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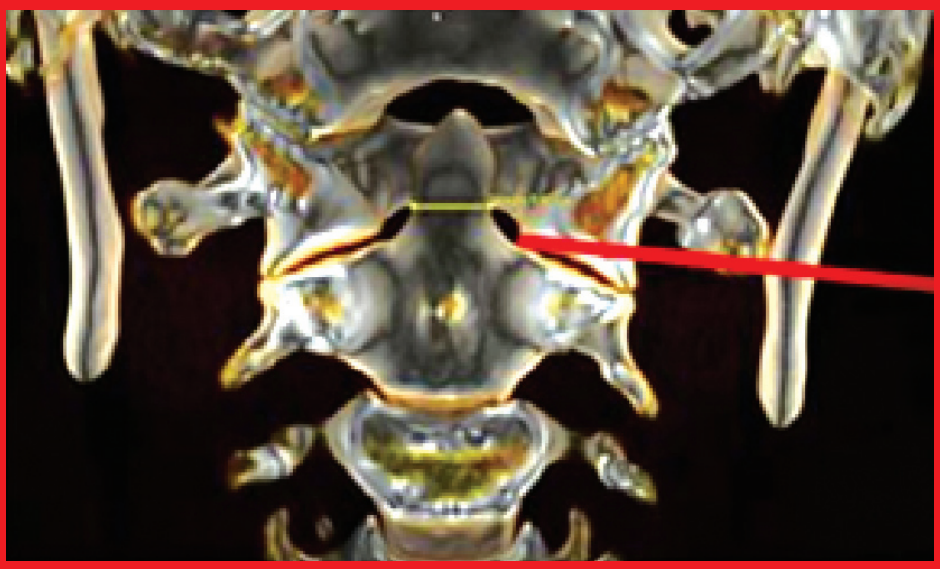

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Evaluation of posture and flexibility in ballet dancers

Hale Öktem[1], Can Pelin[1], Ayla Kürkçüoğlu[1], Merve İzci[1], Tuğçe Şençelikel[2]

[1]*Department of Anatomy, School of Medicine, Başkent University, Ankara, Turkey*
[2]*Department of Biostatistics, School of Medicine, Başkent University, Ankara, Turkey*

Abstract

Objectives: Ballet dancers require a high level of control on their muscles in order to perform various dance figures. Special ballet moves require adaptive changes in order to maintain posture while performing classical ballet dance. The aim of the present study was to evaluate the differences in body postures and range of motion in certain joints between female classical ballet students and female non-dancer students.

Methods: Fifty nine female university students participated in the study; 30 were studying classical ballet at Hacettepe University Ankara State Conservatory and 29 were studying at Başkent University with no professional dancing history. Students in both groups were compared by conducting a body posture analysis anteriorly, laterally and posteriorly with the symmetrigraf chart. Range of motion of the joints was measured using a goniometer and distances were measured using an anthropometer.

Results: Ballet education was a factor in the development of hallux valgus and genu varum deformities ($p<0.001$). Being a ballet dancer or not was determined to be a factor for the development of genu recurvatum ($p=0.004$), but not related to the flexion angle on knee ($p>0.05$). The median values of body flexion and hyperextension showed statistically significant differences between the two groups ($p<0.001$).

Conclusion: Postural defects caused by the adaptive changes that occur during ballet training can be assessed easily by using a symmetrigra. It is also possible to evaluate the degree of the deformities that can develop by time.

Keywords: ballet dancer; posture; range of motion; symmetrigraf

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Introduction

Dance is a performance that requires not only technical skills, but also adequate physical strength and flexibility. Classical ballet training is a long training process that begins at the ages of 10 or 11 and requires intensive practicing. Ballet dancers need to exert a high level of control on their muscles in order to perform various dance figures that are incompatible with human anatomy and to gain expertise in their postures.[1,2] When dancers in their developmental ages lack an adequate level of muscle strength, joint range of motion and flexibility, this intensive training process will engender rapid physical and biomechanical changes that might lead to various permanent changes in their anatomy. These changes are the intrinsic risk factors in terms of injuries.[3,4]

"Turnout" is a position in which ballet dancers force their hip joints and the other joints of their lower limbs to perform an outward rotation while standing in an upright position.[5] The "en pointé" is a position in which the body weight is carried by the joints and ligaments of the foot while standing on tiptoes with special shoes. To achieve the right posture in classical ballet, when these moves are performed repeatedly they lead to adaptations in the musculoskeletal system.[6]

