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Editor-in-Chief
Nihal Apaydın, MD
Department of Anatomy,
Faculty of Medicine, Ankara University,
06100, Sıhhıye, Ankara, Türkiye
Phone: 0090 312 595 82 48
e-mail: napaydin@gmail.com; napaydin@medicine.ankara.edu.tr

Administrative Office
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Anatomical evaluation of sacrum in dry bones

Ayşe Gamze Özcan, Ekrem Solmaz, Mehmet Cengiz Tatar, Ahmet Kağan Karabulut

Department of Anatomy, Faculty of Medicine, Selçuk University, Konya, Türkiye

Abstract

Objectives: The sacrum is a critical bone in various clinical procedures, including caudal epidural blocks, iliosacral screw placements, fetal growth assessment, and sacral nerve stimulation. This study aims to investigate the morphometry and variational morphology of the anatomical formations in the pelvis and dorsal surface of the sacrum.

Methods: Morphometric and morphological characteristics of 30 sacral bones of unknown age and sex were examined. Measurements were made using a digital caliper.

Results: The mean height of the sacrum was 106.67±10.16 mm, while their mean width was 103.60±6.78 mm. The morphometric analysis revealed that the mean length of the sacral hiatus was 18.51±7.44 mm, and the distance between the sacral cornua was 11.80±2.46 mm. The sacral hiatus was most commonly observed in an inverted 'U' shape, while the least common form was bifid. The sacral canal typically displayed a V-shaped morphology. It was determined that the apex of the sacral hiatus most frequently started at the S4 level (80%) compared to the sacral vertebra, and the base of the sacral hiatus mostly ended at the S5 level (93.4%).

Conclusion: Morphometry of the sacrum is essential in guiding clinicians, especially in interventions such as anesthesia and orthopedics. Discrepancies in parameter studies conducted in some countries suggest the significance of ethnic factors. Therefore, it is essential for the number of studies to increase and for physicians to follow the parameters of their society regarding the effectiveness of the treatments.

Keywords: caudal epidural block; sacral canal; sacral hiatus; sacrum

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Introduction

The sacrum is an important bone in our body that connects the trunk and lower extremities and joins the structure of the pelvis, which has an essential place in force transfer. The sacrum, formed by the union of five vertebrae, has two surfaces: the dorsal and pelvic surfaces. It is a triangular bone with its base above and its apex below. Its base articulates with the last lumbar vertebra above. Its apex is the lower part of the sacrum and articulates with the coccyx. Inside the sacrum is a passage called the sacral canal, which is a continuation of the vertebral canal. The four holes on the lateral side of the intermediate sacral crest are called dorsal sacral foramina. The posterior branches of the sacral spinal nerves pass through these foramina.[1,2]

The sacrum is an important bone for clinicians. The sacral length is an essential guide in evaluating fetal growth in obstetrics and gynecology.[3] In pelvic floor disorders such as constipation, fecal, and urinary incontinence, percutaneous electrodes are placed through the dorsal sacral foramina, and sacral nerve stimulation is performed.[4,5] The caudal epidural block is frequently used for anesthesia in various surgeries and for analgesia in diseases such as chronic low back pain and lumbar spinal disorders. Caudal epidural block is the injection of an anesthetic/analgesic agent into the sacral epidural region through the sacral hiatus (SH).[6,7] The protrusion at the bottom of the intermediate sacral crest, the remnant of the inferior articular process of the last sacral vertebra, is called sacral horn (corn). The SH is the opening between the sacral cornua on both sides.[8] During the caudal epidural block, compli-

This study was presented at the 2nd International Congress of Selcuk Health Sciences, Konya, Turkey, on November 30 – December 1, 2023. Its abstract was published in abstract-proceeding e-book, pp. 56–57.

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cations arise due to shape variations and size differences of the SH or technical reasons, and the success rate decreases. These complications include direct injury to spinal nerves, epidural abscess, massive subdural tear, epidural hematoma, ischemia, and hemorrhage. Therefore, caudal epidural block requires precise localization of the SH.[9,10] Any stabilization procedure with instrumentation of the sacrum may be necessary due to the sacrum fractures and associated joint injuries.[11] The iliosacral screw insertion provides stable fixation, and the iliosacral screw applied to the body of the sacrum passes through the S1 pedicle.[12] Although pedicle screws placed in the sacrum are an effective system to provide stabilization, they cause instrument loss and pseudoarthrosis at a higher rate than those applied to the lumbar vertebrae.[13] It is necessary to know the anatomy of the sacrum well to ensure safe intervention in screw-plate applications and to reduce the problems encountered.[12]

The sacrum is an important bone for various clinical situations as mentioned above. Anatomical verification and knowledge of standard structural features of the sacrum are required for a successful procedure. In addition, the procedures' reliability and success depend on the sacrum's anatomical variations. This study aims to measure the morphometry of the anatomical formations in the pelvic and dorsal surfaces of the sacrum and to investigate various variations by obtaining information about their morphology.

Materials and Methods

In this study, morphometric and morphological characteristics of 30 sacral bones of unknown age and sex were examined in the Department of Anatomy. Missing or broken sacrum were excluded from the study. Measurements of anatomical structures were made using a digital caliper (Insize 1108/ Suzhou, People's Republic of China) with a measurement range of 0–150 millimeters (mm) and sensitivity of 0.03 mm.

The following parameters were measured in the morphometric evaluation of the sacrum (Figure 1):

- The SH length (distance from the top of the SH to the end of the sacral cornua),
- The distance from the apex of the sacrum to the highest point of the SH,
- The length between the sacral cornua,
- The distance between the dorsal sacral foramina at the S2 level and the top of the SH,
- The distance between the upper border of the S1 vertebra and the top of the SH,
- The distance between the dorsal sacral foramina at the S2 level and the apex of the sacrum,
- The distance of the highest point of the SH to the highest point of the right lateral sacral crest,
- The distance from the highest point of the SH to the highest point of the left lateral sacral crest,

a

b

c

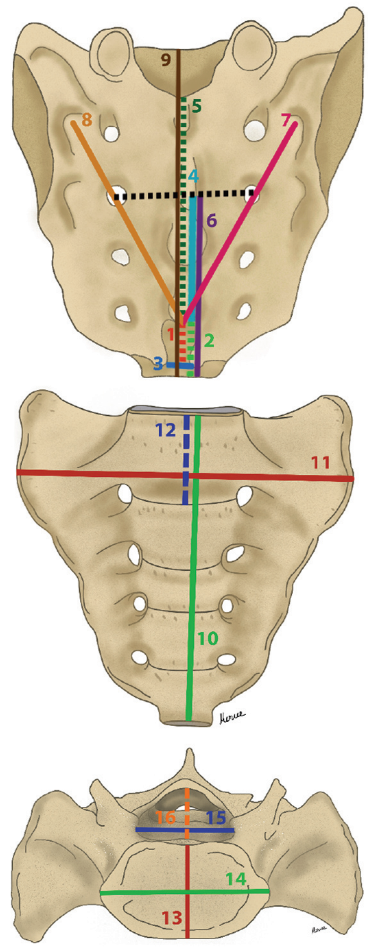

Figure 1. Morphometric measurements of the sacrum. (**a**) Posterior (dorsal) surface; **1.** Length of the sacral hiatus; **2.** The distance from the apex of the sacrum to the highest point of the SH; **3.** The length between the sacral cornua; **4.** The distance between the dorsal sacral foramina at the S2 level and the top of the SH; **5.** The distance between the upper border of the S1 vertebra and the top of the SH; **6.** The distance between the dorsal sacral foramina at the S2 level and the apex of the sacrum; **7.** The distance of the highest point of the SH to the highest point of the right lateral sacral crest; **8.** The distance from the highest point of the SH to the highest point of the left lateral sacral crest; **9.** The height of the sacrum from the dorsal surface. (**b**) Anterior (pelvic) surface; **10.** The sacral height: The distance from the apex of the sacrum to its base (promontory); **11.** The sacral width: The widest distance between the alas; **12.** The mid-height of the body of S1 (distance between the apex and base of the body of S1). (**c**) Superior aspect (base); **13.** The median diameter of the body of S1; **14.** The maximum transverse width of the body of S1; **15.** The sacral canal's maximum width; **16.** The median diameter of the sacral canal.

- The height of the sacrum from the dorsal surface,
- The sacral height: The distance from the apex of the sacrum to its base (promontory),
- The sacral width: The widest distance between the alas,
- The mid-height of the body of S1 (distance between the apex and base of the body of S1),
- The median diameter of the body of S1,
- The maximum transverse width of the body of S1,
- The sacral canal's maximum width,
- The median diameter of the sacral canal.

The following morphological features of the sacrum were also evaluated:

- The shape of the SH (**Figure 2**),
- The shape of the opening of the sacral canal (**Figure 3**),
- The shape of the articular surfaces of the superior articular process (**Figure 4**),
- The dorsal sacral foramina numbers (**Figure 5**),
- The level of the apex of the SH relative to the sacral vertebra (**Figure 6**),
- The level of the base of the SH relative to the sacral vertebra (**Figure 6**).

The sacral height, width, and mid-height of the body of S1 were measured from the pelvic surface. The measurements were repeated twice by the same researcher with an interval of 15 days and evaluated based on their means. Intraclass correlation coefficient (ICC) was computed to assess intra-observer reliability. We found excellent reliability as values were greater than 0.9 in all parameters (**Table 1**).

Statistical analysis was performed with IBM SPSS (Statistical Package for the Social Sciences) Statistics Version 22.0 (Armonk, NY, USA). Each parameter's mean, standard deviation, minimum, and maximum values were calculated. The summary of data was expressed as mean ± standard deviation and percentage.

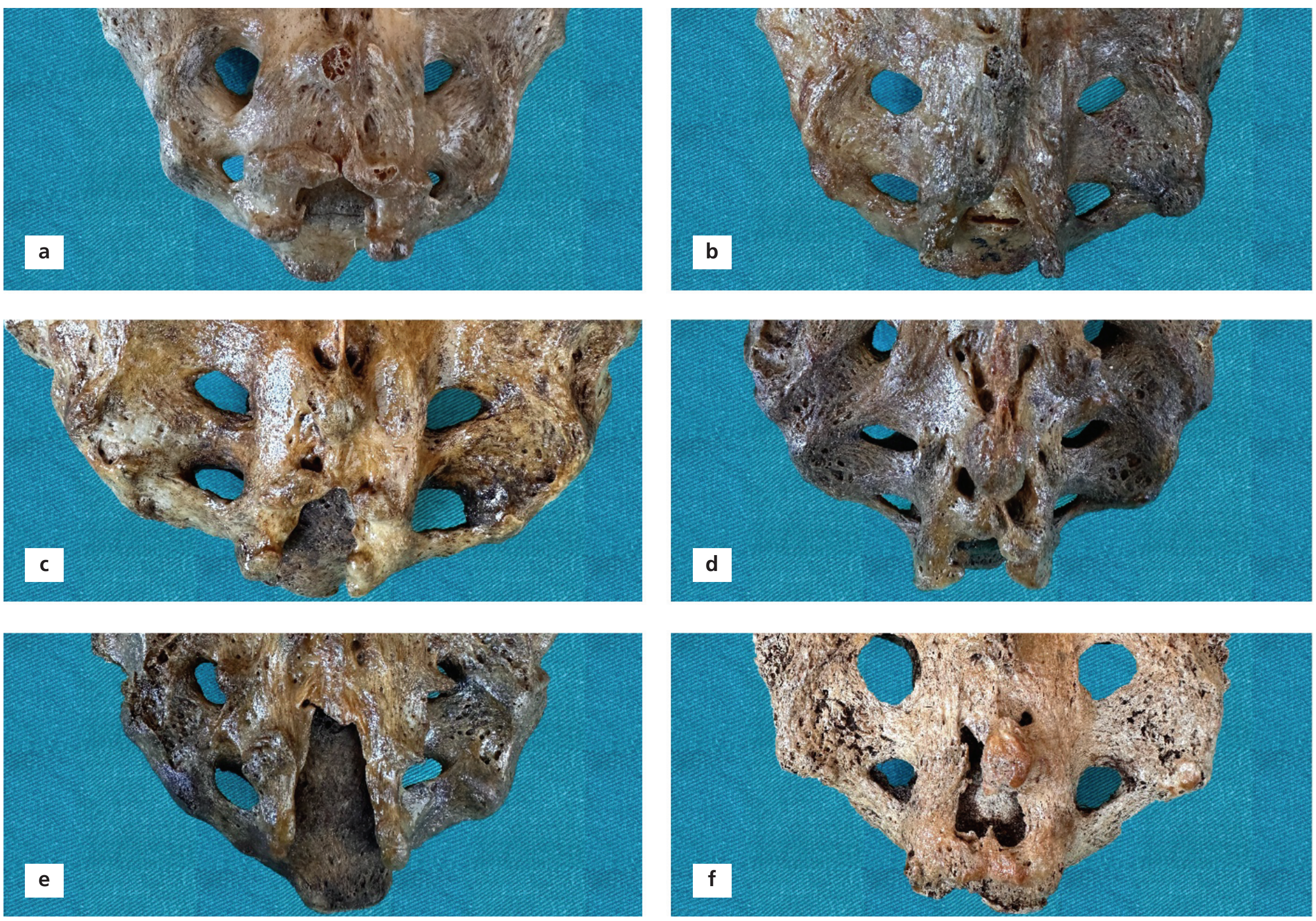

Figure 2. The shape of the sacral hiatus: (**a**) inverted 'U' shape; (**b**) inverted 'V' shape; (**c**) dumbbell shape; (**d**) 'M' shape; (**e**) irregular shape; (**f**) bifid shape.

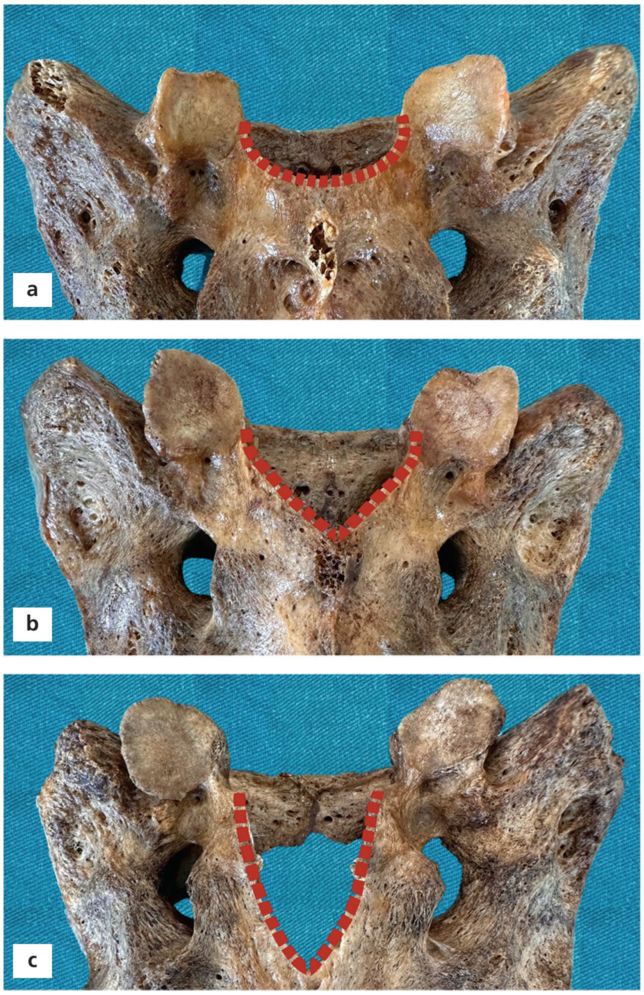

Figure 3. The shape of sacral canal: (**a**) 'U' shape, (**b**) 'V' shape, (**c**) deep 'V' shape.

