiL:** distance between the metatarsophalangeal joint and the distal end of the finger; **FL:** distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; **FW:** distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; **HMF:** distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; **HW:** distance between the widest points of the heel.

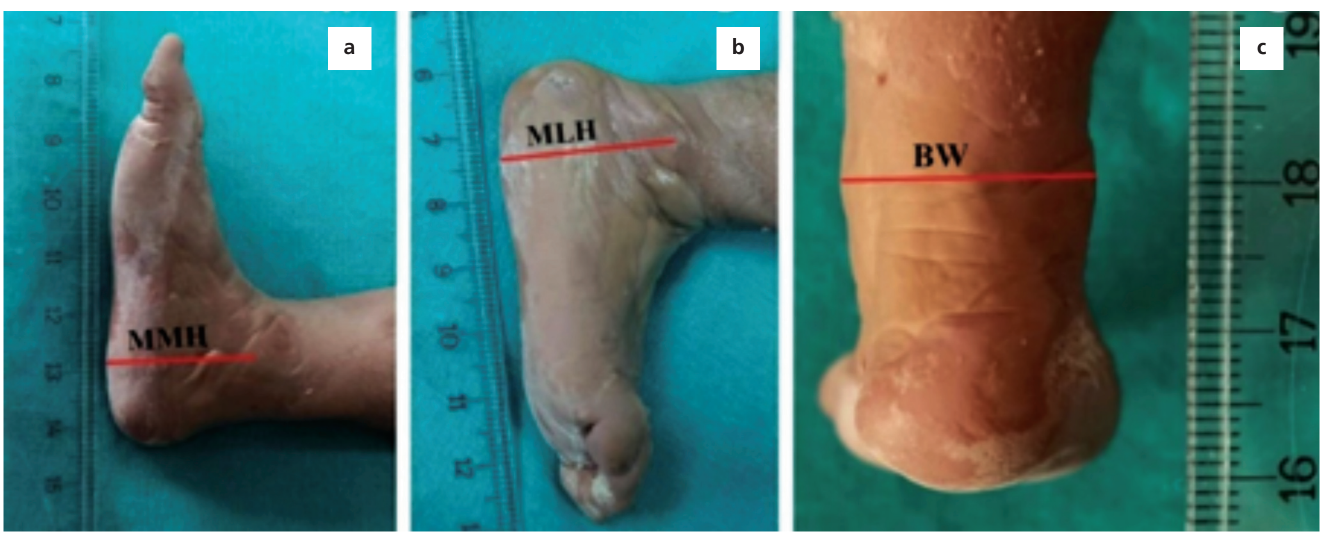

Figure 2. Fetal foot measurement parameters on a 40-week-old male fetus. (**a**) Medial view; (**b**) lateral view; (**c**) posterior view. **BW:** distance between the end points of malleolus medialis and malleolus lateralis; **MLH:** distance between the top of the malleolus lateralis and the heel; **MMH:** distance between the top of the malleolus medialis and the heel.

pendent t-test was used. For comparisons across gestational months, where the data were not normally distributed, the Kruskal-Wallis test was applied for multiple comparisons. Since significant differences were identified, post-hoc analysis was performed. Pearson's correlation analysis was used to assess the relationships between variables. A significance level of $p<0.05$ was considered statistically significant.

Simple linear regression analysis was also performed, using the following equation:

$$y = c + mx$$

where "y" represents the dependent variable (gestational age), "c" is the regression coefficient constant, "m" is the regression coefficient for the independent variable, and "x" represents the independent variable.

Results

In our study, morphometric data were evaluated from 166 fetal feet of 83 human cadaveric fetuses. The mean and standard deviations of the results were calculated according to sex, side, and gestational age (in months). Statistical comparisons were made across these categories (**Tables 1** and **2**). The measured foot parameters showed consistent growth with increasing gestational age (**Figures 3** and **4**). No significant differences were found between consecutive months for any of the parameters, but significant differences were observed between more distant months as fetal growth progressed (**Table 1**). All foot parameters had a strong positive correlation with gestational age, showing continuous improvement throughout the fetal period (**Table 3**). Additionally, no significant differences were observed in comparisons between sex or side for any of the parameters (**Table 2**).

Gestational age was estimated using the fetal foot parameters according to the linear regression equation. As shown in **Table 4**, fetal foot parameters explained between 72% and 90% of the variation in gestational age. This suggests that gestational age can be reliably estimated with a high degree of accuracy when multiple fetal foot parameters are used together.

Table 1
Monthly comparison of fetal foot parameters.

	Gestational age (months)							
Parameters (mm)	4 (n=8)	5 (n=18)	6 (n=24)	7 (n=32)	8 (n=32)	9 (n=24)	10 (n=26)	p-value
FL	21.10±1.47	29.18±4.16	40.34±6.24	47.82±3.97	59.37±5.36	65.31±5.82	75.16±5.23	<0.001
HMF	18.16±1.02	25.29±4.02	34.59±5.30	41.42±3.43	50.93±4.34	55.76±5.58	64.51±5.02	<0.001
FW	7.96±1.04	11.43±2.28	15.44±2.54	19.62±2.41	23.72±2.16	26.89±3.48	30.94±3.18	<0.001
BW	5.87±0.40	8.49±1.37	12.0±1.72	14.05±1.19	17.43±1.58	19.47±2.02	22.24±2.29	<0.001
HW	4.71±0.57	7.01±1.61	9.33±1.95	11.50±1.13	13.41±1.42	14.31±1.69	17.41±1.88	<0.001
MLH	5.09±0.82	6.18±1.23	10.16±2.21	11.81±1.49	14.71±2.58	16.73±2.90	18.23±3.65	<0.001
MMH	5.28±0.42	7.15±1.19	11.74±2.50	13.19±1.43	17.19±2.97	18.98±3.53	21.15±4.10	<0.001
FDL	15.56±1.97	22.05±3.44	30.83±5.65	37.07±3.52	47.66±3.80	51.81±5.55	57.15±3.95	<0.001
AMF	11.47±1.46	15.35±2.46	22.35±4.43	26.56±3.04	34.58±3.25	37.29±5.07	40.56±3.10	<0.001
FiL 1	4.79±0.48	6.99±1.31	9.89±1.82	11.50±1.21	14.47±1.91	16.17±2.11	17.96±1.93	<0.001
FiL 2	4.71±0.51	7.40±1.05	10.16±1.70	12.16±1.07	14.38±1.57	16.40±1.85	17.83±1.59	<0.001
FiL 3	4.26±0.51	6.45±1.12	9.21±1.76	10.60±0.93	12.73±1.46	14.12±1.45	15.85±1.41	<0.001
FiL 4	3.89±0.47	5.96±1.25	8.18±1.32	9.99±0.93	11.95±1.33	12.93±1.66	15.01±1.54	<0.001
FiL 5	3.41±0.46	5.21±1.02	7.41±1.29	8.89±1.01	10.95±1.21	12.27±1.47	13.75±1.72	<0.001

AMF: distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the first and second toes; **BW:** distance between the end points of malleolus medialis and malleolus lateralis; **FDL:** distance between the midpoint of the ankle and the tip of the longest toe; **FiL:** distance between the metatarsophalangeal joint and the distal end of the finger; **FL:** distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; **FW:** distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; **HMF:** distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; **HW:** distance between the widest points of the heel; **MLH:** distance between the top of the malleolus lateralis and the heel; **MMH:** distance between the top of the malleolus medialis and the heel.

Table 2
Mean and standard deviation values of fetal foot parameters with comparisons by gender and side.