Posture is defined as the combination of the positions that the joints assumed in any and every move performed by the body. To ensure stability with the support of ligaments or to make a move at the time of muscle activity, the body achieves a proper stance as a result of the coordina-

This study was an oral presentation at the 19th National Anatomy Congress and International Mediterranean Anatomy Congress (IMAC 2018), Konya, Turkey.

tion between various muscles.[7] Postural stability is necessary when performing a ballet move. This postural activity may occur with the contraction of antagonist muscles, or with the participation of all muscles in the body. The muscle activities required to achieve a posture are not voluntary, as they are regulated automatically by the central nervous system.[8]

In physiological and biomechanical terms, a good posture provides the maximum competence control with minimum effort.[2,9] Posture is affected by genetics, race, gender, season, diet, socioeconomic status, contemporary fashion, profession, hobbies, psychological state, hygiene, sleep, exercising as much as possible in open and fresh spaces, emotional states (such as happiness, sadness, stress etc.), exhaustion, fractures, soft tissue defects, and defects occurring in the normal settlement angles of the joints.[7]

In addition, the postural habits gained by practicing the moves and positions of a branch of sports since childhood also have an impact on posture. When only one side of the body is subjected to effort during exercise, the symmetry of the physical structure may become affected.[2] Injuries that are caused by overuse, such as metatarsal stress fractures, patellofemoral syndrome and cervical disk injuries may occur frequently in ballet dancers depending on their age and experience level.[10]

The aim of the study was to analyse and evaluate the differences in terms of posture and range of motion of certain joints between female classical ballet students and a control group consisting of female non-dancer students.

Materials and Methods

A total of 59 university students between the ages of 18 to 25, including 30 female students studying classical ballet for at least 8–10 years at Hacettepe University State Conservatory and 29 female students studying at Başkent University with no professional dancing history, participated in the study. Participants in both groups had no clinically diagnosed musculoskeletal disorders or symptoms during the study.

Posture analysis of the students was performed using the transparent symmetrigraf of 2 m length and 1 m width (**Figure 1**). The symmetrigraf that was designed for the present study was divided into large squares of 3×3 cm^2 that also contained smaller squares of 1×1 cm^2. There was a thick line in the middle of the chart, overlapped with the midline. In an anatomic position, the participants were assessed anteriorly, posteriorly and laterally.

The anterior analysis evaluated the presence of hallux valgus, inversion and eversion in the feet; tibial torsion, genu varum and genu valgum in the legs; asymmetry between the anterior superior iliac spine (ASIS); and the asymmetry between the right and left shoulders. The lateral analysis evaluated pes planus and pes cavus in the feet; genu recurvatum and flexion in the knees; anterior and posterior tilt in the pelvis; lordosis and kyphosis in the spine; and anterior and posterior tilt in the head. The posterior analysis evaluated pronation and supination in the feet, and it was also assessed whether there was scoliosis in the spine by marking the spinous processes.

In the lateral view, the anterior and posterior tilt in head was assessed to determine whether the head was tilted forward or backward, based on the relation between the tip point of shoulder joint and the auricle.

Figure 1. Symmetrigraf chart. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