Figure 4. The shape of the articular process: (**a**) bilateral concave; (**b**) bilateral flat; (**c**) right flat; left concave.

Results

The distance between the top point of the SH to the top point of the right lateral sacral crest and the top point of the left lateral sacral crest was similar. The right and left distances were measured as 73.88±8.09 mm and 74.71±8.25 mm, respectively (**Table 2**).

The shape of the SH was evaluated based on the study of Bagheri and Govsa.[10] In the form of a sacral canal, a new typing was made by evaluating the bones (**Table 3**). The SH is most commonly seen as an inverted U (n=11, 36.7%) and least as bifid (n=1, 3.4%) (**Figure 2**). The sacral canal was most commonly seen in a 'V' shape (n=15, 50%) (**Table 3**) (**Figure 3**).

The shape of the articular surfaces of the superior articular process was evaluated. While bilateral concave (53.3%) type joint surfaces were seen in 16 of 30 sacral bones, bilateral flat (33.3%) type joint surfaces were seen in 10. The remaining part (n=4, 13.4%) was found to be unilateral flat, or concave (**Figure 4**). The number of dorsal sacral foramina is generally four (n=26, 86.7%), and a small number of five foramina are seen (n=4, 13.3%) (**Figure 5**). While the top of the SH most commonly starts at the S4 level (n=24, 80%) compared to the sacral vertebral body, it has also been observed that it starts at the S3 (n=3, 10%) and S5 (n=3, 10%) levels in a small number of sacral bones. The base of the SH ends at the S5 level in 93.4% (n=28) of the sacral bones (**Figure 6**).

Discussion

The sacrum is an important bone with a broad clinical spectrum and concerns departments such as obstetrics and gynecology, anesthesia, forensic medicine, orthopedics, general surgery, and anatomy. Although there are various studies in the literature covering the sacrum and

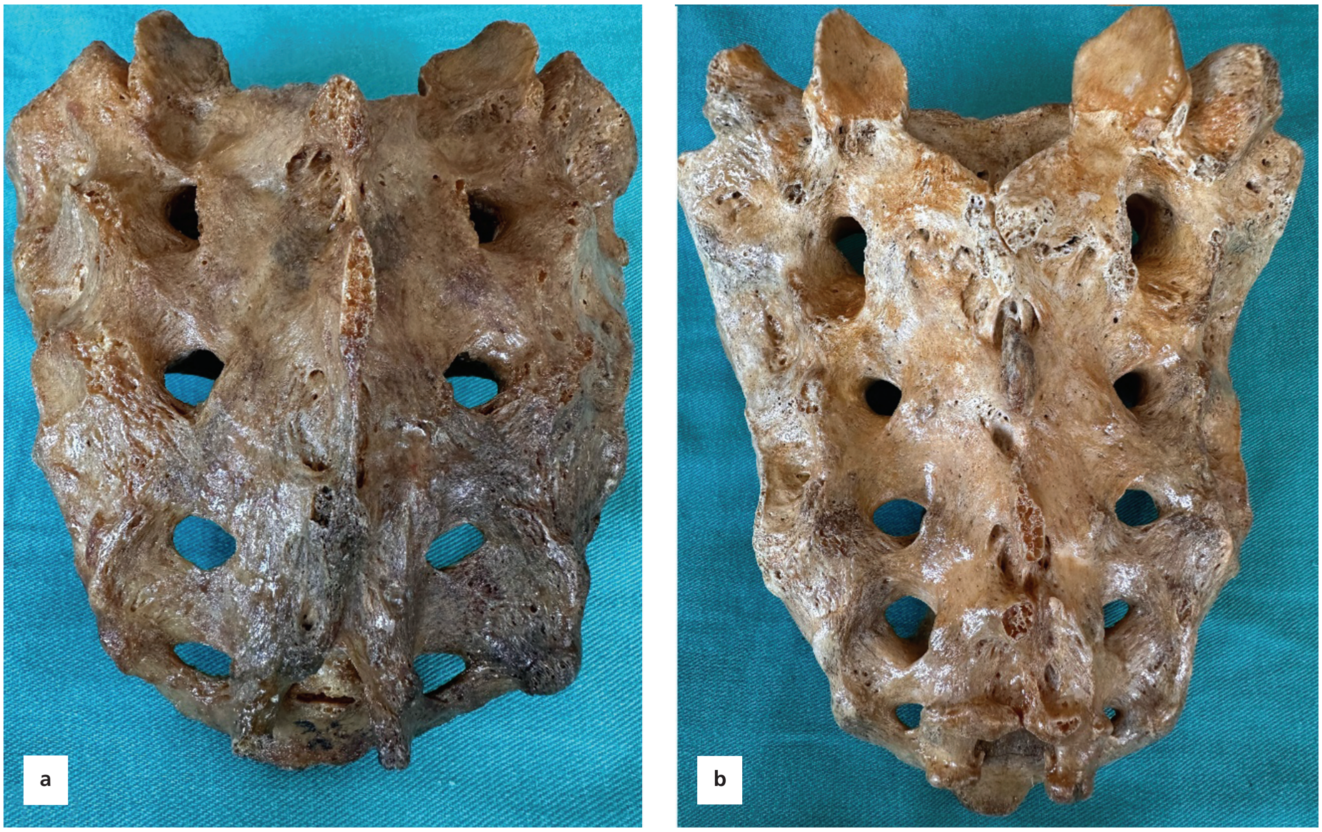

Figure 5. The number of dorsal sacral foramina: (**a**) four; (**b**) five.

Table 1
Intraclass correlation coefficients (ICC) for determination of the intra-observer correlation.

Parameter	ICC	Lower	Upper
1	0.989	0.976	0.995
2	0.926	0.852	0.964
3	0.983	0.965	0.992
4	0.997	0.994	0.999
5	0.986	0.972	0.993
6	0.945	0.888	0.973
7	0.963	0.924	0.982
8	0.996	0.992	0.998
9	0.986	0.971	0.993
10	0.997	0.993	0.998
11	0.981	0.961	0.991
12	0.986	0.970	0.993
13	0.934	0.867	0.968
14	0.973	0.944	0.987
15	0.943	0.886	0.973
16	0.932	0.864	0.967

1. The length of sacral hiatus (SH); **2.** The distance from the apex of the sacrum to the highest point of the SH; **3.** The length between the sacral cornua; **4.** The distance between the dorsal sacral foramina at the S2 level and the top of the SH; **5.** The distance between the upper border of the S1 vertebra and the top of the SH; **6.** The distance between the dorsal sacral foramina at the S2 level and the apex of the sacrum; **7.** The distance of the highest point of the SH to the highest point of the right lateral sacral crest; **8.** The distance from the highest point of the SH to the highest point of the left lateral sacral crest; **9.** The height of the sacrum from the dorsal surface; **10.** The sacral height: The distance from the apex of the sacrum to its base (promontory); **11.** The sacral width: The widest distance between the alas; **12.** The mid-height of the body of S1 (distance between the apex and base of the body of S1); **13.** The median diameter of the body of S1; **14.** The maximum transverse width of the body of S1; **15.** The sacral canal's maximum width; **16.** The median diameter of the sacral canal.

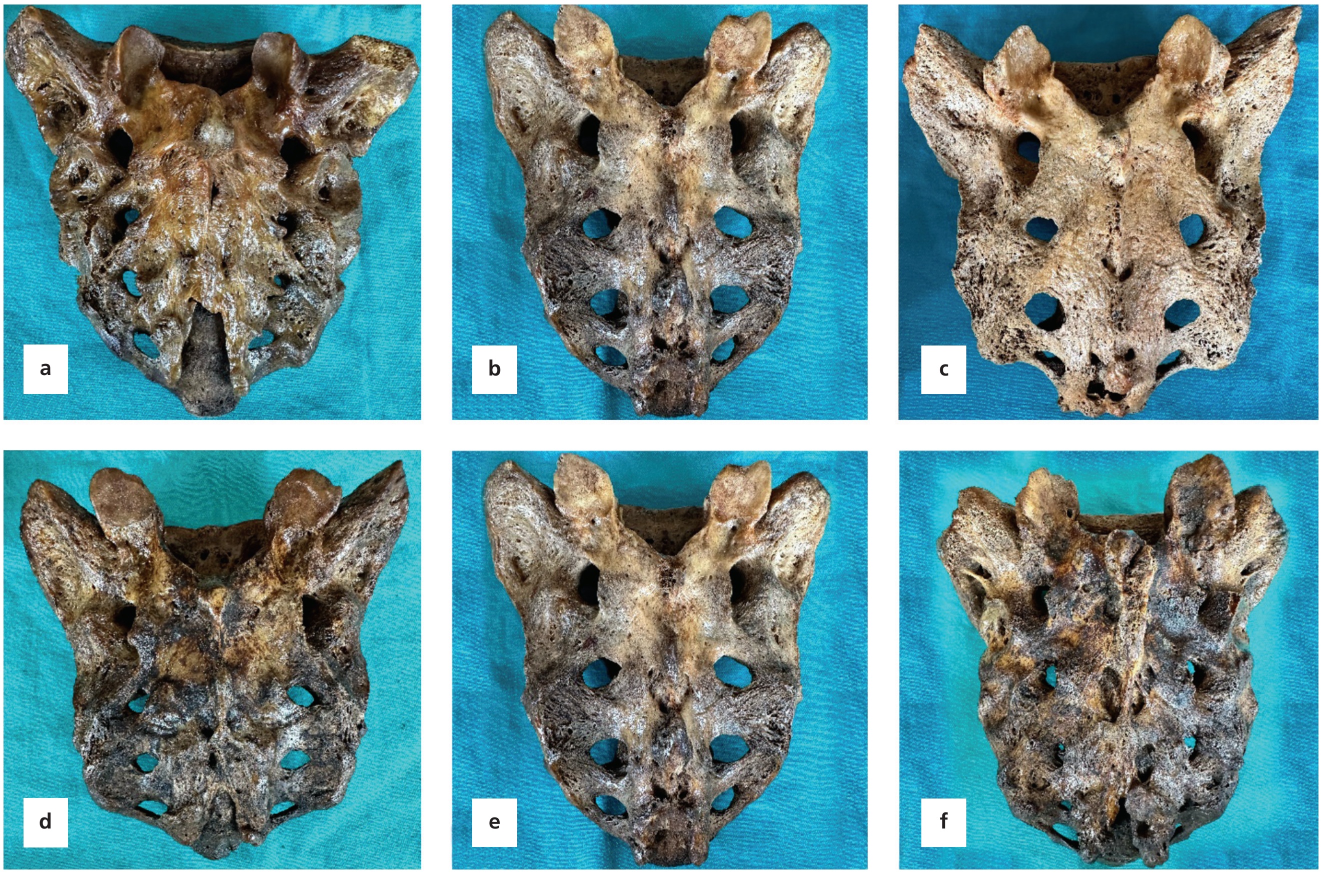

Figure 6. The proximal beginning of sacral hiatus: (**a**) S3, (**b**) S4, and (**c**) S5. The distal end of sacral hiatus: (**d**) S4, (**e**) S5, (**f**) Co1.

related clinical conditions, some of them were also conducted in the field of anatomy. Anatomical structures in the sacrum and the distances between them were evaluated in dry bones belonging to the Anatolian population by measuring them with calipers or the Image J program.[10,11,14] The shape, base, and apex views of the SH of the sacrum are grouped according to classifications.[10,15] Radiological studies such as computed tomography have also been performed in this region.[16]

The procedures performed in the caudal epidural block are performed through the SH, and various medications are administered in the epidural section. SH is usually detected by palpating the sacral cornua.[10] In order to perform a successful caudal epidural block, the length of the SH and the distance between the sacral cornua are essential. SH length has been defined in different ways in studies in the literature. In the studies of Aggarwal et al.,[9] Yılmaz et al.,[14] and Singh et al.,[17] SH length was defined as the distance from the top of the SH to the end of the sacral cornua. Senoglu et al.[6] and Bagheri and Govsa[10] defined the SH length as the distance of the sacrum's apex to the SH's highest point. Due to these differences in the literature, we made both measurements in our research. SH length measurement in study of Aggarwal et al.[9] was considered our first parameter, and SH length measurement in study of Senoglu et al.[6] was considered our second parameter (**Table 2**). Our SH length measurement is similar to the studies by Aggarwal et al.,[9] Yılmaz et al.,[14] and Singh et al.[17] Our measurement of the distance of the apex of the sacrum to the highest point of the SH is compatible with the studies of Senoglu et al.[6] and Bagheri and Govsa.[10] In a caudal epidural block, the distance between the SH and the dural sac is essential regarding the risk of dural puncture. In adults, the dural sac usually ends at the second sacral vertebra (S2) level.[6] In order to determine the distance required to avoid complications, in our study, we measured the distance of the level of the S2 vertebra to the top of the SH and the apex of the sacrum. In our study, the distance of the level of the S2 vertebra to the top of the SH and the sacrum's apex was higher than the values found in study of Singh et al.[17] (**Table 4**). We think this is due to genetic and environmental factors caused by ethnicity. In addition, the fact that values are different between societies reveals that it is essential for each population to create its reference values. We think that our study may contribute to the literature to determine the reference values of the Turkish population.

Another clinically significant feature of the sacrum is its use in iliosacral screwing. Data about the sacrum are essential for the treatment method used in various orthopedic diseases. The iliosacral screw is applied to the body of first sacral vertebra (S1) for the treatment of sacrum fractures and associated joint injuries.[12,18] S1 screwing can be applied anteriorly, anteromedially, and anterolaterally.[13] The diameter of the S1 vertebra was found to be 31±3 mm in study of Basaloglu et al.,[12] while it was 29.47±2.43 mm in study of Sinha et al.[18] Our study found it to be 29.55±2.87 mm, which is similar to the literature. While Morales-Ávalos et al.[19] measured the transverse width of the S1 as 48.72±4.64 mm, it was measured as 49.40±5.89 mm in study of Arman et al.[20] Our study determined it as 46.38±5.65 mm, consistent with the literature.

In our study, the heights of the sacrum were measured separately from the dorsal and pelvic surfaces. Since the inner face of the os sacrum is concave, the height of its outer face was found to be higher than the height of its inner face. These results were consistent with the study of Yılmaz et al.[14] in the Turkish population. However, when we examine the sacral height and width, there are differences due to ethnicity, and in some of the studies, unlike our study, it is observed that the sacral width is greater than the sacral height.[11,19,21]

The shape of the joint surfaces of the superior articular process appears different from each other. Like the study conducted by Elvan et al.,[15] the most common bilateral concave type of joint surface is seen. However, there may be various reasons for the appearance of joint surfaces in different shapes. It may be due to the patient's weight and height, previous diseases, and individual morphological differences.