	Side			Gender		
Parameters (mm)	**Right (n=83)**	**Left (n=83)**	**p-value**	**Female (n=38)**	**Male (n=45)**	**p-value**
FL	52.72±16.47	52.55±16.30	0.947	54.23±16.36	50.79±16.22	0.180
HMF	45.43±14.09	45.01±13.99	0.848	46.53±14.08	43.71±13.84	0.198
FW	21.27±7.27	21.11±7.14	0.888	22.01±7.25	20.25±7.04	0.116
BW	15.58±5.0	15.48±4.93	0.894	15.99±5.11	15.0±4.74	0.201
HW	12.12±3.81	12.09±3.77	0.956	12.59±3.67	11.54±3.84	0.075
MLH	12.85±4.77	13.04±4.69	0.801	13.39±4.51	12.43±4.93	0.193
MMH	14.80±5.46	14.96±5.47	0.849	15.41±5.28	14.27±5.62	0.184
FDL	40.97±13.10	40.97±13.10	0.998	41.86±12.86	39.94±13.30	0.349
AMF	29.38±9.70	29.45±9.45	0.963	30.07±9.26	28.66±9.87	0.346
FiL 1	12.76±4.18	12.76±4.17	0.989	13.14±4.32	12.32±3.95	0.213
FiL 2	12.96±3.97	13.01±3.92	0.941	13.33±4.02	12.58±3.82	0.230
FiL 3	11.33±3.46	11.51±3.51	0.748	11.69±3.47	11.11±3.48	0.292
FiL 4	10.59±3.32	10.65±3.37	0.920	10.93±3.28	10.26±3.38	0.202
FiL 5	9.60±3.19	9.76±3.25	0.755	9.94±3.17	9.37±3.26	0.258

AMF: distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the first and second toes; **BW:** distance between the end points of malleolus medialis and malleolus lateralis; **FDL:** distance between the midpoint of the ankle and the tip of the longest toe; **FiL:** distance between the metatarsophalangeal joint and the distal end of the finger; **FL:** distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; **FW:** distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; **HMF:** distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; **HW:** distance between the widest points of the heel; **MLH:** distance between the top of the malleolus lateralis and the heel; **MMH:** distance between the top of the malleolus medialis and the heel.

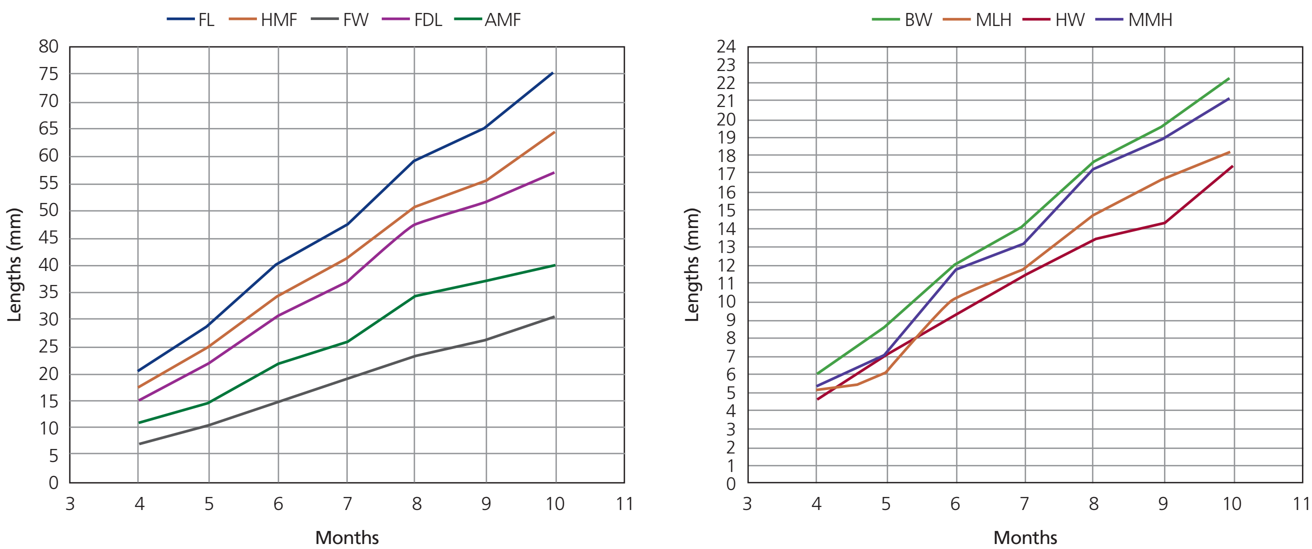

Figure 3. Relationship between fetal foot parameters and gestational age (months). **AMF:** distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the first and second toes; **BW:** distance between the end points of malleolus medialis and malleolus lateralis; **FDL:** distance between the midpoint of the ankle and the tip of the longest toe; **FiL:** distance between the metatarsophalangeal joint and the distal end of the finger; **FL:** distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; **FW:** distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; **HMF:** distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; **HW:** distance between the widest points of the heel; **MLH:** distance between the top of the malleolus lateralis and the heel; **MMH:** distance between the top of the malleolus medialis and the heel.

Discussion

Gestational age is a critical factor in the management, decision-making, prognosis, and follow-up of newborns, particularly preterm infants. Neonatal scoring systems, such as the modified Ballard and Dubowitz scores, are commonly used to determine gestational age based on standardized postnatal assessments of physical and neurological maturity.[3,17] However, applying these scores to assess fetal age can be challenging due to the specialized training and clinical skills required for accurate use. In contrast, measuring foot length with a caliper is a simpler, faster method that requires minimal training and can be used by all levels of healthcare professionals. Moreover, unlike neonatal scoring systems, foot length measurements cause minimal discomfort to the infant.

The World Health Organization's 2012 "Born Too Soon" report emphasized the need for simplified approaches, such as foot measurement, to identify and

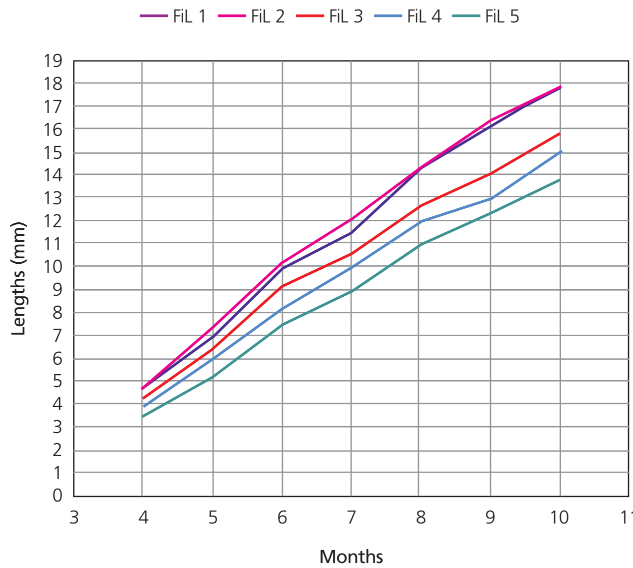

Figure 4. Relationship between fetal finger lengths (FiL) and gestational age (months).

Table 3
Correlation of fetal foot parameters with gestational age (in months).

		FL	HMF	FDL	AMF	FW	HW	BW	MMH	MLH	FiL1	FiL2	FiL3	FiL4	FiL5
Corelation coefficient	Months	0.954	0.952	0.939	0.948	0.911	0.890	0.888	0.939	0.921	0.922	0.934	0.921	0.928	0.923
	FL	1	0.997	0.979	0.958	0.975	0.931	0.985	0.927	0.925	0.972	0.971	0.970	0.973	0.971
	HMF		1	0.977	0.959	0.976	0.930	0.985	0.927	0.925	0.967	0.966	0.962	0.969	0.970
	FDL			1	0.991	0.957	0.900	0.965	0.920	0.921	0.954	0.964	0.959	0.968	0.961
	AMF				1	0.936	0.873	0.943	0.900	0.905	0.932	0.943	0.937	0.945	0.937
	FW					1	0.936	0.964	0.917	0.908	0.953	0.951	0.950	0.958	0.968
	HW						1	0.934	0.870	0.855	0.909	0.905	0.913	0.916	0.920
	BW							1	0.914	0.911	0.961	0.956	0.956	0.957	0.961
	MMH								1	0.962	0.915	0.908	0.903	0.905	0.926
	MLH									1	0.922	0.903	0.899	0.904	0.912
	FiL 1										1	0.967	0.968	0.956	0.954
	FiL 2											1	0.974	0.967	0.959
	FiL 3												1	0.977	0.956
	FiL 4													1	0.972
	FiL 5														1
	P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166

AMF: distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the first and second toes; BW: distance between the end points of malleolus medialis and malleolus lateralis; FDL: distance between the midpoint of the ankle and the tip of the longest toe; FiL: distance between the metatarsophalangeal joint and the distal end of the finger; FL: distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; FW: distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; HMF: distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; HW: distance between the widest points of the heel; MLH: distance between the top of the malleolus lateralis and the heel; MMH: distance between the top of the malleolus medialis and the heel.

Table 4
Simple linear regression equation for estimating gestational age (in months) using fetal foot anthropometric measurements*.

Parameters (mm) (y)	Regression coefficient constant (c)	Regression coefficient for independent variable (m)	r^2	p-value
FL	2.194	0.101	0.904	<0.001
HMF	2.195	0.116	0.896	<0.001
FW	2.691	0.224	0.868	<0.001
BW	2.389	0,327	0.886	<0.001
HW	2.457	0.413	0.824	<0.001
MLH	3.394	0.314	0.727	<0.001
MMH	3.420	0.272	0.739	<0.001
FDL	2.385	0.124	0.883	<0.001
AMF	2.579	0.166	0.845	<0.001
FiL 1	2.644	0.378	0.832	<0.001
FiL 2	2.225	0.404	0.860	<0.001
FiL 3	2.252	0.456	0.848	<0.001
FiL 4	2.428	0.474	0.845	<0.001
FiL 5	2.685	0.493	0.842	<0.001

*The equation y = c + mx was used in the regression analysis. In the equation, "y" represents the dependent variable (gestational age), "c" represents the regression coefficient constant, "m" represents the regression coefficient for the independent variable, and "x" represents the independent variable itself. **AMF:** distance between the midpoint of the ankle and the anterior end point of the metatarsophalangeal fold between the first and second toes; **BW:** distance between the end points of malleolus medialis and malleolus lateralis; **FDL:** distance between the midpoint of the ankle and the tip of the longest toe; **FiL:** distance between the metatarsophalangeal joint and the distal end of the finger; **FL:** distance between Pternion (Pte; heel end point) and the longest toe end point of the foot; **FW:** distance between the medial end point of the first metatarsophalangeal joint and the lateral end point of the fifth metatarsophalangeal joint; **HMF:** distance between Pte and the anterior end point of the metatarsophalangeal fold between the second and third fingers; **HW:** distance between the widest points of the heel; **MLH:** distance between the top of the malleolus lateralis and the heel; **MMH:** distance between the top of the malleolus medialis and the heel.

manage preterm infants early.[3] Several studies have reported ranges for fetal foot length at different gestational ages. For example, Tuncer[16] found foot length ranging from 7.4 to 75.7 mm, Chavan et al.[8] reported foot lengths between 50 and 82.9 mm in fetuses aged 27 to 40 weeks, Majmudar et al.[4] found foot lengths between 50 and 71 mm in fetuses aged 25 to 36 weeks, Stevens et al.[6] reported lengths between 16.13 and 39.86 mm in fetuses aged 14 to 22 weeks, and Shah et al.[18] found foot lengths ranging from 24 to 67 mm in fetuses aged 16 to 39 weeks.

In our study, fetal foot length was measured between 20.01 and 78.3 mm in fetuses aged 13 to 40 weeks, with results consistent with the existing literature (**Table 5**). While there is no comprehensive morphometric data on the fetal foot in the literature, some studies conducted on children or adults have shown that males tend to have significantly longer foot lengths than females. Other studies, however, have reported no significant gender differences. These findings vary between populations.[19–25] Similarly, some studies on adults and children have reported differences in foot length between the right and left sides, though results have varied.[25,26] In our study, no significant differences were found between genders or between the right and left sides.

Ultrasonography is a safe imaging method with no evidence of harm to the fetus and is widely used in studies for fetal measurements. Fetal foot length is an easily measurable parameter, particularly useful when parameters such as head-butt distance, biparietal diameter, head circumference, and femur length cannot be used to determine gestational age. Fetal foot length increases in a normally developing fetus and provides a reliable indicator for gestational age estimation.

In a prospective study conducted by Borgohain and George[27] on 334 Indian pregnant women using antenatal ultrasonography, the correlation coefficients of fetal foot length with head circumference, biparietal diameter, femur length, and abdominal circumference were 0.989, 0.985, 0.994, and 0.808, respectively. This demonstrates a high correlation between fetal foot length and these parameters, with all values being statistically significant

Table 5
Fetal studies on foot length (heel-to-long toe) measurements (mm).

Weeks	Our study (fetal cadaver)	Tuncer[16] (fetal cadaver)	Shah et al.[18] (ultrasound)	Chavan et al.[8] (ultrasound)	Majmudar et al.[4] (ultrasound)	Stevens et al.[6] (ultrasound)	Borgohain and George[27] ultrasound)	Sharma et al.[28] (ultrasound)
8		7.4±0						
9		8.55±0.21						
10		10.45±0.64						
11		14.3±2.69						
12		17.53±4.91						
13	21.6±0.6	22.28±10.32						
14	-	22.95±2.27				16.13	14.8±0	
15	20.6±0.52	26.98±1.98				18.95	20.25±2.9	
16	21.1±2.1	31.69±8.49	24			21.76	-	21.50±2.59
17	20.1±0.1	31.61±2.99	24.8			25.51	25.15±1.81	24.50±1.29
18	28.7±0.6	31.55±4.12	22			29.10	28.25±1.81	26.88±0.83
19	28.6±2	39.06±0.99	28.5			33.62	31.32±1.58	28.16±2.39
20	32±2.5	42.47±5.7	32			36.78	33.69±1.89	33.83±1.94
21	34.2±5.5	46.75±3.46	34			39.12	37.57±1.65	36.33±1.53
22	41.2±1.3	42.93±4.1	37			39.86	40.18±0.91	37.50±0.84
23	36.9±0.1	44.43±9.23	41				42.73±2.05	41.00±4.06
24	44.9±3.1	53.8±0	44				48.35±1.20	41.67±0.58
25	46.2±2.6	50.55±5	44		50		49.23±2.40	48.40±5.18
26	44.4±4.7	-	47		-		53.99±4.50	48.67±2.31
27	50.8±3.5	60.55±2.76	53	50±0	50		51.53±2.12	51.33±1.86
28	50.5±1.7	57.24±2.01	54	55±0	56		57.17±1.60	52.86±2.12
29	55.8±1.3	-	50	56.5±1.7	65		58.66±2.72	57.63±1.92
30	58.1±2.5	70.9±5.8	56	58.8±2.9	59		60.67±3.31	56.86±2.73
31	58.5±3.4	-	60	60±0	58		62.76±2.66	62.29±0.76
32	63.2±7.6	62.5±10.61	62	60.6±2	66		65.78±2.18	61.70±3.27
33	62±2.9	71.7±3.96	61	64.7±1.1	66		66.72±2.52	64.50±4.70
34	63.1±6.1	-	65	65.4±2.4	66		68.98±2.67	67.60±2.30
35	64.5±2.6	78±0	67	70±0	66		70.86±1.19	67.50±3.21
36	70.7±5.6	-	69	70±0	71		71.83±1.49	71.49±1.00
37	67.9±4.5	75.7±0	70	74.5±1.3			73.20±0.84	76.70±0.67
38	75.4±4.3		73	77±2.2				79.00±0.63
39	75.7±4.3		67	80±0.6				80.17±0.75
40	78.3±4.1			82.9±0.8				78.50±7.04

($p<0.001$). Similarly, in a prospective study by Sharma et al.,[28] conducted on 150 pregnant Indian women with gestational ages between 16 and 40 weeks (2020–2021), regression analysis was performed between known gestational age and fetal foot length using ultrasound. The study reported a strong correlation ($r=0.985$, $p<0.001$) between fetal foot length and gestational age, based on simple linear regression analysis.

A systematic review conducted in 2022, which analyzed 20 studies across Asia, North America, Africa, and

Pakistan, found that fetal foot length was highly correlated with gestational age in all included studies.[29] Additionally, Tuncer[16] and Shah et al.[18] demonstrated a strong correlation between foot length and gestational age in their studies on fetuses. Wong[30] reported that foot length showed a linear correlation with gestational age and other parameters, such as biparietal diameter, head circumference, femur length, abdominal circumference, and head-butt length, in fetuses between 10 and 16 weeks. Agnihotri et al.[1] also found a strong correlation between foot length and fetal age in a study conducted on fetal cadavers, with an r^2 value of 0.948 from linear regression analysis. In our study, we observed a similarly strong correlation between foot length and fetal age, with an r^2 value of 0.904. In addition to fetal foot length, we found that other foot parameters, such as toe length, toe and heel width, bimalleolar width, and the heights of the medial and lateral malleoli, also showed a strong correlation with gestational age (**Table 3**). The significant results of these additional foot parameters, along with fetal foot length, suggest that they can be used alongside foot length for more accurate gestational age estimation.