Although the SH shape has been typed differently in the literature, inverted 'U' and inverted 'V' are included in most studies.[22–25] In our study, SH was classified according to the study of Bagheri and Govsa's[10] classification. Consistent with studies in the literature, the most common inverted 'U' shape is seen in our study.[9,15,17,26] (**Table 5**). Few studies evaluate the shape of the sacral canal in the accessible literature. Since some appear as a deeper 'V' shape, we made a new classification for the shape of the sacral canal and divided it into three different groups. Elvan et al.[15] divided the shape of the sacral canal into two groups, 'V' and 'U', and found that the 'V' shape was seen most frequently in 74% of sacrums. Although the 'V' shape was seen most frequently in our study, it was found to be present in 50% (**Table 3**), unlike the study of Elvan et al.[15]

Table 2
The morphometric parameters of the sacrum (mm).

Parameter	Mean±SD (n=30)	Range (min–max)
1	18.51±7.44	4.54–40.1
2	30.94±8.74	16.77–54.82
3	11.80±2.46	6.02–15.94
4	40.05±8.23	25.75–60.21
5	72.06±13.06	43.76–98.63
6	67.37±8.32	55.8–85.29
7	73.88±8.09	57.07–90.24
8	74.71±8.25	61.07–91.83
9	108.55±9.86	94.47–129.31
10	106.67±10.16	87.65–129.53
11	103.60±6.78	83.79–116.33
12	30.66±2.85	26.49–37.38
13	29.55±2.87	23.07–36.94
14	46.38±5.65	37.08–60.37
15	31.66±2.38	26.63–37.94
16	15.26±2.50	8.35–19.03

1. The length of sacral hiatus (SH); **2.** The distance from the apex of the sacrum to the highest point of the SH; **3.** The length between the sacral cornua; **4.** The distance between the dorsal sacral foramina at the S2 level and the top of the SH; **5.** The distance between the upper border of the S1 vertebra and the top of the SH; **6.** The distance between the dorsal sacral foramina at the S2 level and the apex of the sacrum; **7.** The distance of the highest point of the SH to the highest point of the right lateral sacral crest; **8.** The distance from the highest point of the SH to the highest point of the left lateral sacral crest; **9.** The height of the sacrum from the dorsal surface; **10.** The sacral height: The distance from the apex of the sacrum to its base (promontory); **11.** The sacral width: The widest distance between the alas; **12.** The mid-height of the body of S1 (distance between the apex and base of the body of S1); **13.** The median diameter of the body of S1; **14.** The maximum transverse width of the body of S1; **15.** The sacral canal's maximum width; **16.** The median diameter of the sacral canal.

Table 3
The results of sacral hiatus and sacral canal shapes.

The shape of the sacral hiatus	Frequency (n)	Percentange (%)
Inverted 'U'	10	33.4
Inverted 'V'	8	26.6
Dumbbell	5	16.6
M	4	13.4
Irregular	2	6.6
Bifid	1	3.4
The shape of the sacral canal	**Frequency (n)**	**Percentange (%)**
V	15	50
U	12	40
Deep V	3	10

Table 4
The morphometric parameters of the sacrum in studies (mean±SD, mm).

Parameter	Senoglu et al.[6] (2005)	Aggarwal et al.[9] (2009)	Bagheri and Govsa[10] (2017)	Yılmaz et al[14] (2018)	Singh et al.[17] (2018)	Present study (2024)
1	-	18.81±7.58	-	19.84±9.32	21.73±8.92	18.51±7.44
2	32.09±9.92	-	28.07±7.1	29.84±11.05	-	30.94±8.74
3	17.47±3.23	11.95±2.78	13.48±2.69	12.63±3.02	11.59±3.25	11.80±2.46
4	35.37±10.4	30.16±14.07	34.68±7.09	21.69±6.86	30.3±11.01	40.05±8.23
5	68.74±13.16	-	72.85±10.99	-	59.58±14.66	72.06±13.06
6	65.25±9.39	-	-	-	52.03±6.54	67.37±8.32
7	67.10±9.95	59.92±8.4	62.82±5.58	64.34±9.91	57.54±10.02	73.88±8.09
8	67.53±9.48	59.99±8.31	61.44±5.5	67.81±11.93	58.32±10.59	74.71±8.25
9	-	-	-	104.65±14.38	-	108.55±9.86
Parameter	**Basaloglu et al.[12] (2005)**	**Arman et al.[20] (2009)**	**Hassanein[21] (2011)**	**Morales-Ávalos[19] (2012)**	**Sinha et al.[18] (2013)**	**Present study (2024)**
10	103.1±11.3	-	114.3±8.8	97.49±7.16	100.07±7.9	106.67±10.16
11	105.3±7.1	-	103.9±9.1	110.04±5.97	101.78±6.97	103.6±6.78
12	30.2±2.8	30.22±2.35	30.7±4.7	31.11±2.8	28.06±2.3	30.66±2.85
13	31±3	31.42±2.83	33.6±5	31.93±2.91	29.47±2.43	29.55±2.87
14	52.6±7	49.4±5.89	54.5±6.4	48.72±4.64	46.02±4.64	46.38±5.65
15	30.3±2.5	31.31±3.16	29.4±3.9	31.07±2.65	27.77±3.83	31.66±2.38
16	15±3.2	21.81±3.66	16.4±2.7	15.13±2.4	11.95±3.79	15.26±2.5

1. The length of sacral hiatus (SH); **2.** The distance from the apex of the sacrum to the highest point of the SH; **3.** The length between the sacral cornua; **4.** The distance between the dorsal sacral foramina at the S2 level and the top of the SH; **5.** The distance between the upper border of the S1 vertebra and the top of the SH; **6.** The distance between the dorsal sacral foramina at the S2 level and the apex of the sacrum; **7.** The distance of the highest point of the SH to the highest point of the right lateral sacral crest; **8.** The distance from the highest point of the SH to the highest point of the left lateral sacral crest; **9.** The height of the sacrum from the dorsal surface; **10.** The sacral height: The distance from the apex of the sacrum to its base (promontory); **11.** The sacral width: The widest distance between the alas; **12.** The mid-height of the body of S1 (distance between the apex and base of the body of S1); **13.** The median diameter of the body of S1; **14.** The maximum transverse width of the body of S1; **15.** The sacral canal's maximum width; **16.** The median diameter of the sacral canal).

In addition to measuring the parameters related to the SH, it was also determined at which level it started relative to the vertebrae. In the relevant studies in the literature, it is seen that it most frequently starts at the S4 level and ends most frequently at the S5 level. It is also stated that it is also dokepleted at the Co1 level in fewer bones.[9,17,25,27] The findings of our study were consistent with the literature. Although the most common dorsal sacral foramina in

Table 5
The shape of sacral hiatus defined in previous studies (n).

Study	n	Country	Inverted "U'	Inverted 'V'	Dumbbell	M	Irregular	Bifid
Aggarwal et al.[9] (2009)	114	India	46	36	-	1	18	5
Nadeem[22] (2014)	100	Saudi Arabia	56	14	10	-	16	2
Malarvani et al.[24] (2015)	100	Nepal	35	32	3	-	14	2
Vasuki et al.[23] (2016)	75	India	27	15	16	-	13	3
Bagheri and Govsa[10] (2017)	87	Turkey	29	17	6	9	17	3
Kujur and Gaikwad[26] (2017)	45	India	20	11	4	-	7	2
Singh et al.[17] (2018)	56	India	34	14	2	2	4	-
David[25] (2019)	61	India	14	8	2	-	14	2
Elvan et al.[15] (2021)	20	Turkey	5	3	5	3	2	-
Present study (2024)	30	Turkey	10	8	5	4	2	1

the sacrum is four, it is stated that there are sometimes five and sometimes three foramina in the literature.[15,27,28] In our study, although there were four foramina most frequently (n=26, 86.7%), there were also five foramina in a few bones (n=4, 13.3%). The number of foramen may change due to lumbalization of the sacrum or sacralization of the lumbar and coccygeal vertebrae.[15]

One of the limitations of our study was that it was a dry bone study, so age and gender could not be determined. It is a known fact that there are differences between genders in the pelvis and sacrum. Our study does not include differences between genders. Additionally, the number of bones used in our study is relatively small. Conducting a national study on this subject and using a higher number of bones may contribute to determine reference values according to ethnicity.

Conclusion

Considering all these, morphometric measurements of the sacrum are essential to guide clinicians, especially in applications such as caudal epidural block and iliosacral screwing. The fact that there are differences between studies for some parameters in studies conducted in various countries in the literature shows that ethnicity is important. For this reason, it is essential to increase the number of studies for physicians to follow their population's parameters regarding the treatments' effectiveness.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

AGÖ: Project development, data collection, data analysis, manuscript writing; ES: project development, data analysis, manuscript writing; MCT: project development, manuscript writing; AKK: project development, manuscript editing.

Ethics Approval

This study involving human participants was conducted in accordance with the ethical standards established by the Institutional and National Research Committee, following the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study approved by the Selçuk University Faculty of Medicine noninvasive clinical research ethics committee (Date: 01.08.2023, Meeting No: 2023/15, Decision No: 2023/370).

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ORCID ID:
A. G. Özcan 0000-0002-9946-3026;
E. Solmaz 0000-0002-5091-0251;
M. C. Tatar 0000-0002-8661-8308;
A. K. Karabulut 0000-0002-9635-8829

deomed

Correspondence to: Ekrem Solmaz, MD, PhD
Department of Anatomy, Faculty of Medicine,
Selçuk University, Konya, Türkiye
Phone: +90 332 224 38 66
e-mail: drsolmazekrem@gmail.com

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Chest wall deformities detected in lung radiographs during routine health screening in young healthy male athletes training for police services duty

Kemal Buğra Memiş[1], Muhsin Özgün Öztürk[1], Sonay Aydın[1], Edhem Ünver[2]

[1]*Department of Radiology, Faculty of Medicine, Erzincan Binali Yıldırım University, Erzincan, Türkiye*
[2]*Department of Chest Diseases, Faculty of Medicine, Erzincan Binali Yıldırım University, Erzincan, Türkiye*

Abstract

Objectives: Chest wall deformities are a series of abnormalities that extend from the sternum to the vertebral column and often cause aesthetic and psychological problems. Most chest wall deformities are caused by cartilaginous malformations such as pectus excavatum and pectus carinatum. The aim of this study was to provide a detailed description of chest wall abnormalities in young male athletes with no existing complaints.

Methods: A comprehensive health assessment was performed on 1600 young men at the Erzincan Police Vocational Training Centre in March 2023. The evaluation included chest radiographs, pulmonary function tests, electrocardiography, transthoracic echocardiography, haemogram, biochemical test findings and comorbidities. Haller index scale was used to grade the severity of pectus deformity in individuals with pectus excavatum.

Results: Pectus excavatum deformity was detected in 16 individuals (1%). Pectus carinatum was detected in only one individual (0.06%). Only one of the patients with chest wall deformity had an abnormal pulmonary function test, especially in the form of a minor obstructive pattern. In addition, 11 individuals in this group had associated electrocardiographic abnormalities. These abnormalities did not cause significant clinical findings.

Conclusion: Our study showed that the prevalence of chest wall deformities in physically active young men is comparable to the prevalence of chest wall deformities reported for the general population in the available literature. Furthermore, this study demonstrated a higher prevalence of electrocardiographic abnormalities in subjects with chest wall deformities.

Keywords: chest radiograph; electrocardiography; pectus carinatum; pectus excavatum; respiratory function tests

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Introduction

Chest wall deformities (CWDs) cover a wide range of abnormalities from the sternum to the vertebral column. The main reasons why individuals seek medical advice are usually related to aesthetic issues and psychological well-being. A small proportion of those with deformities present with clinically significant complaints. Depending on the specific type of abnormality, its severity and associated conditions, functional breathing problems and significant cardiopulmonary consequences may occur.[1,2] Hence, it is crucial for patients to accurately identify abnormalities and determine any associated conditions.

The literature reports a frequency of 1% for chest abnormalities in the general population.[3] CWDs that occur from the sternum to the vertebral column can be categorised into five types based on their specific anatomical region: cartilaginous, costal, combination of costochondral, sternal, and costovertebral. The categorization of CWDs developed by Acastello is shown in **Table 1**.[4,5]

The majority of CWDs globally are caused by cartilaginous malformations (pectus excavatum and pectus carinatum).[1] Pectus excavatum (PE) occurs in around 1 to 10 per 1000 live births and represents 90% of CWDs. This deformity is defined by the existence of a sternal depression of varying depth caused by irregular growth of the

Table 1
The Acastello classification of chest wall deformities based on the deformity region.[5]

	The anatomical region of deformity	Specific appearance
Type 1	Cartilaginous	Pectus excavatum Pectus carinatum
Type 2	Costal	Simple or complex (Agenesis, hypoplasia, bifid…)
Type 3	Combination of costochondral	Poland's syndrome VACTER syndrome
Type 4	Sternal	Sternal cleft (+/– ectopia cordis) Currarino Silvermann syndrome
Type 5	Costovertebral	Simple or syndromic

basal costal cartilage structures. PE, the exact etiology of which remains unknown, usually appears as a congenital disorder that arises throughout childhood or adolescence. In moderate and severe cases, PE may force the heart to rotate to the left, cause sternal depression, and reduce the chest's anteroposterior width.[1,2,5] The Haller index (HI) is used to determine the severity of the PE deformity. HI is the ratio of the transverse diameter of the rib-cage to its anteroposterior diameter. It is around 2.5 in a normal chest, but in pectus excavatum the index is >3.25, it is necessary to use radiological imaging techniques such as radiography or computed tomography.[6,7]

Pectus carinatum (PC), the second most prevalent malformation, results in significant physical, aesthetic, and psychological issues as a result of the anterior protrusion of the sternum and cartilaginous ribs. Prevalence of PC among teenagers is around 1 in 1000. PC is less common than PE, however in specific geographic regions, PC is nearly the same or more common than PE. Just like PE deformity, the exact cause of pectus carinatum is yet unclear.[8–10]

Pectus excavatum has been related to reduced exercise capacity, pain in the chest, and a negative self-image. Furthermore, as pectus excavatum and carinatum abnormalities are linked to hereditary disorders like Marfan Syndrome, it is crucial to identify them early on for the prompt detection of life-threatening aortic conditions, particularly in those engaged in athletic activities.[11]

The goal of our study was to provide a detailed description of chest wall abnormalities observed on chest radiographs during health screening in young male persons who practice sports without existing complaints, to establish the incidence of these deformities, and to determine any potential associated medical conditions.

Materials and Methods

In March 2023, a comprehensive health assessment was performed in our hospital for a group of 1600 young men selected for training at the Erzincan Police Vocational Training Centre. The retrospective evaluation included chest radiographs, pulmonary function tests, electrocardiography (ECG), transthoracic echocardiography, haemogram, biochemical test findings and analysis of comorbidities.

The study population consisted of 1600 individuals screened for CWD by chest radiography. This study cohort was compared with those diagnosed with CWD in terms of abnormalities in pulmonary function tests, ECG, transthoracic echocardiography findings and laboratory test data. Chest radiographs were performed two-view, posteroanterior and lateral. The x-ray scans were evaluated by a radiologist who has 10 years of expertise. Patients with thoracic wall deformity detected using plain radiography were recorded. The HI was computed for every person with suspected PE in this study, using the formula suggested by Haller et al.[12] The HI is calculated by dividing the transverse diameter of the chest in PA radiographs by the shortest width between the front edge of the vertebral body and the posterior surface of the sternum measured in lateral radiographs (**Figure 1**).