Our study has several limitations. Firstly, the small sample size is a notable limitation, which led to the use of a regression equation for gestational age in months rather than weeks. Additionally, the use of formaldehyde to fix the fetal cadavers, as well as storing them in formaldehyde, may have caused some tissue shrinkage. This factor should be considered when interpreting the study results. Furthermore, data collection was performed by a single observer, and intraobserver and interobserver reliability were not assessed. However, the parameters showed statistically significant correlations ($p<0.001$), and our results were consistent with findings from other studies. Our study is pioneering in its analysis of foot-related parameters beyond just fetal foot length. We presented more comprehensive data on fetal foot morphometry than previous studies, demonstrating that additional foot parameters, such as toe length, heel width, and bimalleolar width, can also be useful for estimating gestational age. This correlation between fetal foot morphometric data and gestational age can be particularly helpful in cases involving anomalies, such as fragmentation during abortion, anencephaly, hydrocephalus, and short limb dysplasia, where traditional measurements like head-butt length, head circumference, and femur length cannot be used. It is also valuable for determining gestational age after spontaneous abortion. Moreover, our findings suggest that foot and foot-related parameters can be useful for age assessment in premature babies and those receiving treatment in neonatal units, offering a practical and accessible method for age determination. The simple measurement of foot and related parameters could also be used to estimate gestational age for babies born outside of hospitals, without requiring a specialist. We suggest that the data obtained from our study will contribute significantly to future research in fields such as anatomy, radiology, obstetrics, perinatology, and fetopathology.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

AEC: project development, data collection, data analysis, manuscript writing; AD: project development, manuscript writing; KÖ: data analysis, manuscript editing; YK: manuscript editing.

Ethics Approval

Fetuses were obtained from the Obstetrics and Gynaecology Hospital with the permission of their families. Approval was obtained from the Süleyman Demirel University Faculty of Medicine Clinical Research Ethics Committee before the study (05/03/2019-86). All procedures performed in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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ORCID ID:
A. E. Canbaloğlu 0000-0002-7560-7865;
A. Dursun 0000-0003-4568-8761;
K. Öztürk 0000-0002-5552-8684;
Y. Kastamoni 0000-0002-3504-5853

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Correspondence to: Abdurrahim Eyüp Canbaloğlu
Department of Physiotheraphy and Rehabilitation,
Faculty of Health Sciences, Istinye University, Istanbul, Türkiye
Phone: +90 534 649 23 22
e-mail: abdurrahim.eyup@gmail.com

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Identification of hyoid bone morphometry in terms of gender in the Turkish population

Ayşe Keven[1], Serra Öztürk Bostancı[2], Güneş Aytaç[3], Muzaffer Sindel[2]

[1]*Department of Radiology, Faculty of Medicine, Akdeniz University, Antalya, Türkiye*
[2]*Department of Anatomy, Faculty of Medicine, Akdeniz University, Antalya, Türkiye*
[3]*Department of Anatomy, John A Burns School of Medicine, University of Hawai'i at Mānoa, Mānoa, Hawaii, USA*

Abstract

Objectives: This study aimed to investigate differences in the morphology of the hyoid bone between genders.

Methods: This retrospective cross-sectional study analyzed patient records from the Akdeniz University Faculty of Medicine, Department of Radiology. The study included 51 male and female patients, aged 19 to 29, who underwent neck CT scans between January 1, 2015, and January 1, 2016. Measurements taken included the length (BL) and width (BH) of the hyoid bone corpus, length of the greater horns (CL), lower end width of the greater horns (CWI), upper end width of the greater horns (CWS), lower end length of the greater horns (CHI), upper end length of the greater horns (CHS), and the distance between the right and left upper edges of the greater horns (WCS).

Results: The values for CL, CWI, CHI, BL, BH, and WCS were significantly higher in males compared to females (p<0.05). However, no statistically significant difference was found between genders for CWS and CHS (p>0.05).

Conclusion: This study provides valuable insights that could contribute to the fields of anatomy, forensic medicine, and anthropology.

Keywords: forensic medicine; hyoid bone; morphometry; sex determination

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Introduction

The hyoid bone is connected to the pharynx, mandible, and cranium through various muscles and ligaments, playing a crucial role in swallowing and respiratory functions through its associated structures.[1] The oropharyngeal complex which is involved in swallowing, chewing, speech, and breathing, is significantly influenced by the development of the hyoid bone, as its growth affects the functionality of this region.[2–4] Understanding the morphometric characteristics of the hyoid bone can be important in the surgical treatment of cancers, as well as respiratory and swallowing disorders in this area. Additionally, abnormalities in the hyoid bone have been linked to conditions like sleep apnea.[5]

Beyond its clinical importance, the hyoid bone also serves as a useful tool in anatomy, anthropology and forensic medicine for determining gender. Previous studies have demonstrated that the fused hyoid bone exhibits sexual dimorphism, making it valuable for gender identification.[6,7] While some researchers suggest that the hyoid bone may be more useful than other bones for determining gender,[8] the accuracy of gender determination depends on the number of bones examined.[9]

Though the literature predominantly highlights the skull and pelvic skeleton as the most reliable bones for sex determination,[10] studies investigating sexual dimorphism through hyoid bone measurements are relatively scarce.

Therefore, the aim of this study is to explore potential anatomical differences between male and female hyoid bones using CT scan images and to establish new guidelines for anatomical classification based on anthropometric parameters.

This study was a poster presentation at the 17th National Anatomy Congress, 5–9 September 2016, Eskişehir, Türkiye.

Materials and Methods

This retrospective cross-sectional study was conducted using patient records from the Akdeniz University Faculty of Medicine, Department of Radiology. A total of 51 patients (29 males and 22 females), aged between 19 and 29, who underwent neck CT scans between January 1, 2015, and January 1, 2016, were included to analyze the anatomy of the hyoid bone. Measurements included the length (BL) and width (BH) of the hyoid bone corpus, length of the greater horns (CL), lower end width of the greater horns (CWI), upper end width of the greater horns (CWS), lower end length of the greater horns (CHI), upper end length of the greater horns (CHS), and the distance between the right and left upper edges of the greater horns (WCS).

Patients with neck trauma or motion artifacts were excluded from the study. The images were obtained using a Siemens Somatom Dual Source CT scanner (Siemens Healthcare AG, Erlangen, Germany) and derived from axial, sagittal, and coronal reformatted images (512×512 matrix, 1 mm section thickness, 100 kV voltage, 55 mAs current) transferred to a workstation. Additional processing was performed to isolate the hyoid bone by removing surrounding muscles, bones, and soft tissues, resulting in 3-dimensional volume-rendered images of the os hyoideum. Statistical analyses were conducted using the SPSS for Windows, version 23.0 (IBM, Armonk, NY, USA). Comparisons between male and female data were performed using Student's t-test and a p-value of <0.05 was considered statistically significant.

Results

The measurements taken from the hyoid bone are illustrated in **Figure 1**. The average values of the data and corresponding p-values are presented in **Table 1**. Significant differences were found in several measurements between males and females, with CL, CWI, CHI, BL, BH, and WCS values being significantly higher in males ($p<0.05$) (**Table 1**).

For males, the average BL (length of the hyoid bone corpus) was 23.04 mm, while for females, it was 18.93 mm. The average BH (width of the hyoid bone corpus) was 9.21 mm in males and 8.02 mm in females. The average CL (length of the greater horns) was 31.44 mm in males,

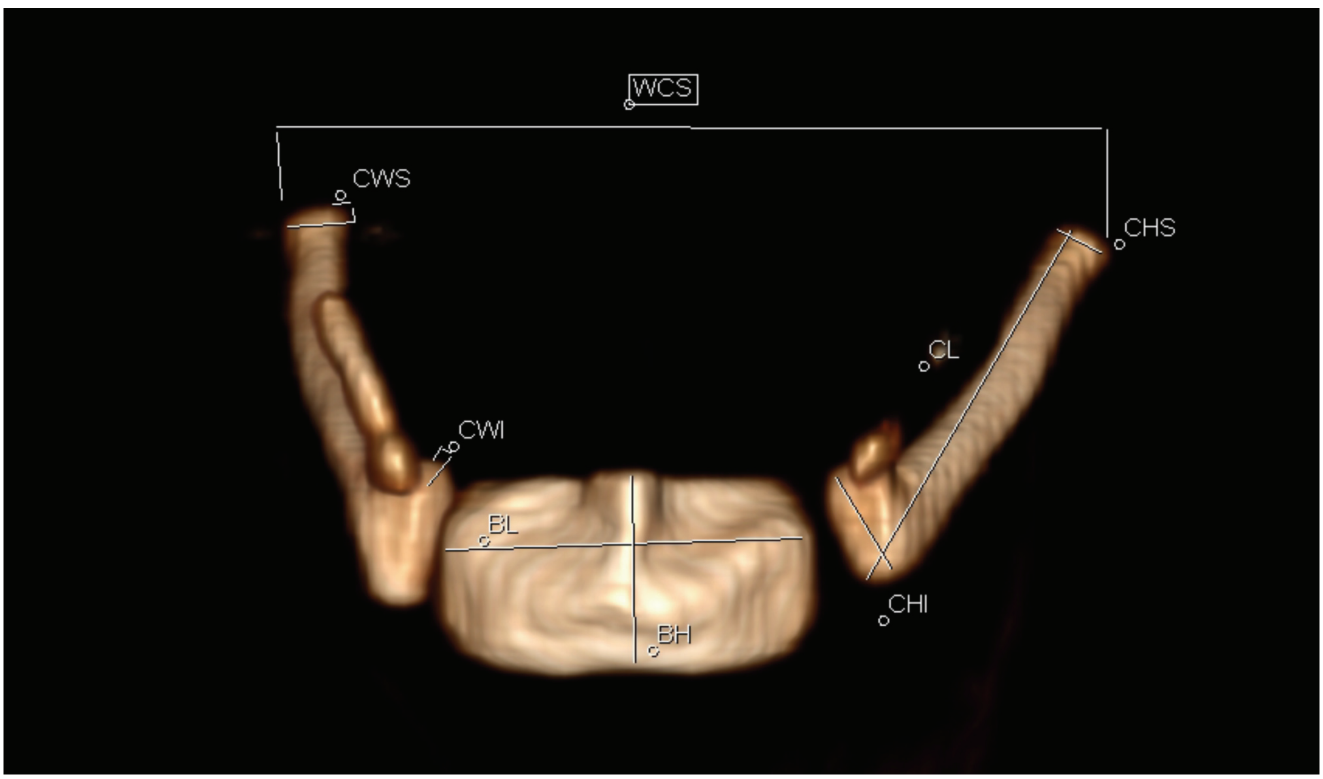

Figure 1. The measured sections on the hyoid bone. **BL:** the length of the corpus hyoid bone; **BH:** width of the corpus hyoid bone; **CL:** length of greater horns; **CWI:** the lower end width of the greater horns; **CWS:** the width of the greater horns at the upper end; **CHI:** the lower end length of the greater horns; **CHS:** the upper end length of the greater horns; **WCS:** the distances between the right and left upper edges of the greater horns.

compared to 26.55 mm in females. The average CWI (lower end width of the greater horns) was 4.93 mm in males and 3.53 mm in females. For CHI (lower end length of the greater horns), the average value in males was 7.51 mm, while in females it was 5.45 mm. The WCS (distance between the right and left upper edges of the greater horns) was 45.40 mm in males and 40.78 mm in females.

There was no statistically significant difference between the CWS (upper end width of the greater horns) and CHS (upper end length of the greater horns) values between the sexes (p>0.05) (**Table 1**). The average CWS value for both males and females was 2.78 mm. The average CHS value was 45.40 mm for males and 40.78 mm for females. The distribution of these findings by sex is shown in **Figure 2**.

Table 1
Osteometric measurements of the hyoid bone.

Dimensions	Female	Male
BL	18.93±2.76 mm	23.04±1.96 mm
BH	8.02 ±1.58 mm	9.21±1.70 mm
CL	26.55±3.75 mm	31.44±3.65 mm
CWI	3.53±0.57 mm	4.93±1.98 mm
CWS	2.78±0.35 mm	2.78±0.53 mm
CHI	5.45±1.04 mm	7.51±1.06 mm
CHS	2.94±0.49 mm	3.03±0.42 mm
WCS	40.78±4.65 mm	45.40±6.01 mm

BL: the length of the corpus hyoid bone; **BH:** width of the corpus hyoid bone; **CL:** length of greater horns; **CWI:** the lower end width of the greater horns; **CWS:** the width of the greater horns at the upper end; **CHI:** the lower end length of the greater horns; **CHS:** the upper end length of the greater horns; **WCS:** the distances between the right and left upper edges of the greater horns.

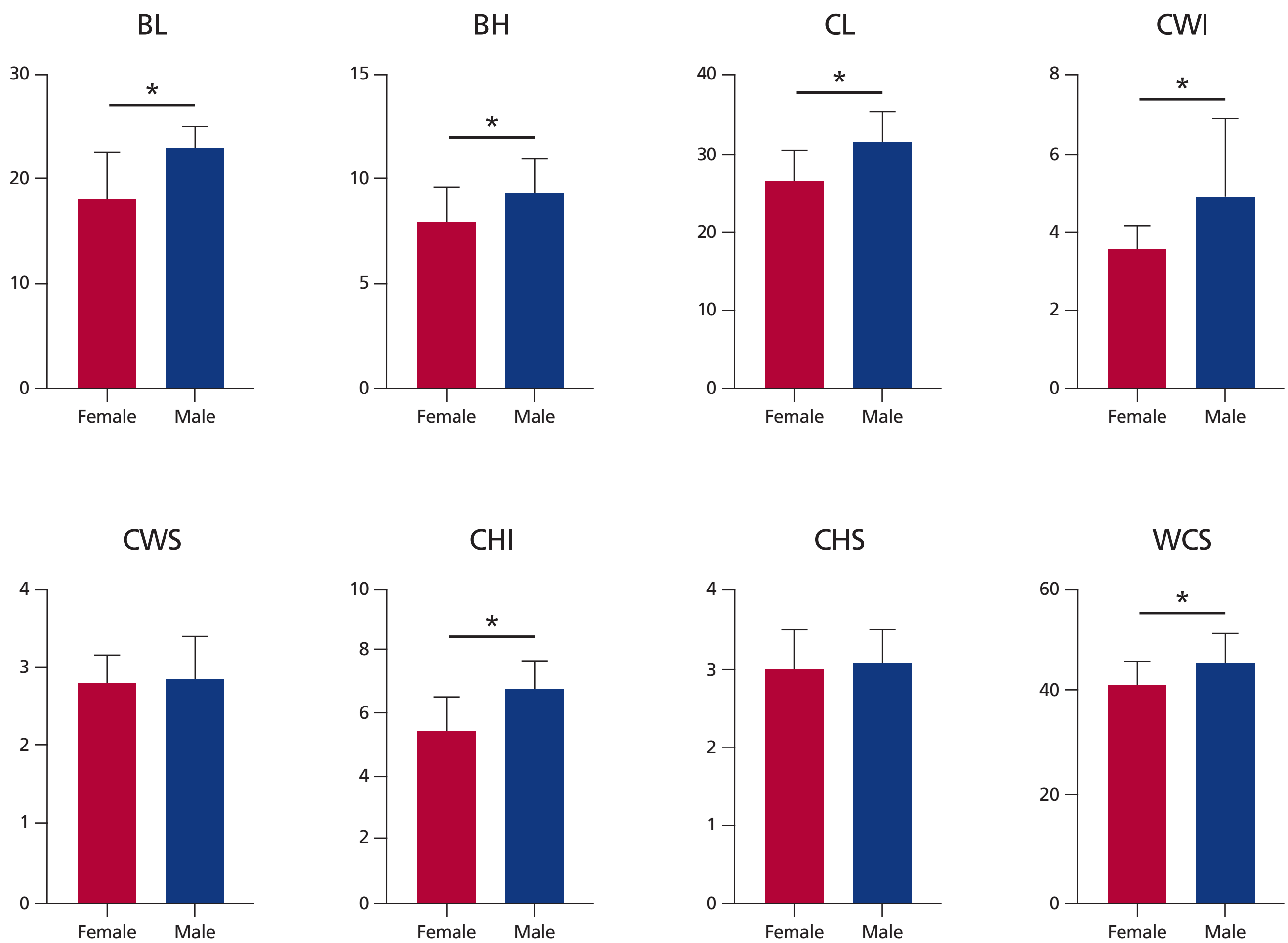

Figure 2. Distribution of measurements between male and female groups (*p<0.005). **BL:** the length of the corpus hyoid bone; **BH:** width of the corpus hyoid bone; **CL:** length of greater horns; **CWI:** the lower end width of the greater horns; **CWS:** the width of the greater horns at the upper end; **CHI:** the lower end length of the greater horns; **CHS:** the upper end length of the greater horns; **WCS:** the distances between the right and left upper edges of the greater horns.