The HI scale was also used to grade pectus deformity in patients with PE. During the grading process, we considered the study conducted by Daunt et al.[6] In accordance with their findings, instances with the HI ranging from 2.7 to 3.2 were classified as mild PE, instances with the HI between 3.2 and 3.5 were classified as moderate PE, and those with the HI over 3.5 were classified as severe PE.

The study population's respiratory function tests, electrocardiography, and transthoracic echocardiography

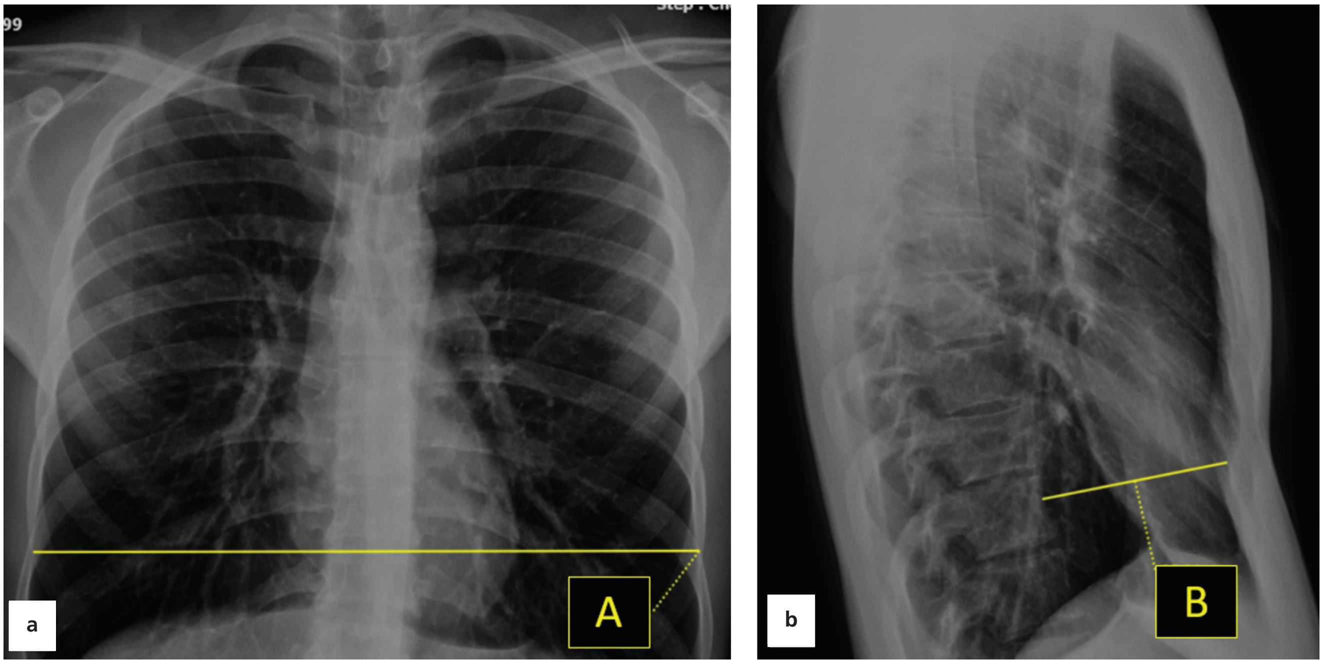

Figure 1. The figure shows how the measurements determining the Haller index were performed. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 24-year-old male with pectus excavatum. A: the transverse diameter of the thorax is measured from the inner surface of the costae on both sides, where the diameter is widest; B: measurement of the shortest distance between the anterior edge of the vertebral body and the posterior surface of the sternum on lateral radiographs.

findings were acquired from the hospital information system and recorded. Haemoglobin (Hb), hematocrit (Htc), platelet count (Plt), white blood cell count (WBC), neutrophil count, lymphocyte count, and serum lactate dehydrogenase (LDH) levels were retrieved from the hospital's laboratory data.

IBM SPSS Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The normal distribution of the data was tested with Kolmogorov-Smirnov test. Continuous parameters without normal distribution were stated as median (minimum-maximum). Categorical data were stated as frequencies (n) and percentages (%). Mann-Whitney U test was used to compare the median values of the age and the laboratory parameters between chest wall deformity and healty groups. Chi-Square test was used to compare the percentages of ECG and respiratory function test abnormalities between the groups. A two-tailed value of $p<0.05$ was considered statistically significant.

Results

The study population consists of 1600 people for whom we conducted CWD screening by chest radiography. The entire group consisted exclusively of male volunteers. Following the screening, CWD was identified in a total of 17 (1.06%) individuals of the 1600 participants tested. The overall age distribution of study population was found to be a minimum of 20, a maximum of 30, and a median age of 24. The age distribution of those diagnosed with CWD ranged from a minimum of 21 to a maximum of 28, with a median age of 25 ($p=0.28$).

Pectus excavatum deformity was identified in 16 (1%) individuals (**Figure 2**). According to the Haller index, 13 (0.81%) cases were categorised as mild excavatum, 2 (0.12%) cases as moderate excavatum, and 1(0.06%) case as severe excavatum. The subtypes of CWD identified throughout the screening are shown in **Table 2**. Out of the total cases, one (0.06%) was diagnosed with pectus carinatum (**Figure 3**).

Table 2
Types of chest wall deformities detected in the study.

Type of CWD	n (%)
Pectus excavatum (PE)	16 (1%)
Mild PE	13 (0.81%)
Moderate PE	2 (0.12%)
Severe PE	1 (0.06%)
Pectus carinatum	1 (0.06%)

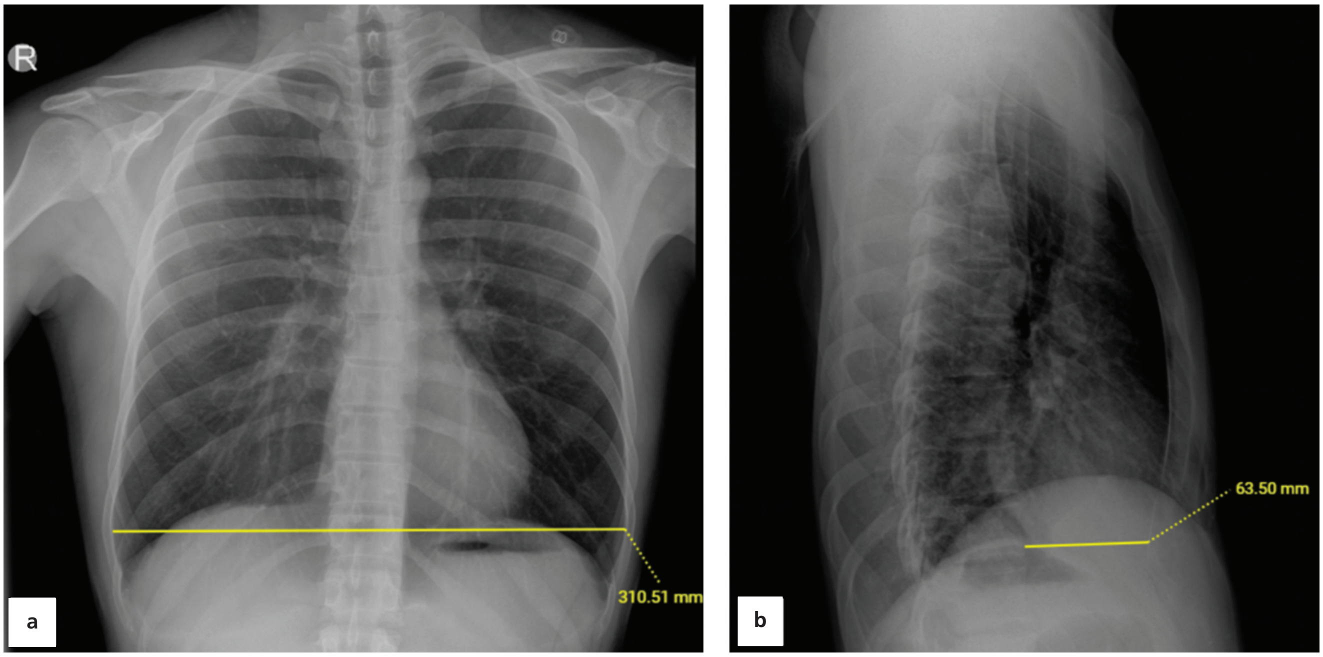

Figure 2. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 25-year-old male with pectus excavatum. Haller index was calculated as 4.89.

Mild obstructive abnormalities were detected in pulmonary function test results in 26 out of 1600 participants (1.6%). CWD was detected in only 1 (0.06%) of them and this person had mild PE deformity (p=0.19). The prevalence of test abnormality in PE has been shown to be 6.2%.

ECG abnormalities, including T wave inversions, bradycardia, tachycardia, arrhythmias, bundle branch

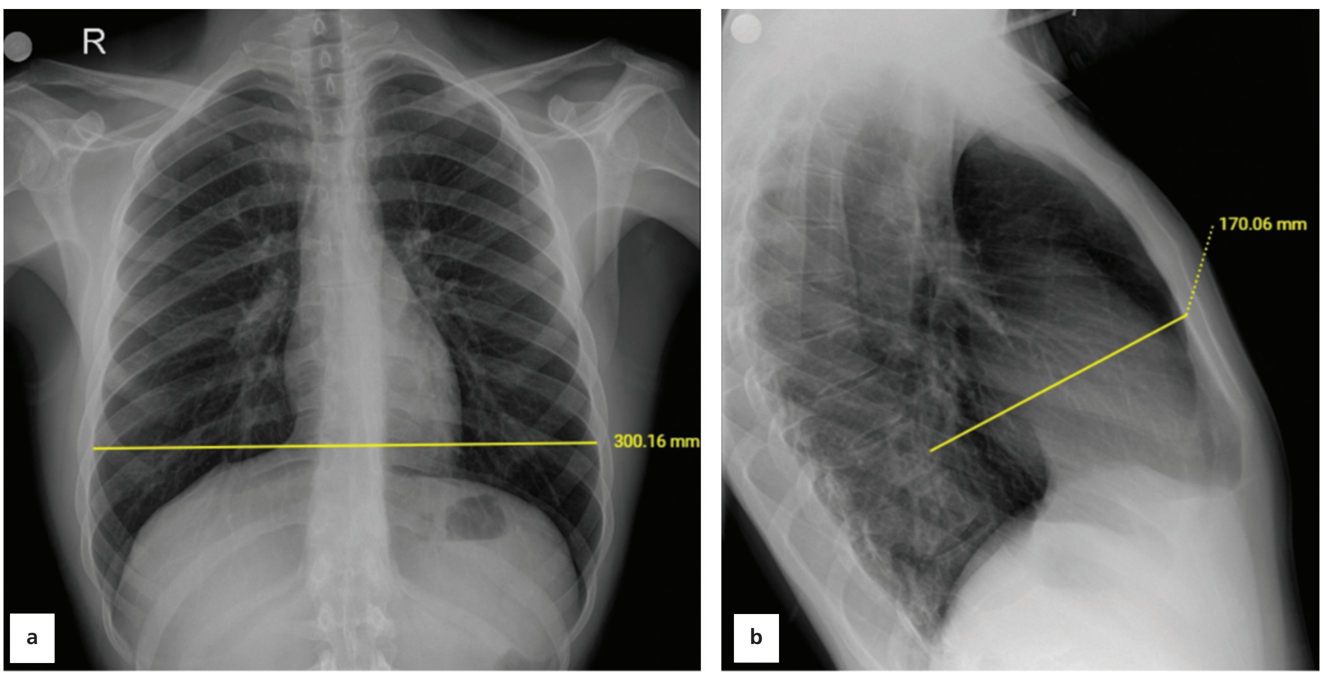

Figure 3. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 21-year-old male with pectus carinatum. Haller index was calculated as 1.76.

Table 3
Electrocardiography (ECG) abnormalities detected in the study population.

	Type of ECG abnormality	n (%)
Study population		1600
	T wave inversions	45 (2.81%)
	Bradycardia	47 (2.942%)
	Tachycardia	70 (4.38%)
	Arrhythmias	7 (0.44%)
	Bundle branch blocks	5 (0.31%)
	Ventricular extra beats	2 (0.12%)
Chest wall deformities		17
Mild PE	T wave inversions	3 (17.6%)
	Bradycardia	3 (17.6%)
	Tachycardia	2 (11.8%)
	Right bundle branch blocks	1 (5.9%)
Moderate PE	T wave inversions	1 (5.9%)
	Right bundle branch blocks	1 (5.9%)

block and ventricular extrasystoles, were detected in 176 (11%) of the total 1600 participants (**Table 3**). Among persons who have been diagnosed with CWD, 11 (67.7%) patients had specific abnormalities in their ECGs. These abnormalities included T wave inversions (V1–V4 leads) in 4 (23.5%), bradycardia in 3 (17.6%), tachycardia in 2 (11.8%) and right bundle branch blocks in 2 (11.8%) patients. Out of 11 particioants, 9 had a mild excavatum deformity while 2 had a moderate excavatum deformity. Individuals with CWD had a higher occurrence of ECG abnormalities compared to the research participants ($p=0.01$). However, these abnormalities did not cause significant clinical findings.

Transthoracic echocardiography was normal in all individuals with thoracic deformity and no abnormality was found in haemogram and biochemistry parameters (**Table 4**). Furthermore, no other systemic or syndromic disease was identified in the patients.

Discussion

For many years, most chest wall anomalies, such as pectus excavatum, were considered an incidental finding with no significant clinical consequences. In general, it does not cause symptoms severe enough to require surgical intervention. However, there is evidence in the literature that it can lead to complaints and symptoms such as palpitations,

Table 4
The relationship between laboratory parameters and the presence of chest wall deformities.

	CWD exist (n=17)	No CWD (n=1583)	
	M (min-max)	M (min-max)	p-value*
Age (years)	25 (21–28)	24 (20–30)	0.280
Hemoglobin (g/dL)	14.3 (13–16.8)	13.8 (12.5–17.7)	0.341
WBC (×10^3/μL)	7.76 (6.45–9.53)	7.1 (4.75–10.59)	0.207
Platelet (×10^3/μL)	215.3 (196.4–318)	231.1 (178.2–364)	0.195
Lymphocyte (×10^3/μL)	3.21 (2.76–4.24)	3.02 (1.96–5.75)	0.255
Neutrophil (×10^3/μL)	4.23 (3.48–7.45)	4.06 (3.05–8.18)	0.354
Hematocrit (%)	41.35 (38.3–44.6)	40.45 (36.7–48.7)	0.315
LDH (U/L)	215 (139–455)	239 (107–847)	0.169

*P-value was obtained from Mann–Whitney U test. **CWD:** chest wall deformity; **LDH:** lactate dehydrogenase; **M:** median.

fatigue and exertional dyspnea.[13] In this study, the frequency of chest wall deformities detected during health screening in young male athletes without any complaints was evaluated and possible related pathologies were tried to be determined.

Aligned with the existing body of research, our findings indicate that PE was the most commonly observed CWD, with a prevalence rate of 88%. Fokin et al.[2] revealed that PE accounts for roughly 90% of all CWDs in their study. In line with the findings reported by Fokin et al.,[2] our investigation revealed a prevalence rate of 1 in 1000 for PE.

We conducted HI assessments using 2-way chest radiographs to determine the severity of PE deformities. There has been a growing difference of opinion in recent years about the evaluation of individuals with PE deformity using imaging techniques. There are two separate groups that recommend evaluating the severity and morphology of PE with conventional radiographs or thorax CT. Studies have shown that there is no significant difference between the HI calculated from conventional radiography and that from CT. Mueller et al.[14] conducted a comparison between the Haller index acquired from chest radiographs and the one obtained from CT scans. The average HI among the 12 children was 3.97 in CT, whereas the chest X-ray HI was 4.08 (Pearson correlation value: 0.984). Accordingly, they recommend that performing chest CT scans on patients without symptoms is unnecessary and that the level of radiation exposure can be minimised by using chest X-rays to measure the HI. This study conducted by Mueller et al. demonstrates that there is no significant difference in the measurement of HI when using either chest CT or chest X-ray. Therefore, the utilisation of chest CT is not essential for accurately estimating HI. This literature data confirms that not measuring the HI values from chest CTs, as we did in our study by using chest radiographs, will not result in a limitation.

The prevalence of PC detected in our study was 0.06%, which is similar to the rates reported by McHam et al.[9] Nevertheless, in particular some geographic regions and race, the prevalence of PC is nearly equivalent to or greater than that of PE.[1,15,16] Further radiographic data reveals that minor subtypes of PC may be present in around 5% of the population. Our study population did not include any patients with mild PC deformity.

Malek et al.[17] supports that PE is associated with reduced exercise capacity due to impaired cardiovascular performance rather than physiological disorders (physical deconditioning) and respiratory dysfunction. We found that individuals with PE deformity were more likely to have electrocardiographic abnormalities rather than respiratory problems, which supports this observation. Hence, it is crucial to detect CWDs, particularly PE, as the exercise capacity of individuals in our study population who will be trained to work in security services should not be low. Moreover, some case reports demonstrate how PE deformity can lead to episodes of syncope in young athletes due to compression of the right ventricle.[18] In addition, it is important to identify individuals with CWD within our study population, as well as their decreased capacity for exercise.

Existing studies demonstrates a positive correlation between the degree of deformity in individuals with PE and the occurrence of respiratory test abnormalities. Patients with mild deformities often exhibit obstructive type functional pathologies, however as the severity of deformity grows, the prevalence of restrictive pathologies has been seen to reach up to 14%.[17,19] We noticed a minor obstructive respiratory condition among one patient in the deformity group, which is in alignment with existing research on its prevalence. The absence of restrictive type respiratory dysfunction can be attributed to the limited number of individuals exhibiting moderate and severe PE deformity. Furthermore, another contributing factor to the low prevalence of spirometric test anomalies in our study sample is the inclusion of persons who engage in physical activities. Because previous studies have demonstrated that physical activity improves respiratory function.[17,20]

The prevalence of abnormal ECG findings in these cases of CWD was discovered to be 47.8%, which closely aligns with the values reported in existing literature.[21,22] Also, the ECG abnormalities we identified in individuals with CWD correlate with the anomalies often observed in existing literature. These abnormalities included T wave inversions, bradycardia, tachycardia, and right bundle branch blocks. Our idea suggests that the abnormal ECG results, which often arise from the right heart, are caused by mechanical compression of the right ventricle due to pectus excavatum in the mediastinal area.

Our study has some strengths. Firstly, the assessment of CWD was performed in an unbiased manner using radiological images. Furthermore, data were collected by documenting medical history, laboratory tests, pulmonary function tests and analysing ECG and echocardiography data. Thus, cardiopulmonary function could also be objectively assessed. To the best of our knowledge, there is no study in the current literature examining the prevalence of CWD in a population without any medical problems and engaged in sports activities. Our study is unique in this respect and in terms of reflecting this situation in the Turkish population.

However, this study has some limitations. One of them is that the study was conducted in a single centre in a specific geographical area and age range. Furthermore, the study population included only male participants, thus excluding prevalence data from females. Finally, as radiographs were analysed by only one radiologist at a time, there is a lack of information on both inter- and intra-observer agreement.

Conclusion

The prevalence of CWD in young men who play sports and have no other medical problems is similar to the prevalence observed in the general population as documented in the available literature. Our study is the first and largest study on this specific population in the literature. CWD has not been shown to increase the risk of any comorbidities in this specific population, except for ECG abnormalities that are not clinically significant.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

KBM: designed and conducted the research, analyzed the data and wrote the manuscript; EÜ: designed the research; MÖÖ: performed the research, analyzed the data and wrote the manuscript; SA: designed the research, contributed towards analytic tools, analyzed the data and wrote the manuscript. All authors have read and approve the final manuscript.

Ethics Approval

This retrospective study was carried out in compliance with the Declaration of Helsinki and received approval from the Erzincan University Ethics Committee (Protocol code: EBYU-KAEK-2023-10/9, Date: 07/06/2023). Due to the research's methodology, the requirement for informed consent was waived.

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ORCID ID:
K. B. Memiş 0009-0007-6746-3906;
M. Ö. Öztürk 0009-0000-3356-3481;
S. Aydın 0000-0002-3812-6333;
E. Ünver 0000-0002-0322-8102

Correspondence to: Kemal Buğra Memiş, MD
Department of Radiology, Faculty of Medicine,
Erzincan Binali Yıldırım University, Erzincan, Türkiye
Phone: +90 506 820 12 63
e-mail: kemalbugramemis@gmail.com

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Bibliometric analysis of the most cited one hundred anatomy articles in the 100th year of the Turkish Republic

Hanife Ertürk, Kenan Öztürk, İhsan Hız, Yadigar Kastamoni

Department of Anatomy, Faculty of Medicine, Süleyman Demirel University, Isparta, Türkiye

Abstract

Objectives: Bibliometric studies are the analysis of publications in the literature using statistical methods. In order to show the trending topics in the field of anatomy, the 100 most cited articles in the field of anatomy written by researchers from Turkey were analyzed using data obtained from Web of Science (WoS).

Methods: The data included in the study were collected by typing the word "anatomy" in the "all fields" category in the Web of Science database. Articles written by researchers from Turkey between 1980 and September 10, 2023 were included in the study. The data were transferred to the VOSviewer 1.6.19 program for detailed analysis and analyzes were performed.

Results: Of the 100 most cited articles, 33 were cadaveric studies, 25 were radiologic studies, 13 were clinical studies, 6 were animal experiments, 6 were morphometry studies, 4 were dry bone, 3 were fetal cadavers, 2 were editorial comments and 2 were anatomy education. Six articles were related to veterinary anatomy. Keyword analysis, author citation analysis, co-authorship analysis, country citation analysis, and institution citation analysis were also performed.

Conclusion: The bibliographic analysis of the 100 articles in our study will help anatomists to understand which topics they should study in their future anatomy studies.

Keywords: anatomy; attribution; bibliometric analysis; VOSviewer; Web of Science (WOS)

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Introduction

Anatomy has been a fundamental and indispensable component of medical science throughout history. The first written sources on anatomy date back to the Egyptian Papyrus (3000–2500 BC). Anatomy developed with the contributions of researchers such as Hippocrates, Andreas Vesalius, and Leonardo Da Vinci and is still developing with cadaver dissections, radiological methods, animal experiments, and clinical practices.[1]

Bibliometric analysis is a method employed to understand the current status and study areas of a research field. This method is applied by analyzing the numerical data of scientific publications with visualization software. Unlike the systematic literature review, bibliometric analysis does not provide a comprehensive and in-depth review of the research area. Instead, it provides a perspective on the overall state of the research area. Bibliometrics, which can also be used as a preliminary stage of a systematic literature review, can also create a framework for a systematic literature review. It provides quantitative findings on country, author, university, and journal productivity, weak and strong research areas, literature gaps, collaboration networks, potential opportunities, and widespread effects of the outputs in an area. Bibliometric analysis compares research areas and enables the determination of research trends. Therefore, bibliometric analysis is becoming an increasingly important tool for understanding and interpreting knowledge in the research area.[2–5]

Materials and Methods

The Web of Science (WoS) database is one of the most comprehensive resources for bibliometric analysis. It provides its users with access to a range of resources, including

This study was presented as a poster at the 23rd National Anatomy Congress, September 11–15, 2023, Ankara, Türkiye.

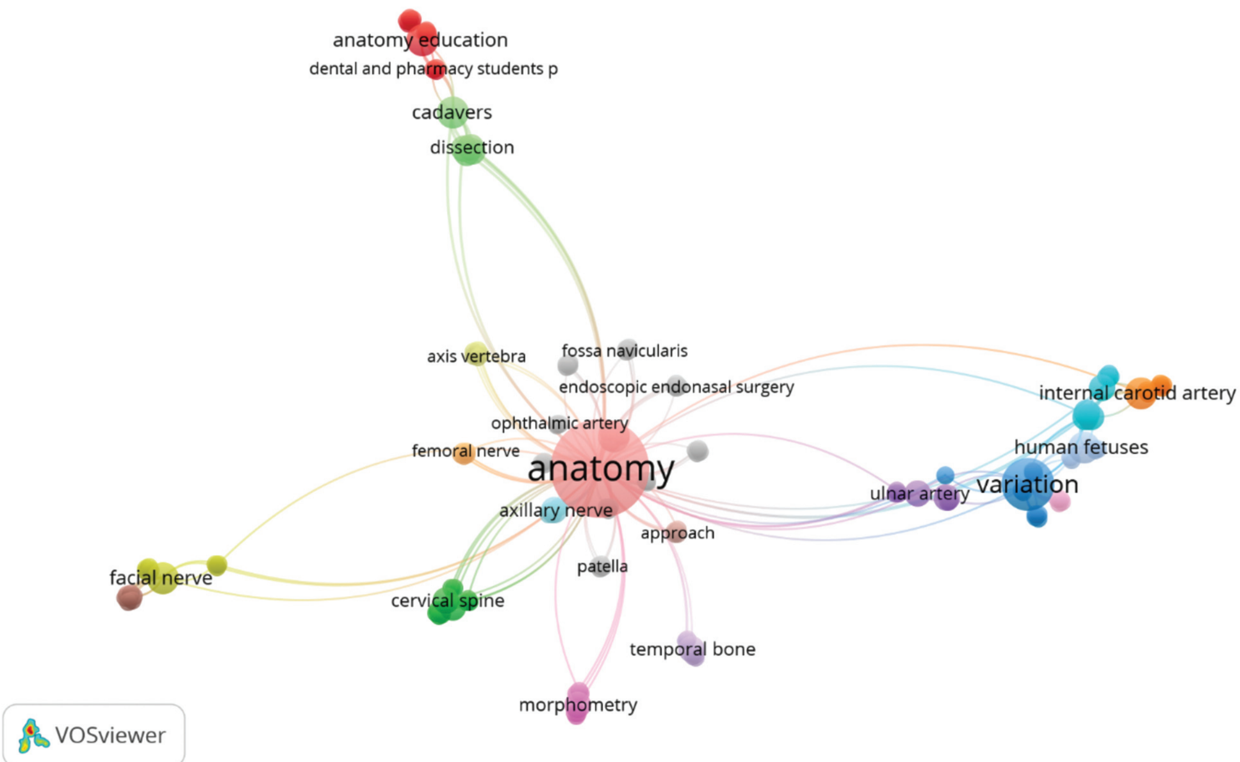

Figure 1. Keyword analysis.

citation databases. It indexes many journals and articles. The data in the study were collected by searching the word 'anatomy' in the 'all fields' category in the Web of Science (WoS) database. Articles with at least 1 citation written in English and published internationally by the researchers of our country between 1980 and 10.09.2023 were included in the study. The one hundred most cited articles were identified and exported from the Web of Science (WoS) database. Detailed data analysis was conducted in VOSviewer 1.6.19 software. This analysis software allowed us to create maps by processing interrelated information.

Results

Based on our analysis, the article "Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors" by Iwanaga et al. and contributed from Türkiye by Nihal Apaydın and Gülgün Şengül was the most cited article with 234 citations.

The keyword analysis showed that research articles from Türkiye mostly used the words 'anatomy, variation, stereology, MRI, and facial nerve' (**Figure 1**). The type and number of studies and the journals and the number of citations are given in **Tables 1** and **2**.

According to the co-authorship analysis of the authors, a network map was created by setting a criterion of at least 1 publication and at least 1 citation to identify the authors who collaborated the most. According to the analysis performed among the authors with the highest collaboration, 7 large clusters and 27 authors were found (**Figure 2**).

A reference to a common work cited by two independent sources is called a bibliometric match. This shows that

Table 1
Types and number of studies.

Study type	Number
Cadaver study	33
Radiological study	25
Clinical study	13
Animal experiment	6
Studies with healthy individuals	6
Dry bone	4
Fetal cadaver	3
Editor review	2
Anatomy training	2
Veterinary anatomy	6
Total	**100**

Table 2
Number of citations by journal.

Journal	Number of citations
Surgical and Radiologic Anatomy	278
Clinical Anatomy	101
Folia Morphologica	78
International Journal of Morphology	73
Annals of Anatomy Anatomischer Anzeiger	49
Journal of the Anatomical Society of India	21
Anatomia Histologia Embryologia Journal of Veterinary Medicine Series	16
Journal of Anatomy	18
Microscopy Research and Technique	15
Anatomical Record Advances in Integrative Anatomy and Evolutionary Biology	10
Acta Anatomica	7
Anatomia Histologia Embryologia Journal of Veterinary Medicine Series C Zentralblatt für Veterinarmedizin Reihe	6
Brain Structure and Function	5
Acta Zoologica	5
Cells Tissues Organs	2
Anatomical Record Part A Discoveries in Molecular Cellular and Evolutionary Biology	2
European Journal of Morphology	2

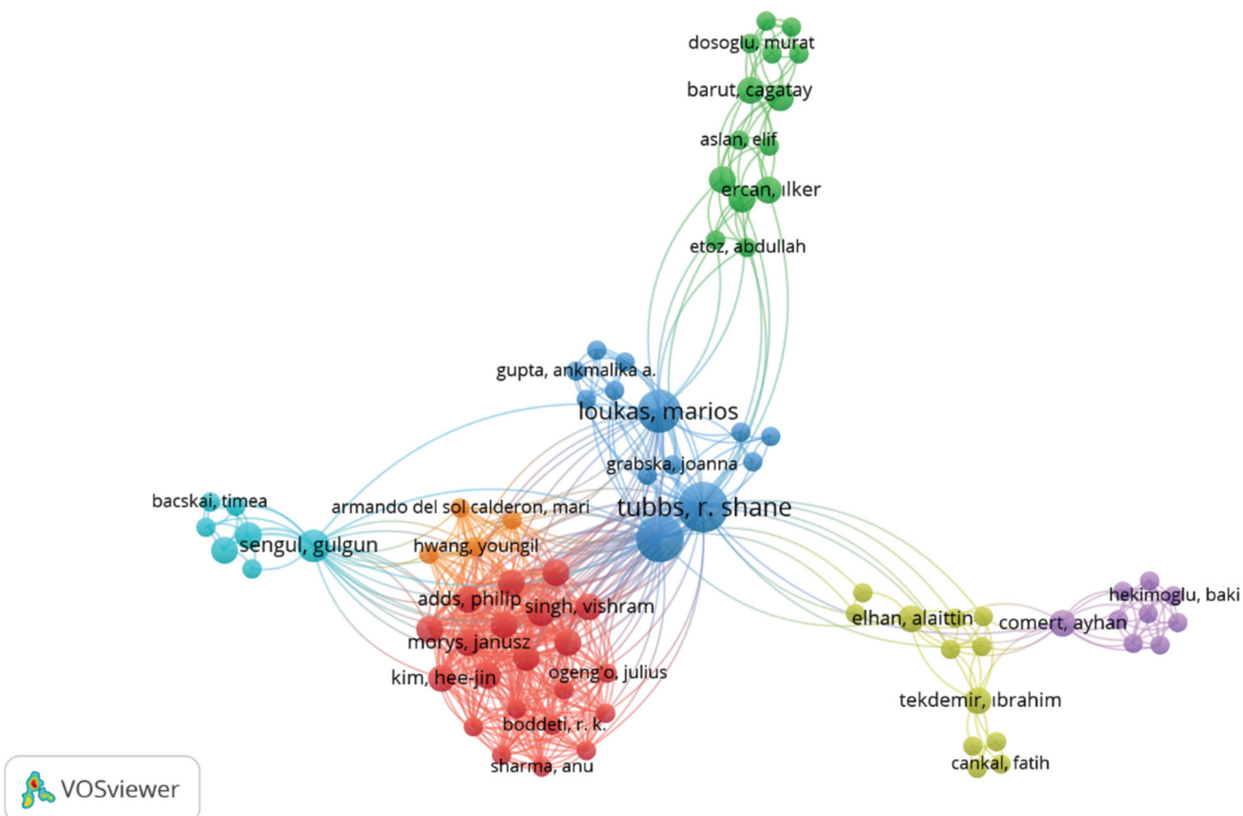

Figure 2. Co-authorship analysis.