Discussion

The morphometric values and variations of the hyoid bone are critical for both clinical and anthropological evaluations. Given its close relationship with muscles, ligaments, fascia, the sternum, and clavicle, any dysfunction of the hyoid bone can lead to both local and systemic issues.[11] Therefore, understanding the anatomical dimensions, angles, and morphology of the os hyoideum is essential in the surgical treatment of cancers, as well as respiratory and swallowing disorders in this region.[12]

In our study, we examined the morphological characteristics of the hyoid bone, specifically the body, and the height and width parameters of the greater horns (cornu majus). Although our results were similar to those of Kinschuh et al.,[8] the values for females in our study were slightly lower. When compared to the study by Dursun et al.[13] the CL, BL, BH, and WCS values were consistent. However, our CWI value was found to be approximately half of the value reported in that study

In the study by Kim et al.[14] most of the hyoid bone measurements were similar between males and females, with the exception of WCS. In our study, the WCS value for females was 40 mm, while Kim et al.[14] reported it as 35 mm. However, our WCS value for males was very similar. These small differences could be attributed to variations in the demographic characteristics of the study populations, differences in measurement techniques, or inherent differences in hyoid bone sizes.

All of our measurements showed that the hyoid bone dimensions were larger in males compared to females. Werner et al.[15] also observed that the width of the hyoid bone was greater in males, although they found the length to be longer in females. The CL, BL, and BH values of our study were consistent with those reported by Chatzioglou et al.[16] on adult hyoid bones, regardless of gender. In their study, the average WCS length was 43.89 mm, while we found it to be 40 mm in females and 45 mm in males. Similarly, while they reported an average CL length of 30 mm, we found it to be 26 mm in females and 31 mm in males.

In the study by Shimizu et al.[17] it was noted that the body and greater horns of the hyoid bone were longer in males, and the width of the corpus was wider. Our study corroborated these findings, as we also observed that the length of the greater horns, the widths of both the lower and upper ends, as well as the length and width of the corpus, were larger in males compared to females.

Conclusion

Knowing the measurements of the hyoid bone is crucial for determining both age and gender. Some researchers suggest that assessing sex from the hyoid bone is simpler compared to other bones, and thus, recommend its use in cases where bone analysis is needed for gender determination. We believe that the comprehensive measurements obtained in our study will provide valuable insights and make a significant contribution to the fields of anatomy, forensic medicine, and anthropology.

Conflict of Interest

Authors declare that they have no conflict of interest.

Author Contributions

AK: project development, data collection, data analysis, manuscript writing; SOB: project development, data analysis, manuscript writing; GA: project development, manuscript writing; MS: project development, manuscript editing.

Ethics Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the suitably constituted Ethical Committee at the Researches Department of Akdeniz University, within which the work was undertaken, and the study conforms to the Declaration of Helsinki (Protocol code:2012-KAEK-20, date: 03.08.2016).

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ORCID ID:
A. Keven 0000-0002-1662-8586;
S. Öztürk Bostancı 0000-0003-1002-0059;
G. Aytaç 0000-0003-4902-2844;
M. Sindel 0000-0002-6594-1325

deomed

Correspondence to: Serra Öztürk Bostancı, PhD
Department of Anatomy, Faculty of Medicine,
Akdeniz University, Antalya, Türkiye
Phone: +90 554 801 84 71
e-mail: serraozturk@akdeniz.edu.tr

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Learning outcomes for postgraduate education in anatomy based on national qualifications framework

Behice Durgun

Department of Anatomy, Faculty of Medicine, Çukurova University, Adana, Türkiye

Abstract

Postgraduate education provides students with a higher level of education in their chosen subject of study. This study described and discussed learning outcomes for postgraduate education in anatomy, drawing on the author's own experiences. Because learning at higher levels is contingent on acquiring prerequisite knowledge, skills, and competences at lower levels, learning outcomes based on lower-level qualifications were established for each degree. The arrangement of postgraduate programs varies greatly not only between nations but also among the universities within the same country. Having a uniform framework appears to be a useful and novel guideline for institutions. The National Qualifications Framework for Higher Education in Türkiye (NQF-HETR) provides specific explanations for degrees based on learning outcomes and content to build new qualifications. Learning outcomes reflect what a learner is expected to know, understand, and/or be able to do by the end of a learning period. There are three categories of learning outcomes: knowledge, skills, and competences. Learning outcomes for postgraduate education in anatomy provide a means of translating the goals of an anatomy course or program into a set of competences, as well as providing students with clear indications of their paths through postgraduate education and what levels of knowledge and skills will qualify them for degree awards. Learning outcomes also provide a useful language for communicating about a curriculum.

Keywords: anatomy education; learning outcomes; national qualifications framework; postgraduate education

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Introduction

Postgraduate programs represent a crucial part of university education and research. Traditionally, they were primarily viewed as a path to pursuing academic careers in the future. In recent years, there has been a rapid increase in the number of postgraduate candidates and major changes in the global job market. Therefore, universities have to change postgraduate programs to adapt to new conditions. Postgraduate education has also increased in importance in the context of the Bologna Process since the Berlin Communiqué (2003), which, following a recommendation from the European University Association (EUA), included doctoral programs as the "third cycle" after bachelor's and master's degrees.[1,2]

Master's programs (second cycles) focus on developing specific professional or occupational abilities. A master's degree is typically obtained through research, coursework, or both. A study is gaining an in depth understanding of a given field of study, typically by independent investigation. In Türkiye, there are two types of master's programs: those with and without a thesis.[3]

Doctoral programs (third cycles) are regarded as a critical source for the next generation of researchers, acting as the primary link between European Higher Education (EHE) and European Research Areas (ERA).[2,4] As a result, they have become an official and significant component of the political agenda for the Bologna Process. However, doctoral programs differ significantly from the first and second cycles of higher education. The primary characteristics of doctoral programs are: (a) a thorough review of the literature, experimentation, or other systemic approach to a body of knowledge; (b) an original research project resulting in a significant contribution to knowledge and understanding and/or the application of knowledge within a field of education; and (c) a substantial and well-ordered thesis demonstrating the relationship of the research to the broader framework of the field.[3–6]

In this study, learning outcomes for master's and doctoral degrees in anatomy based on "National Frameworks of Qualifications for Higher Education in Türkiye (NQF-HETR)" were described and discussed with the contribution of the author's own experiences and studies.

Qualifications

National frameworks of qualifications are typically constructed using similar elements to those indicated in the Berlin Communiqué (2003).[1] Qualifications are defined in this report as any degree, diploma, or certificate issued by a competent authority, attesting that specific learning outcomes have been achieved. This usually follows the successful completion of a recognized higher education program.[2]

Learning Outcomes

Learning outcomes are one of the most important building blocks for openness in higher education systems and certifications. They were the focus of a Bologna Conference held in Edinburgh on July 1–2, 2004, when all issues of their application were discussed in light of Bologna developments.[7]

Learning outcomes are the expression of what a learner is supposed to know, comprehend and do after completing a learning process. The use of active verbs to represent knowledge, comprehension, application, analysis, synthesis, and evaluation, among other things, distinguishes learning outcome statements. The "outcomes-based approaches" have consequences for qualifications, curriculum design, teaching, learning, and assessment, as well as quality assurance.

Learning outcomes a) help teachers to translate the aims of a course or program of study into a set of competencies that the learner is expected to be able to demonstrate by satisfactorily performing a set of assessment tasks, b) make it easier to recognize and give credit for learning acquired in another institution, and c) help employers to understand what they can expect a graduate to know, understand and be able to do.[3,8]

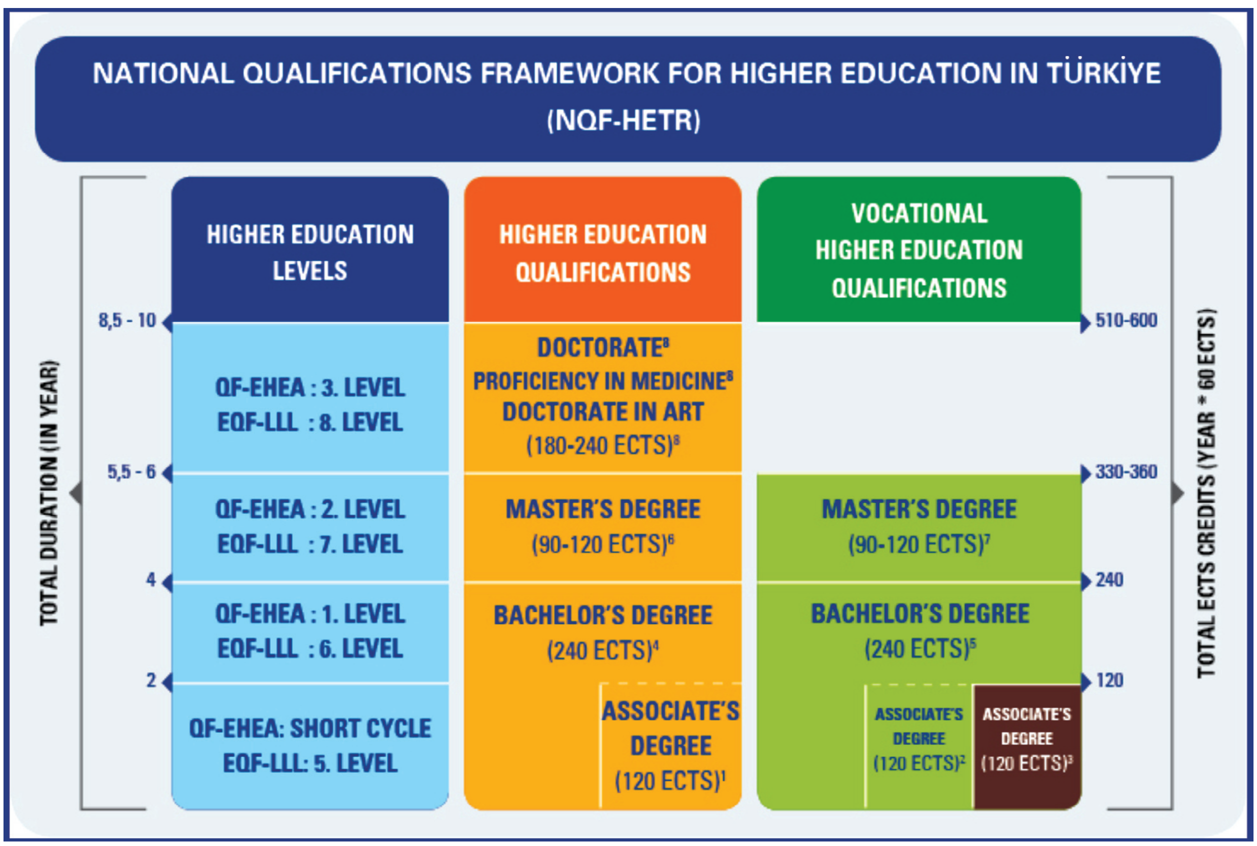

Figure 1. Qualifications' profiles for NQF-HETR levels. Retrived from http://tyyc.yok.gov.tr/

Descriptors of Learning Outcomes

Descriptors of learning outcomes include three components: (a) theoretical and conceptual knowledge; (b) cognitive and practical skills; and (c) competences. The shared qualification descriptors (Dublin descriptors) produced as part of the Joint Quality Initiative (JQI) comprise generic competences (skills and knowledge) as well as qualities like the ability to learn, analyze and synthesize, and so on.[5,8]

National Qualifications Framework for Higher Education in Türkiye (NQF-HETR)

Türkiye participated in the Bologna Process in 2001, and since then it has been actively involved in the process under the responsibility and coordination of the Council of Higher Education (CoHE, YÖK). The development of the National Qualifications Framework for Higher Education in Turkey (NQF-HETR) has been a major success in the framework of the Bologna Implementations in Türkiye.[8,9] The importance of NQF-HETR is that it presents not only certain explanations among the degrees based on the learning outcomes but also content to design new qualifications. The process involves the careful mapping of national qualifications (their levels, learning outcomes, and descriptors) with the cycle descriptors identified for the European overarching framework. NQF-HETR can be defined with four cycles, including associate's, bachelor's, master's, and doctoral degrees, with its current design. Defining these qualification groups in NQF-HETR with different profiles and their degrees is important for the transparency and comprehensibility of NQF-HETR.[8]

Table 1

Master's level (Level7) qualifications in Türkiye. These qualifications may be applied to the field of health.

National Qualifications Framework for Higher Education in Turkiye (NQF-HETR)* 7. Level (Associate's) Qualifications						
			COMPETENCES			
NQF-HETR LEVEL	KNOWLEDGE - Theoretical - Conceptual	SKILLS - Cognitive - Practical	Competence to work independently and take responsibility	Learning competence	Communication and social competence	Field specific competence
7 MASTER'S _____ EQF-LLL: 7. level _____ QF-EHEA: 2. cycle	- Develop and deepen knowledge in the same or in a different field to the proficiency level based on Bachelor level qualifications. - Conceive the interdisciplinary interaction which the field is related with.	- Use of theoretical and practical knowledge within the field at a proficiency level. - Interpret the knowledge about the field by integrating the information gathered from different disciplines and formulate new knowledge. - Solve the problem faced related to the field by using research methods.	- Independently conduct studies that require proficiency in the field. - Take responsibility and develop new strategic solutions as a team member in order to solve unexpected complex problems faced within the applications in the field. - Demonstrate leadership in contexts that require solving problems related to the field.	- Evaluate knowledge and skills acquired at proficiency level in the field with a critical approach and direct the learning.	- Communicate current developments and studies within the field to both professional and non-professional groups systematically using written, oral and visual techniques by supporting with quantitative and qualitative data. - Investigate, improve social connections and their conducting norms with a critical view and act to change them when necessary. -Communicate with peers by using a foreign language at least at a level of European Language Portfolio B2 General Level. - Use advanced informatics and communication technology skills with software knowledge required by the field.	- Audit the data gathering, interpretation, implementation and announcement stages by taking into consideration the cultural, scientific, and ethic values and teach these values. - Develop strategy, policy and implementation plans on the issues related to the field and assess the findings within the frame of quality processes. - Use the knowledge, problem solving and/or implementation skills in interdisciplinary studies.

*Retrived from http://tyyc.yok.gov.tr/

Qualification Profiles for NQF-HETR Levels

Qualification profiles under the NQF-HETR were judged to be adequately divided as (1) Qualifications for Higher Education and (2) Qualifications for Vocational Higher Education (**Figure 1**). The level descriptors (generic learning outcomes) for associate's, bachelor's, master's, and doctoral degrees, as well as all levels of higher education under the NQF-HETR system, were developed, as were their qualification profiles (differences). **Tables 1** and **2** reflect the qualifications for both master's and doctoral levels as defined in the NQF-HETR.

Bloom categorized educational objectives (learning outcomes) into three "domains": cognitive, emotional, and psychomotor. Bloom also categorizes cognitive outcomes into subcategories ranging from the most basic to the most sophisticated. According to Bloom's Taxonomy, learning at higher levels depends on having obtained prerequisite knowledge and skills at lower levels. The main difference between Bloom's Taxonomy and NQF-HETR classification is that the emphasis has shifted from instructional objectives which describe what instructors do, to the student learning outcomes which describe what students can do as a result of their educational experiences.[10,11]

Learning Outcomes for Master's and Doctorate Education in Anatomy

NQF-HETR is a guide to plan both the education of master's, doctoral or speciality education as well as the core curriculum in anatomy. For example; The Turkish Society of Anatomy and Clinical Anatomy (TSACA) has prepared an "Anatomy Core Education Program" taken into consideration NQF-HETR for Anatomical Applications and Scientific Activities for Medical Specialization and Doctoral Students on 04.12.2019.[12] NQF-HETR is also used to prepare questions for the assesments.[11]

In **Table 3**, two separate columns were created based on the author's experiences to compare the learning outcomes for anatomy master's and doctoral education based on NQF-HETR.

Table 2

Doctorate level (Level 8) qualifications. These qualifications may be applied to the field of health.