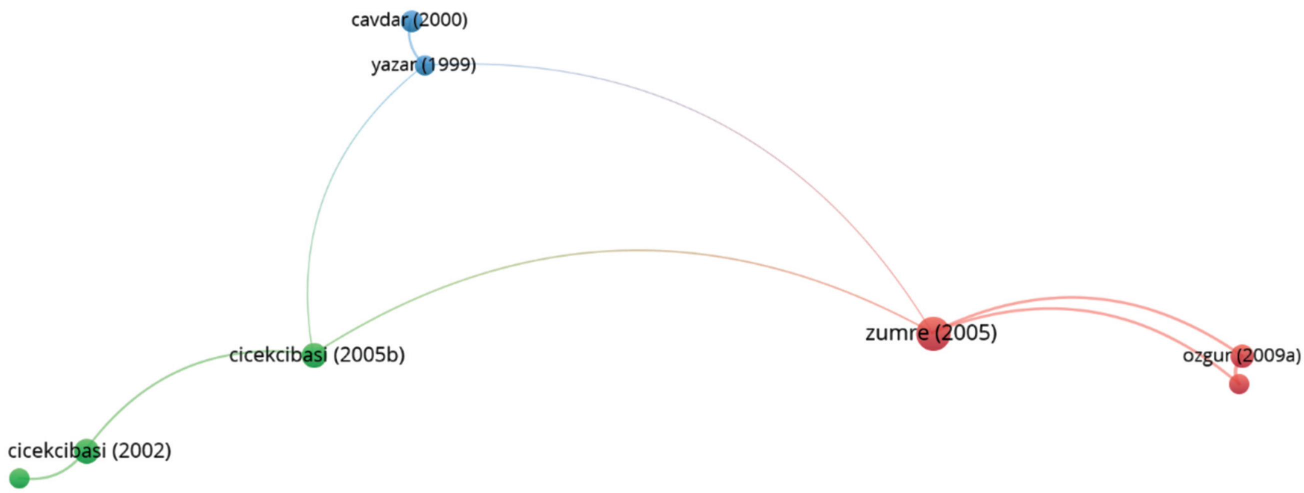

Figure 3. Bibliographic match analysis of texts.

the two sources focus on the same research or subject. **Figure 3** shows the bibliographic match analysis of the texts selected with the criterion of receiving at least 1 citation.

The citation analysis of the institutions selected with the criterion of having published at least 1 work and received 1 citation is presented in **Figure 4**, the analysis of the authors' reference to other countries is given in **Figure 5**, and the analysis of the authors reference to each other is shown in **Figure 6**.

Discussion

Bibliometric studies provide quantitative information about the historical development of the area of science studied. Moreover, bibliometric research provides insight into the future vision of a scientific area. Many scientists have made significant contributions to the history of anatomy, which starts with Andreas Vesalius (1514–1564), known as the father of modern anatomy and the author of the book De humani corporis fabrica.[1,4] Anatomical studies that started with animal dissection have acquired various areas of study under the influence of advancing technology over the years. Animal experiments, radiological studies, clinical studies, and artificial intelligence applications are some of them. In the present study, we aimed to identify the trend anatomy topics and journals with the bibliometric analysis of the 100 most cited articles in the history of the Turkish Republic and the change in the areas of study over the years.

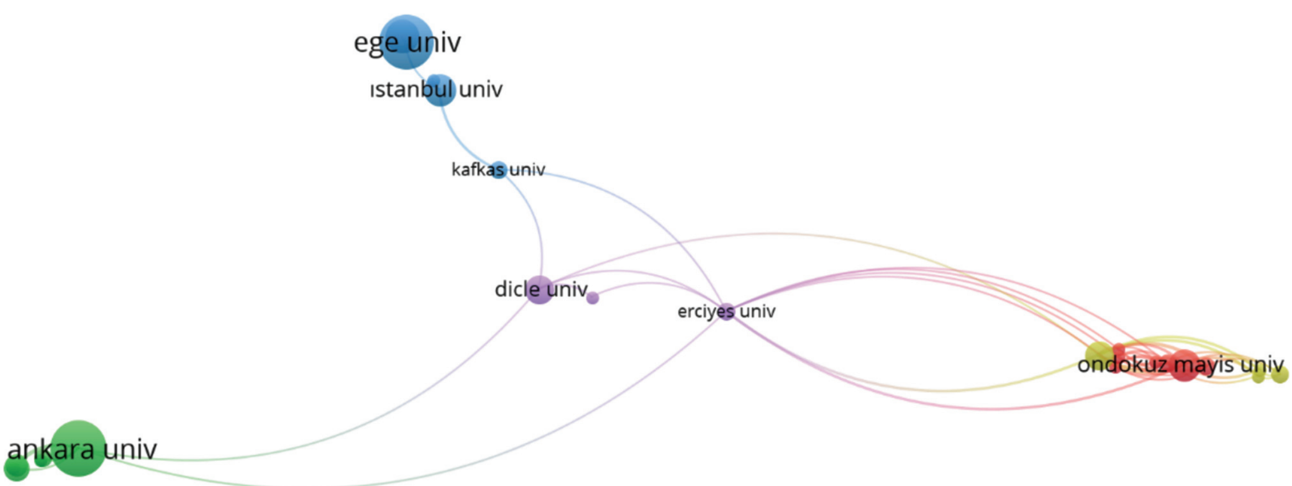

Figure 4. Citation analysis of institutions.

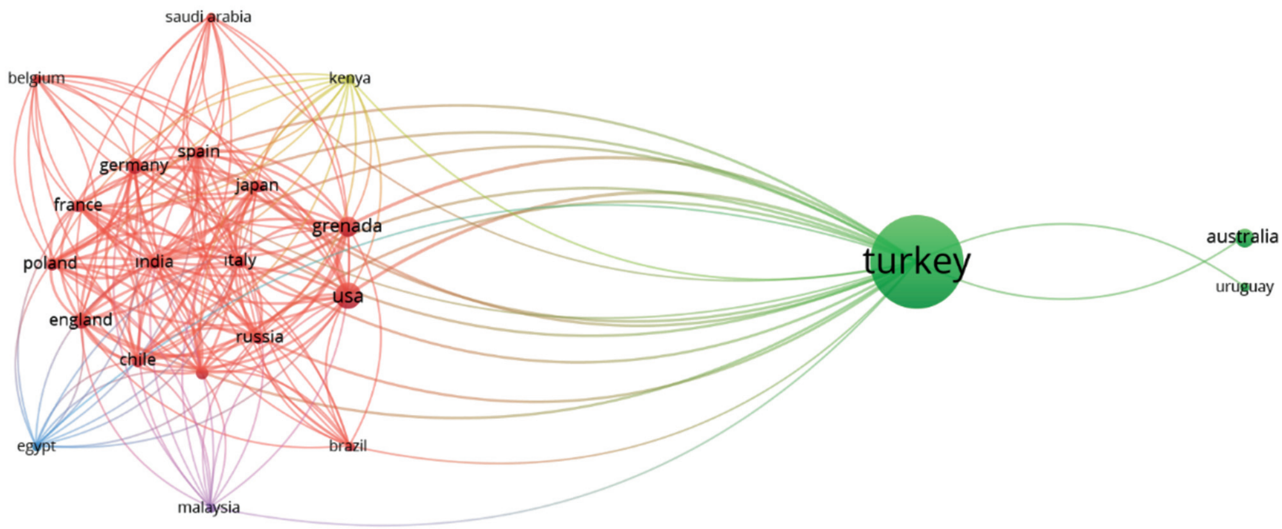

Figure 5. Analysis of authors' reference to other countries.

Gürses et al.[6] examined the publication rates of oral and poster presentations at national anatomy congresses held in Türkiye between 2007 and 2008 and found that the most preferred journal was Surgical and Radiologic Anatomy. In another study, Tellioglu et al.[7] stated that the highest publication rate of the publications by Turkish anatomists between 2000 and 2014 was in Surgical and Radiologic Anatomy. Furthermore, in a study conducted by selecting Türkiye and in the category of anatomy and morphology, in which studies up to 2019 through the Web of Science (WoS) database were included, Bahşi et al.[8] reported that the most cited journal was Surgical and Radiologic Anatomy. Similar to these two studies, the most preferred journal in this study was found to be Surgical and Radiologic Anatomy. In our study, the most cited anatomy journal was found as Surgical and Radiologic Anatomy. We believe that the number of citations of journals is significant for making studies by anatomists more accessible and visible.

In the bibliometric analysis conducted for the period between 2007 and 2018 in the journal "Anatomy", the official publication organ of the Turkish Society of Anatomy and Clinical Anatomy, Adanır et al.[9] reported that the article type with the highest citation average was "anatomy education" when the number of citations was reviewed according to article types. Upon evaluating the original articles, clinical and cadaver studies were stated to have the highest citation average. Meanwhile, it was reported that studies with the highest citation average in case reports were cadaver studies. In our study, the most cited cadaver studies regarding the subject are followed by radiological studies and clinical studies. Bibliometric analysis shows that cadaver studies constitute a significant part in the field of anatomy. We think that cadaver

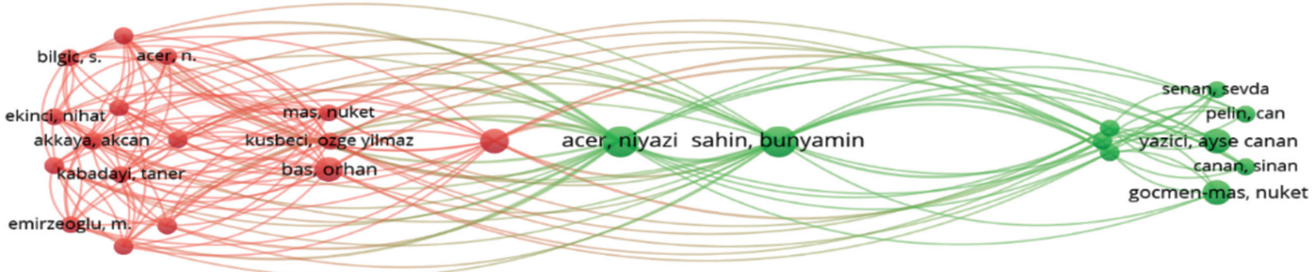

Figure 6. Analysis of authors' reference to each other.

studies are necessary to guide research in the field of anatomy and improve the quality of education.

In the citation analysis of the institutions in the Web of Science (WoS) database, Bahşi et al.[8] reported that the most cited institutions by the authors of our country were Ankara University, Hacettepe University, and Dicle University. In our study, when the citation analysis of the institutions was performed, the most cited institutions were found to be Ankara University, Hacettepe University, and Ege University. We assume that the establishment dates of the institutions and the opportunities offered to the institutions affect the number of citations. The limitation of the study is that only articles in the Web of Science (WoS) database were included in the study. In addition, articles published in 1980 and before are not included in this database.

Conclusion

As a result, bibliometric studies have some limitations, but they provide valuable information in the field of anatomy. Although research in the field of anatomy has gradually evolved toward neuroanatomy and radiology studies throughout the history of the Turkish Republic and worldwide, cadaver and morphometry studies remain important. It is clear that anatomy studies are still regarded as the main implementation area of all medical knowledge. We think that the bibliometric analysis of the 100 most cited anatomy articles in the hundredth year of the Turkish Republic will help anatomists find gaps in the literature and find inspiration for their future studies.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

HE: conception, data collection and/or processing, literature review; KÖ: supervision, data collection and/or processing, analysis and/or interpretation, critical review; İH: design, literature review, critical review; YK: conception, design, supervision, analysis and/or interpretation, literature review, critical review.

Ethics Approval

In this study, all guidelines specified to be applied within the scope of the "Scientific Research and Publication Ethics Directive for Higher Education Institutions" were followed. There is no need to obtain ethics committee approval in our study.

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ORCID ID:
H. Ertürk 0000-0003-3892-1035;
K. Öztürk 0000-0002-5552-8684;
İ. Hız 0000-0001-5407-7669;
Y. Kastamoni 0000-0002-3504-5853

deomed

Correspondence to: İhsan Hız, MD
Department of Anatomy, Faculty of Medicine,
Süleyman Demirel University, Isparta, Türkiye
Phone: +90 0542 289 32 50
e-mail: drihsanhiz@gmail.com

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Review

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Review of extraosseous and intraosseous blood supply of the carpal bones

Aybegüm Balcı

Department of Anatomy, Ankara University School of Medicine, Ankara, Türkiye

Abstract

The blood supply of the carpal bones has been updated and described with new dissection, vascular filling and imaging techniques. It is very important to know the vascular anatomy of the carpal bones in order to predict vascular insufficiency and associated avascular necrosis that may occur as a result of any injury such as fracture. This article reviews the extraosseous and intraosseous vascular supply of the carpal bones. The carpal bones are supplied by three vascular arches formed by the radial, ulnar and anterior interosseous arteries on the dorsal and palmar sides of the wrist. These contribute to the dorsal and palmar carpal vascular systems, which consist of transverse arteries connected by longitudinal anastomoses. The scaphoid and capitate have a high risk of avascular necrosis, while the trapezium, triquetrum, pisiform and 80% of the lunate have a lower risk. With the development of new imaging techniques, new information is added to the literature. With the increase in three-dimensional studies, intraosseous vascularity and its correlation with carpal bone fractures and its relationship with avascular necrosis will be revealed more clearly.