National Qualifications Framework for Higher Education in Turkiye (NQF-HETR)* 8. Level (Associate's) Qualifications						
			COMPETENCES			
NQF-HETR LEVEL	KNOWLEDGE - Theoretical - Conceptual	SKILLS - Cognitive - Practical	Competence to work independently and take responsibility	Learning competence	Communication and social competence	Field specific competence
8 DOCTORATE —— EQF-LLL: 8. level —— QF-EHEA: 3. cycle	- Develop and deepen the current and advanced knowledge in the field with original thought and/or research and come up with innovative definitions based on Master's degree qualifications. - Conceive the interdisciplinary interaction which the field is related with; come up with original solutions by using knowledge requiring proficiency on analysis, synthesis and assessment of new and complex ideas.	- Evaluate and use new information within the field in a systematic approach. - Develop an innovative knowledge, method, design and/or practice or adapt an already known knowledge, method, design and/or practice to another field; research, conceive, design, adapt and implement an original subject. - Critical analysis, synthesis and evaluation of new and complex ideas. - Gain advanced level skills in the use of research methods in the field of study.	- Contribute the progression in the field by producing an innovative idea, skill, design and/or practice or by adapting an already known idea, skill, design, and/or practice to a different field independently. - Broaden the borders of the knowledge in the field by producing or interpreting an original work or publishing at least one scientific paper in the field in national and/or international refereed journals. - Demonstrate leadership in contexts requiring innovative and interdisciplinary problem solving.	- Develop new ideas and methods in the field by using high level mental processes such as creative and critical thinking, problem solving and decision making.	- Investigate and improve social connections and their conducting norms and manage the actions to change them when necessary. - Defend original views when exchanging ideas in the field with professionals and communicate effectively by showing competence in the field. - Ability to communicate and discuss orally, in written and visually with peers by using a foreign language at least at a level of European Language Portfolio C1 General Level.	- Contribute to the transition of the community to an information society and its sustainability process by introducing scientific, technological, social or cultural improvements. - Demonstrate functional interaction by using strategic decision making processes in solving problems encountered in the field. - Contribute to the solution finding process regarding social, scientific, cultural and ethical problems in the field and support the development of these values.

*Retrived from http://tyyc.yok.gov.tr/

Table 3
Learning outcomes for anatomy master's and doctoral education based on NQF-HETR *[to be continued]*.

MASTER LEVEL 7 (CYCLE 2)	DOCTORATE LEVEL 8 (CYCLE 3)
KNOWLEDGE - Theoretical - Conceptual	
- Explain and deepen the anatomical concepts and fields of study based on Bachelor level qualifications. - Desribe the normal gross anatomy, vascularization, innervation, lymphatic drainage, and functional relationships of the structures. - Differentiate variations and abnormalities in the human body. - Define the surface anatomy of the structures. - Combine knowledge of anatomy with knowledge of other fields. - Use anatomical knowledge to explain the clinical cases. - Understand the technologies, technical equipment, cadavers, models, and microscopic techniques essential in the anatomy discipline. - Interpret, evaluate, synthesize, and combine anatomy with other disciplines to provide new information. - Design scientific researches in the field of anatomy and creates a report. - Identify commonly used statistical approaches in anatomy and related fields.	- Develop and deepen current and advanced knowledge on the functional relationships of organs, structures, and systems based on Master's degree qualifications with original thought and/or research and reach the original definitions that will bring innovation to the field of anatomy. - Explain variations and anomalies in the human body based on phylogenetic and ontogenetic development. - Conceive the interdisciplinary interactions related to anatomy; analyze, synthesize, and evaluate original and new ideas. - Distinguish 2D and 3D radiological images of structures and integrate this information with knowledge of anatomy. - Make interpretations about clinical cases by using anatomy knowledge. - Develop new methods for anatomy education. - Develop an original idea, method, and design/application that brings innovation to anatomy or implements a known thought, method, and design/application in different fields. - Choose accurately statistical methods, implements for the research of anatomy and related disciplines and analyze and synthesize within the scope of ethical rules. - Write the report of a research in which he or she participated and publishes or presents it in peer-reviewed national or international journals or scientific meetings.
SKILLS - Cognitive - Practical	
- Perform the macroscopic and microscopic dissection of the cadaver with appropriate techniques. - Draw the reference points, superficial contours, and projections of structures, vessels, and nerves on the living human body. - Follow the ethical rules in proceedings after dissection, obtaining, conservation, and using process of cadaver. - Perform experiments and measurements in the field of anatomy. - Interpret the knowledge about anatomy by integrating the information gathered from different disciplines and formulating new knowledge. - Solve the problem faced related to anatomy by using research methods.	- Perform investigations by using tools, devices, instruments, and technologies required by the anatomy field and related disciplines at an advanced level and develop new and creative solutions for problems. - Evaluate and use new information within the anatomy field with a systematic approach. - In advanced-level skills in the use of research methods in the field of anatomy.
COMPETENCES Competence to work independently and take responsibility	
- Conduct research on anatomy and related fields independently or as a team member. - Take responsibility and develop new strategic solutions in order to solve unexpectedly complex problems faced within the applications of anatomy. - Demonstrate leadership in contexts that require solving problems related to anatomy.	- Broaden the borders of knowledge in the anatomy field by producing or interpreting an original work or publishing at least one scientific paper in the field in national and/or international refereed journals. - Demonstrate leadership in contexts requiring innovative and interdisciplinary problem solving.
Learning competence	
- Evaluate knowledge and skills acquired at the proficiency level in the field with a critical approach and direct the learning.	- Develop evidence-based new ideas and methods in the anatomy field by using mechanisms of creative and critical thinking, problem solving, and decision-making.

Table 3
Learning outcomes for anatomy master's and doctoral education based on NQF-HETR *[continued]*.

MASTER LEVEL 7 (CYCLE 2)	DOCTORATE LEVEL 8 (CYCLE 3)
Communication and social competence	
- Communicate current developments and studies within the anatomy field to both professional and non-professional groups systematically by using written, oral, and visual techniques, supported by quantitative and qualitative data. - Investigate, improve social connections and their norms with a critical view, and act to change them when necessary. - Communicate with peers by using a foreign language, at least at the European Language Portfolio B2 General Level. - Use advanced informatics and communication technology skills with the software knowledge required by the anatomy field.	- Use the current developments and knowledge regarding the anatomy field for the benefit of children, families, national values, and societies in accordance with the facts of the country. - Defend original views when exchanging ideas in the anatomy field with professionals and communicate effectively by showing competence in the field. - Discuss and make visual, written, and oral communication with peers by using the C1 level for the Common European Framework of Reference for Languages at an advanced level.
Field specific competence	
- Audit the anatomical data gathering, interpretation, implementation, and announcement stages by taking into consideration cultural, scientific, and ethical values. - Develop strategies, policies, and implementation plans on the issues related to the anatomy field and assess the findings within the framework of quality processes. - Use knowledge, problem-solving skills, and/or implementation skills in interdisciplinary studies.	- Communicate functionally by using mechanisms of ethical and strategic decision-making for solving encountered problems; contribute to and maintain the process of information society by presenting scientific, technological, social, and cultural advancements related to the anatomy field. - Demonstrate functional interaction by using strategic decision-making processes to solve problems encountered in the field of anatomy. - Contribute to the solution-finding process regarding social, scientific, cultural, and ethical problems in the anatomy and related fields and support the development of these values.

Training in Core and Transferable Skills

Acknowledging the diverse career paths available to postgraduates and the complex demands of the global job market, universities have made it a priority to offer a broad selection of courses and modules within their postgraduate programs. In the field of anatomy, different types of training such as lectures, seminars, colloquia, and summer schools provide scientific training in core research skills such as research methodology, techniques, management, analysis, diffusion, problem-solving, scientific writing, publishing, awareness of scientific ethics and intellectual property rights, etc. Additionally, these training programs also provide instruction in transferable (generic) personal and professional skills and competences such as writing and communication skills, networking and teamwork, materials and human resources (i.e. cadaver) management, time management, career management including job-searching tactics, leadership abilities, and so on. Scientific training in essential research abilities is typically necessary, however it is usually provided voluntarily to meet the individual needs of postgraduate anatomy applicants through a range of modules or courses.

Conclusion

Finally, it is preferable to raise awareness about the importance of improving postgraduate programs and career opportunities in anatomy. Higher education institutions, government ministries of education and research, innovation and technology, and national scientific councils should all work collaboratively to address this issue.

The wide variety of scientific disciplines has had an important effect on the structure of postgraduate education. These differences must be considered when designing postgraduate programs in anatomy, but they should not be interpreted as a barrier to developing novel methods of providing candidates with the opportunity to improve their abilities and gain additional experience in an international and interdisciplinary research environment, as well as to be better prepared for future possibilities.

Conflict of Interest

None.

Ethics Approval

Since this study is a review and reflects the author's perspectives on the topic, ethical approval was not required.

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ORCID ID:
B. Durgun 0000-0003-0065-551X

Correspondence to: Behice Durgun, PhD
Department of Anatomy, Faculty of Medicine,
Çukurova University, Adana, Türkiye
Phone: +90 532 577 78 95
e-mail: bdurgun@cu.edu.tr

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