Keywords: arterial supply; carpal bone; extraosseous vascularity; intraosseous vascularity; vascular anatomy

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Introduction

The vascularity of the carpal bones has been updated and defined until today with new dissection, vascular filling and imaging techniques. It is essential to know the vascular anatomy of the carpal bones in order to predict vascular failure and the resulting avascular necrosis, that may occur as a result of any damage such as fractures. This article reviews the extraosseous and intraosseous vascular supply of the carpal bones.

Extraosseous Vascularity of the Carpal Bones

The carpal bones are supplied by three vascular arches each on the dorsal and palmar sides of the wrist, formed by the radial, ulnar and anterior interosseous arteries (**Figure 1**). They contribute to the dorsal and palmar carpal vascular systems, which consist of transverse arteries connected by longitudinal anastomoses. The arches on the dorsal side are the dorsal radiocarpal, dorsal intercarpal and basal metacarpal. On the palmar side, there are palmar radiocarpal, palmar intercarpal and deep palmar arches.[1]

After the brachial artery divides into radial and ulnar arteries, the radial artery first gives the radial recurrent artery in the proximal part of the forearm. Then, radial artery gives palmar carpal branch. The palmar radiocarpal and intercarpal arches are formed by anastomosing with the palmar carpal branch of the radial artery and the common interosseous artery and palmar carpal branch of the ulnar artery. The palmar radiocarpal arch is located more proximally and is generally formed by radial, ulnar and anterior interosseous arteries, and its variations are few. It extends transversely proximal to the radiocarpal joint. The palmar intercarpal arch extends transversely between the proximal and distal rows of carpal bones, and its variations are common.[1–3]

The dorsal radiocarpal arch is the most proximal of the dorsal carpal network and occurs deep to the extensor muscle tendons at the level of the radiocarpal joint. Although this network is formed by radial, ulnar and anterior interosseous arteries, there are variations in which ulnar and anterior interosseous arteries do not participate. The dorsal intercarpal arch runs between the proximal and distal rows of carpal bones. It is the largest of the three

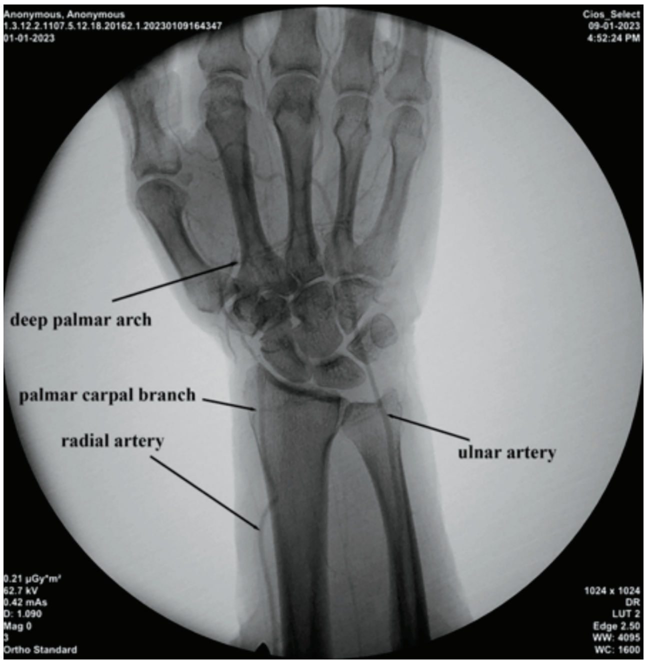

Figure 1. C-arm scopy image of main arteries responsible for supplying the carpal bones.

dorsal arches. It anastomoses with the dorsal radiocarpal arch to supply the lunate and triquetrum. The distal or basal metacarpal arch runs along the bases of the metacarpal bones, just distal to the carpometacarpal joint, and is the smallest of the dorsal arches. It can also anastomose with the perforating branches of the deep palmar arch in the 2nd, 3rd and 4th interosseous spaces. Dorsal arches are connected to each other by longitudinally extending branches.[1,4]

Dorsal intercarpal, palmar radiocarpal and deep palmar arches can always be seen in humans, while dorsal radiocarpal arch is seen in 80%, basal metacarpal arch is seen in 27%, and palmar intercarpal arch is seen in 53%. Most carpal bones are fed by branches coming from these arches. As an exception, the dorsal and lateral aspects of the trapezium and the scaphoid are also supplied by branches coming directly from the radial artery, and the pisiform and triquetrum are fed by branches coming directly from the ulnar artery.[1]

Intraosseous Vascularity of the Carpal Bones

Gelberman and Gross[5] classified the carpal bones for risk of avascular necrosis according to their intraosseous vascular pattern. According to them, scaphoid, capitate and the 8–10% of the lunate are located in the group 1. These bones have highly risk of avascular necrosis. Group 2 consists of trapezoid and hamate and, group 3 has trapezium, triquetrum, pisiform and 80% of lunate (**Table 1**).

Scaphoid

The scaphoid is the most common fractured carpal bone. Avascular necrosis is seen especially after proximal pole fractures. The scaphoid receives arteries mainly from radial artery. The palmar carpal branch of the radial artery supplies the proximal part, superficial palmar branch of the radial artery supplies the middle and distal part of the palmar surface. On the dorsal surface, the dorsal scaphoid artery that a branch of the radial artery supplies the scaphoid. This artery usually anastomoses with the dorsal branch of the anterior interosseous artery.[6,7]

The intraosseous vascularity of the scaphoid dependent to single artery which supplies major part of the bone. On the dorsal side, one artery enters the bone from dorsal ridge and supplies the proximal 70–80% of the bone, while the other artery enters to the bone from the tubercle on the palmar side and supplies the distal 20–30% of the bone.[6,8–14] According to Gelberman and Gross,[5] and, Gelberman and Menon,[6] the scaphoid has a high risk of avascular necrosis because it consists of large areas of bone containing single intraosseous artery and there is no anastomosis between the arteries supplying different areas. However, according to the study by Morsy et al.[8] analyzing the intraosseous vascularity of the scaphoid by micro-computed tomography, there is anastomosis between the vessels located proximal and distal to the bone in 15% of cases and some scaphoids have better perfusion than others.

While, according to Gelberman and Gross,[5] and, Gelberman and Menon,[6] and Taleisnik,[10] the vessels at the attachment of the scapholunate ligament on the dorsal side does not contribute to the intraosseous vascularity, Morsy et al.[8] and Xiao et. al.[15] showed that the

Table 1
Classification of carpal bones according to the risk of avascular necrosis due to intraosseous vascular pattern.

Group 1	Group 2	Group 3
Scaphoid	Trapezoid	Trapezium
Capitate	Hamate	Triquetrum
Lunate (8–20%)		Pisiform
		Lunate (80–92%)

entrance of the vessels located at the attachment of the scapholunate ligament to inside the bone.

Capitate

The capitate receives blood supply from dorsal intercarpal, basal metacarpal, palmar intercarpal arches and recurrent branches of the ulnar artery. On the dorsal side, 2–4 vessels enter to the bone from concave part of it. Vessels entering from distal half of the bone run retrogradely and supply the head and body of the bone. Vascular supply of the head of the bone is provided by 1–3 vessels entering to the bone on the palmar side. There is 30% anastomosis between palmar and dorsal vessels. The proximal pole of the capitate has rich vascularity, while the articular surface has poor vascularity.[11] Kadar et al.[11] and Xiong et al.[12] used micro-computed tomography to identify a vessel directly supplying this pole in the proximal part of the capitate in 70% of the cases. It may explain why most capitate waist fractures do not progress to proximal pole avascular necrosis. Xiong et al.[12] also reported that the main vascular branches supplying the capitate originate from around the ligaments.

Trapezoid

The trapezoid receives vascular supply from intercarpal and basal metacarpal arches and recurrent branches of the radial artery. The 3–4 vessels entering the bone from the dorsal side are responsible for 70% of the vascularization of the bone. The 1–2 vessels entering the bone from the palmar side are responsible for 30% of the vascularization of the bone. There is no anastomosis between dorsal and palmar vessels.[13]

Hamate

The hamate receives vascular supply from dorsal intercarpal arch, terminal branches from anterior interosseous artery and recurrent branches of the ulnar artery. 3–5 vessels entering from dorsal surface supply the 30–40% of the bone. On the dorsal surface, vessels entering into bone from the lateral surface of the hook of hamate are responsible major intraosseous vascularization of the hamate. These vessels anastomose with dorsal vessels at a rate of 50%.[13,14] In the micro-computed tomography studies of Xiao et al.,[9] the number of arteries in the dorsal region was found to be higher, indicating that the blood circulation in the dorsal region may be more dominant. According to Panagis et al.[13] 1–2 vessels entering from the medial surface of the hamate hook do not anastomose with other vessels, whereas Wang et al.[16] defined anastomosis between the vessels in the body and hook in their studies performed with micro computed tomography. The lack of direct vascular supply to the proximal part of the bone predisposes to avascular necrosis.[13,15,16]

Lunate

The lunate receives vascular supply from radiocarpal and intercarpal arches, dorsal and palmar branches of the anterior itnterosseous artery and, recurrent branches of the ulnar artery.[13,17] Dubey et al.[18] described the foramina of the bone surface and identified that palmar foramina are wider than dorsal. Van Alphen et al.[19] analyzed the diameter of the vessels in their studies performed with micro computed tomography and found that palmar vessels were wider than dorsal.[18,19] While in 80% of the lunate, nutrient vessels enter the bone from palmar and dorsal surfaces, in 20% of lunate they enter from only palmar surface. This pattern may explain that some lunate bones prone to Kienböck's disease which is idiopatic avascular necrosis of the lunate. For 80% of the lunate, dorsal and palmar interosseous vessels anastomose each other. According to the distribution of the interosseous vessels, the lunate is classified in 3 patterns; Y, I and X. Y is the most common pattern and X is the least common pattern.[13,19]

Triquetrum

Triquetrum is supplied from the dorsal and palmar sides by small branches from the dorsal intercarpal, dorsal radiocarpal and palmar radiocarpal arches and, ulnar artery.[1] In 2023, the vascular foramina of the triqetrum were described and suggested that the arterial supply of the triquetrum mainly provide by vessels entering dorsal surface.[20] In other studies which examine vessels with vascular filling, it has been reported that 2–4 vessels entering from the protrusion on the dorsal side nourish the dorsal 60% of the bone, and 1–2 vessels entering from the proximal and distal sides of the palmar side where it articulates with the pisiform nourish the palmar 40% of the bone. Vascular anastomoses are present on the dorsal and palmar sides.[13,21] Triquetrum is included in the group of carpal bones with low risk of avascular necrosis because there is no single artery dominance in its nutrition and the vessels anastomose within the bone.[5] Although avascular necrosis is rare, it is usually observed after trauma.

Pisiform

The proximal part of the pisiform is supplied by dorsal carpal branch of the ulnar artery; the distal part is supplied by branches of the deep palmar arch and the lateral part is supplied by directly branches of the ulnar artery. While proximal vessels enter the bone from attachment area of the tendon of the flexor carpi ulnaris, distal vessels enter from below the articular surface with triquetrum.[13,22]

Trapezium

The trapezium receives 1–3 vessel on the dorsal side, 1–3 vessel on the palmar side and 3–6 vessel on the lateral side from distal branches of the radial artery. There is anastomosis between these vessels. Dorsal intraosseous vascular pattern is dominant.[13]

Conclusion

It is important to know how the blood supply of a bone because when a bone is fractured, it can show a union depending on this blood supply pattern. Avascular necrosis usually occurs after nonunion and results in the death of bone and bone marrow cells due to decreased bone vascularity and eventually mechanical failure. The scaphoid and capitate have a high risk of avascular necrosis, while the trapezium, triquetrum, pisiform, and 80% of lunate have a lower risk. With the development of new imaging techniques, new information is being added to the literature. With the increase in three-dimensional studies, intraosseous vascularity and its correlation with carpal bone fractures and its relationship with avascular necrosis will be revealed more clearly.

Acknowledgement

The author extends deepest appreciation to those who selflessly contributed their bodies for scientific exploration, thereby enhancing anatomical research and improving healthcare practices.[23]

Conflict of Interest

This study declares no conflicts of interest.

Ethics Approval

The methods employed in this study followed the ethical guidelines established by the institutional research committee and were in accordance with the principles outlined in the 1964 Helsinki Declaration and its subsequent amendments.

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ORCID ID:
A. Balcı 0000-0002-6345-1082

Correspondence to: Aybegüm Balcı, MD
Department of Anatomy, Ankara University School of Medicine, Ankara, Türkiye
Phone: +90 312 595 82 40
e-mail: aybegumakin1@gmail.com

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A unique variation of the common peroneal nerve: a case report

Kıvanç Goral , Tania Marur

Department of Anatomy, Cerrahpaşa Faculty of Medicine, Istanbul University-Cerrahpaşa, Istanbul, Türkiye

Abstract

This variation was observed in the left lower extremity of a 75-year-old male cadaver fixed with formalin, ethanol and glycerol solution. The common peroneal nerve was divided into six terminal branches. These branches were identified as deep peroneal nerve, superficial peroneal nerve, two muscular branches to the tibialis anterior and two muscular branches to the peroneus longus. Knowledge of the variations of the common peroneal nerve and its branches is important in knee and proximal leg operations.

Keywords: cadaver; common peroneal nerve; variations

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Introduction

The common peroneal (fibular) nerve generally diverges as the terminal branch of the sciatic nerve in the lower 1/3 of the thigh. After leaving the sciatic nerve as a terminal branch, it travels obliquely outward and laterally in the popliteal fossa. During this course it passes between the tendon of the biceps femoris muscle and the lateral head of the gastrocnemius muscle. Continuing its course, the common peroneal nerve enters deep into the peroneus longus muscle by winding from lateral of neck of the fibula. Deep to the peroneus longus muscle, it divides into two terminal branches called the deep peroneal nerve and the superficial peroneal nerve. It gives articular and cutaneous branches before dividing into its terminal branches. It provides innervation of the knee joint and proximal tibiofibular joint through the articular branches. It gives cutaneous branches named lateral sural cutaneous nerve and sural communicating nerve. The lateral sural cutaneous nerve innervates the skin of anterior, lateral and posterior aspects of the proximal part of the leg. The sural communicating nerve participates in the formation of the sural nerve. Its terminal branch named the deep peroneal nerve stimulates all the muscles in the anterior compartment of the leg and two small muscles in the dorsum of the foot. It also receives sensation of the skin between the big toe and second toe. The other terminal branch of the common peroneal nerve named the superficial peroneal nerve stimulates the leg lateral compartment muscles. It also receives sensation of the lateral part of the lower leg and most of the dorsum of the foot and toes.[1–3]

During the 4th week of embryonic life, limb buds appear in the anterolateral region of the body wall. Upper limb buds are located opposite the lower cervical and upper thoracic spinal segments. The lower limb buds are located opposite the lumbar and upper sacral spinal segments. After the formation of the limb buds, nerve fibers from the related spinal segments are distributed into the mesenchymal tissue. The neuromuscular interactions that occur with the nerves distributed between the muscle cells are necessary for the realization of healthy limb functions in the future.[4] Conditions that may occur in these complex pathways where the nerve fibers from the relevant spinal segments travel until they reach the muscle fibers can cause nerve variations.

Common peroneal nerve is one of the most frequently injured nerves of the lower extremity. Its protection against trauma is low due to its superficial course especially when winding around the fibula neck. The common peroneal nerve can also be damaged because of many surgical procedures. It can be injured especially in interventions related the proximal leg, popliteal fossa and the knee area. It has been stated that the common peroneal nerve can be damaged as a result of total knee arthroplasty.[5] The common peroneal nerve can be damaged as a result of high tibial osteotomy.[6] It has also been reported that the common peroneal nerve can be damaged after the operation of the short saphenous vein.[7] It has also been reported that the common peroneal nerve can be damaged during arthroscopic knee surgery.[8]

In total damage to the common peroneal nerve, result in paralysis occurs in the muscles in the anterior and lateral compartments of the leg. For this reason, extension and eversion movements of the ankle cannot be performed. In those patients, foot drop occurs because the anterior compartment muscles cannot work and therefore the feet rub against the ground while walking. In addition, sensory loss is seen in the anterior and lateral regions of the leg and almost all of the dorsum of the foot.[1–3]

Case Report

A unique anatomical variation of the common peroneal nerve was observed in the left lower extremity of a 75-year-old male cadaver during the dissections we performed in the laboratory of the Department of Anatomy of Istanbul University-Cerrahpaşa, Faculty of Medicine. In this case, the common peroneal nerve divided into six terminal branches deep to the peroneus longus muscle as it looped around the neck of the fibula in the left lower extremity. (**Figures 1** and **2**) In this case, the common peroneal nerve divided into terminal branches before piercing the anterior intermuscular septum. Two of these six branches were the deep peroneal nerve and the superficial peroneal nerve. Two branches were muscle branches to the tibialis anterior muscle. The remaining two branches were muscle branches to the peroneus longus muscle. After separating from the common peroneal nerve, the deep peroneal nerve pierced the anterior intermuscular septum and entered the anterior compartment of the leg. After separating from the common peroneal nerve, the superficial peroneal nerve ran deep into the peroneus longus muscle. The two muscle branches to the tibialis anterior muscle entered the muscle lateral to the muscle after piercing the anterior intermuscular septum. Two muscle branches to the peroneus longus muscle entered the muscle medial to the muscle. The point where the common peroneal nerve divided into terminal branches was determined to be distal to the apex and head of the

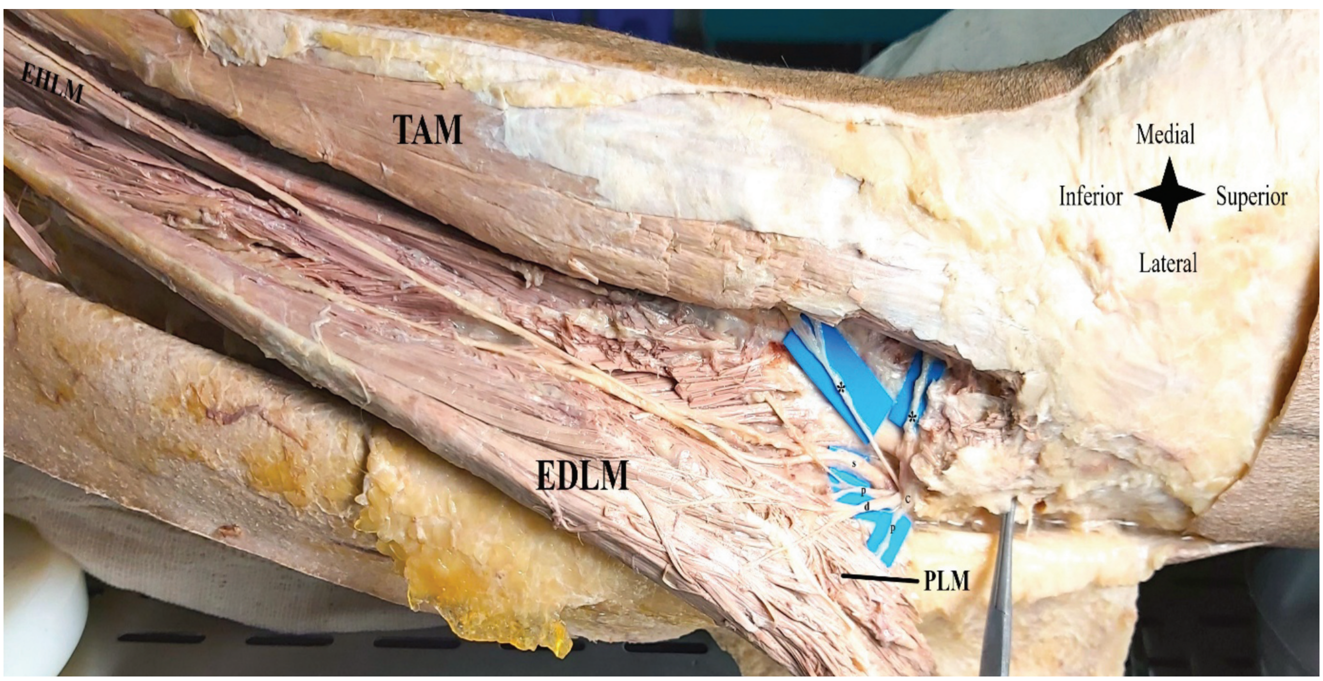

Figure 1. Division of the common peroneal nerve in the left lower extremity. EDML and PML origins were cut and retracted laterally. **c:** common peroneal nerve; **d:** deep peroneal nerve; **EDLM:** extensor digitorum longus muscle; **EHLM:** extensor hallucis longus muscle; **p:** muscular branches to the peroneus longus muscle; **PLM:** peroneus longus muscle; **s:** superficial peroneal nerve; **TAM:** tibialis anterior muscle, *****: muscular branches to the tibialis anterior muscle.

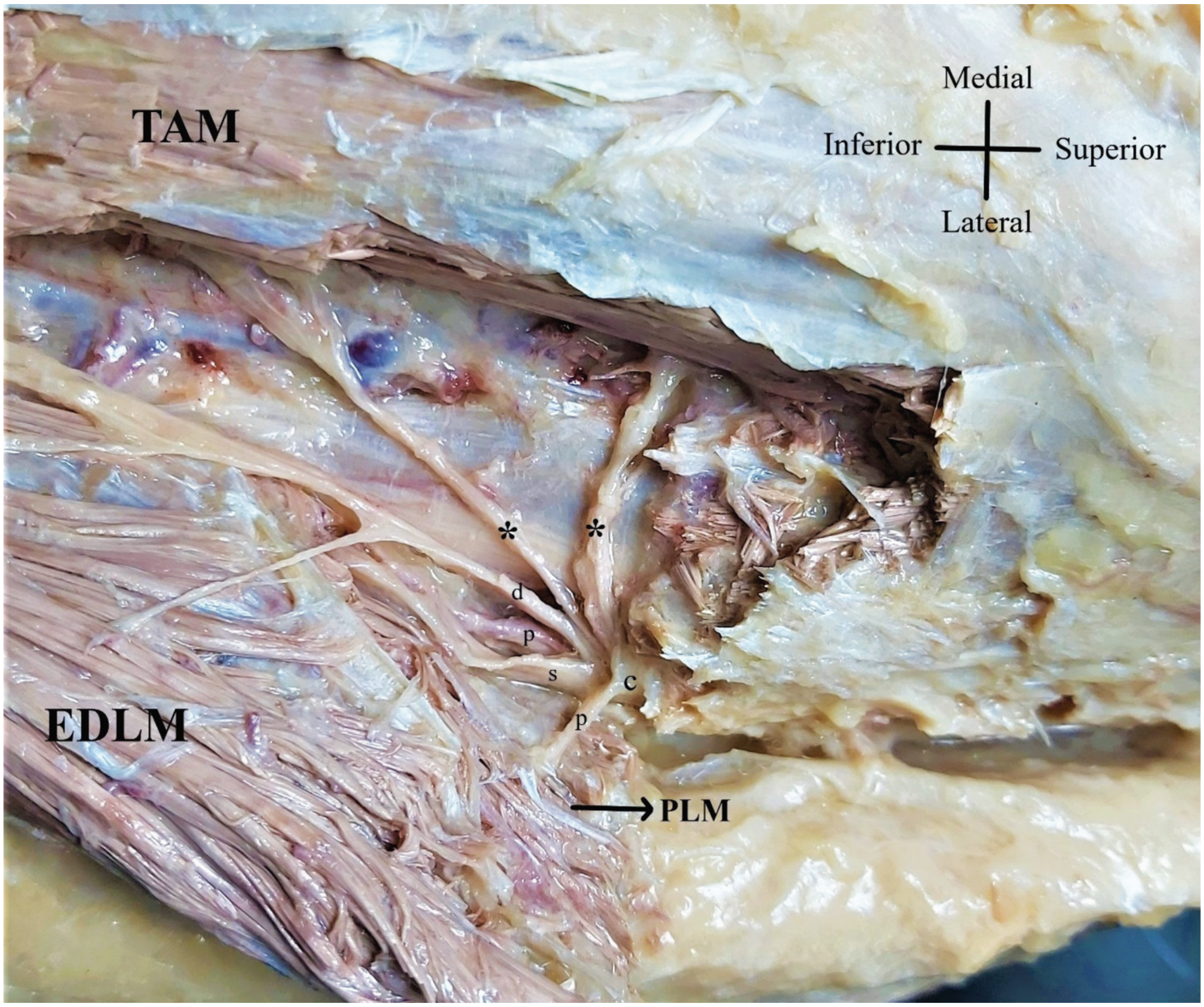

Figure 2. Division of the common peroneal nerve into six terminal branches in the left lower extremity, close-up view of **Figure 1**. **c**: common peroneal nerve; **d**: deep peroneal nerve; **EDLM**: extensor digitorum longus muscle; **p**: muscular branches to the peroneus longus muscle; **PLM**: peroneus longus muscle; **s**: superficial peroneal nerve; **TAM**: tibialis anterior muscle, *****: muscular branches to the tibialis anterior muscle.

fibula (**Figure 3**). The distance from the point where the common peroneal nerve branches into its terminal branches to the apex of the fibula was 2.8 cm and the distance to the most prominent point of the fibular head was 1.3 cm. In the right lower extremity of the same cadaver, the common peroneal nerve was divided into three terminal branches: deep peroneal nerve, superficial peroneal nerve and muscular branch to the tibialis anterior muscle.

Discussion

The common peroneal nerve may be damaged in operations around the knee and proximal leg. Therefore, it is very important to know the anatomical features and variations of the common peroneal nerve. In the literature, there are studies on the terminal branching characteristics of the common peroneal nerve. However, very few studies have published the variations related to the separation of the common peroneal nerve into terminal branches. In classical anatomy books, it is stated that the common peroneal nerve is divided into two terminal branches called deep peroneal and superficial peroneal nerve.[1–3] Deutsch et al.[9] reported that the common peroneal nerve was divided into two terminal branches as deep peroneal and superficial peroneal nerve in all cases

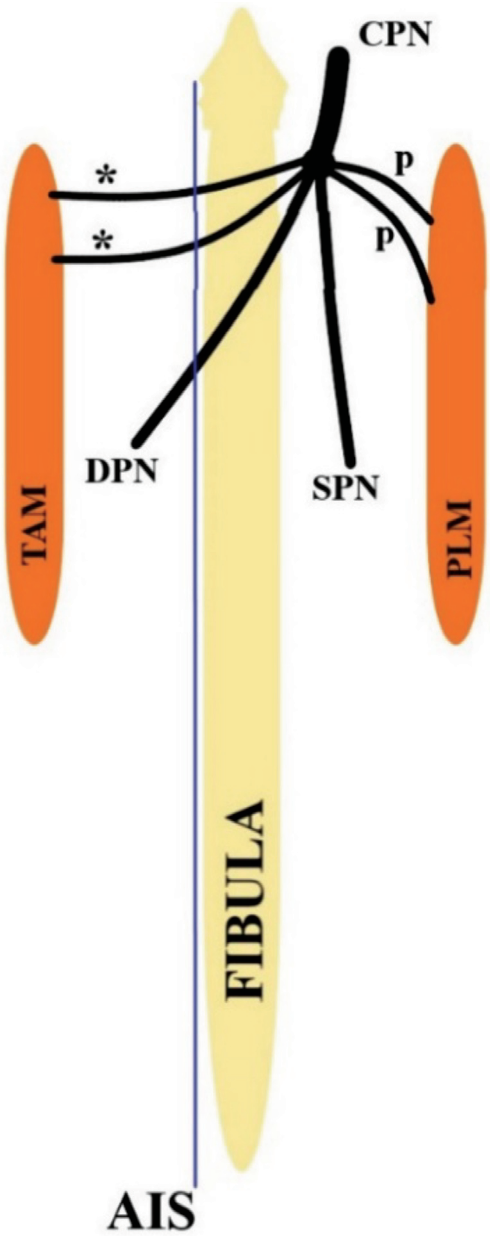

Figure 3. Schematic drawing of the division of the common peroneal nerve into six branches in the left lower extremity. **AIS:** anterior intermuscular septum; **CPN:** common peronal nerve, **DPN:** deep peroneal nerve; **p:** muscular branches to the peroneus longus muscle; **PLM:** peroneus longus muscle; **SPN:** superficial peroneal nerve; **TAM:** tibialis anterior muscle; ***:** muscular branches to the tibialis anterior muscle.

they examined. Kudoh and Sakai[10] found that the common peroneal nerve was divided into two terminal branches as classically described in their study Olcay et al.[11] reported that the common peroneal nerve divides into three terminal branches as anterior recurrent, deep peroneal nerve and superficial peroneal nerve. Chetty et al.[12] reported that the common peroneal nerve divided into two or three terminal branches.

When we look at the classical anatomy books and literature studies, we can say that the common peroneal nerve is divided into two terminal branches as deep and superficial peroneal nerve. In some studies in the literature, it has been reported that the common peroneal nerve is sometimes divided into three terminal branches. The variation of the division of the common peroneal nerve into terminal branches seen in the left lower extremity of the case we examined has not been previously reported in the literature. We think that this variation will be helpful for surgeons especially in operations around the knee and proximal fibula. In addition, in cases with this variation, we can say that isolated muscle weakness or paralysis may be seen in these muscles due to isolated destruction of the muscle branches to the peroneus longus muscle and/or tibialis anterior muscle in traumas that may occur at the level of the fibula head and neck.

Conclusion

We think that this unique variation in the left lower extremity of our case which has not been previously published in the literature will reduce the possibility of injury to the common peroneal nerve and its branches especially in surgical procedures around the knee and the proximal leg.

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Conflict of Interest

The authors declare that there are no conflicts of interest relevant to this study.

Author Contributions

KG: project development, data collection, manuscript writing; TM: project development, data editing, manuscript editing

Ethics Approval

This study was ethically approved by the Cerrahpaşa School of Medicine Ethics Committee (reference no: E-83045809-604.01.02-54387).

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ORCID ID:
K. Goral 0000-0002-2947-9065;
T. Marur 0000-0002-7658-0107

Correspondence to: Kıvanç Goral, MD
Department of Anatomy, Cerrahpaşa Faculty of Medicine,
Istanbul University-Cerrahpaşa, Istanbul, Türkiye
Phone: +90 212 414 30 00
e-mail: kivanc.goral@iuc.edu.tr

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