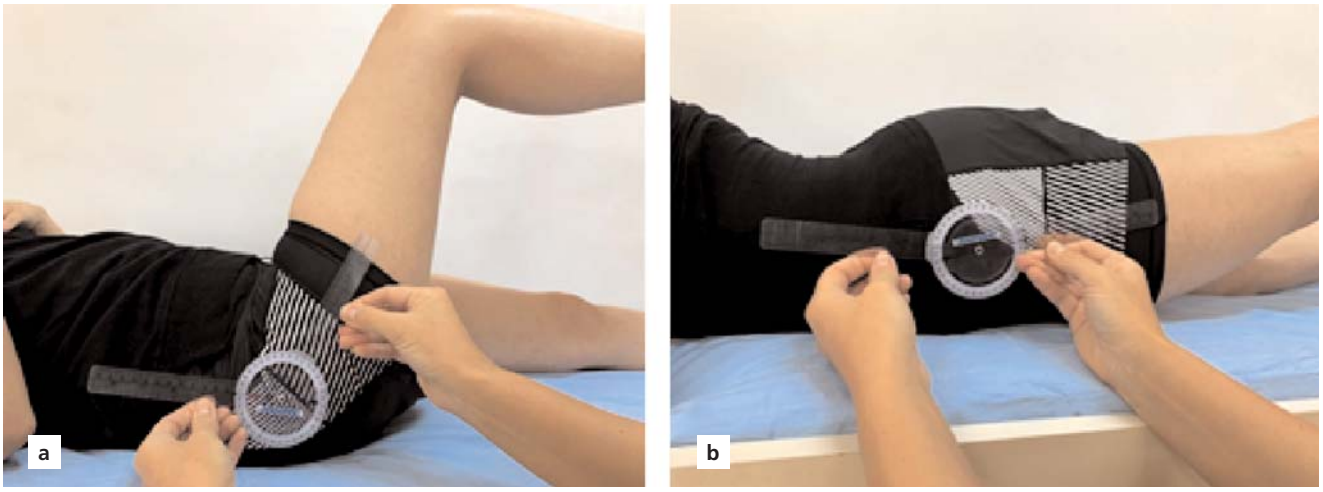

Figure 2. Measurement of the flexion (**a**) and extension (**b**) angles of the hip joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Increased pelvic inclination was considered as an anterior pelvic tilt, while decreased pelvic inclination was considered as a posterior pelvic tilt.

The range of joint motion in flexion and extension of hip joint, knee joint, in dorsiflexion, in plantar flexion of the ankle, and in inversion and eversion motions were measured using goniometer as seen in **Figures 2a–b**, **3a–b**, **4**, and **5a–b**. Body flexion, hyperextension, rotation and lateral flexion, hip abduction angle and hamstring length were measured using anthropometer.

Body flexion and extension were assessed anthropometrically. To measure body flexion, the participants were made to stand on a 40 cm-high block and asked to reach the maximum level of forward flexion without bending their knee. Then, the distance between the distal of the third toe and the block was measured. The values below the block surface were assessed as positive, and the ones above as negative. To measure body extension, the participants were made to face a wall, and with their pelvis and body fully in contact with the wall, the participants were then asked to stand upright. First, the distance between the jugular incisure and the wall was measured. This value was subtracted from the value obtained by measuring the distance between the jugular incisure and the wall while the body was in maximum backward extension by supporting the pelvis.

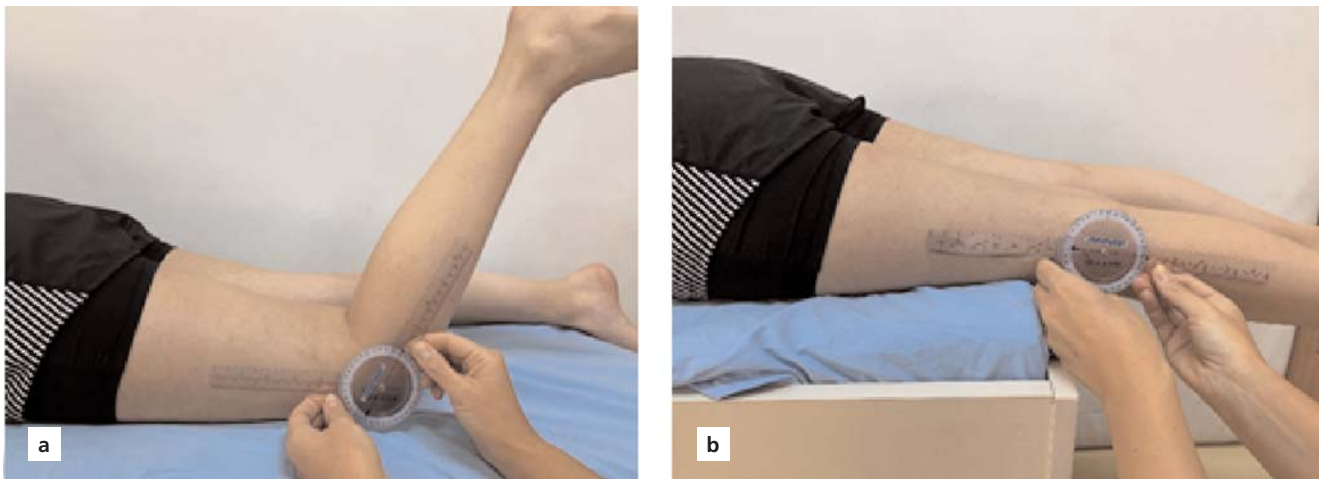

Figure 3. Measurement of the flexion (**a**) and hyperextension (**b**) of the knee joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

To measure the body rotation, the participants were first made to face the wall, and the distance between the acromion and the wall was measured while the pelvis was in full contact with the wall. Following, with one shoulder and the pelvis still in full contact with the wall, the other shoulder was moved away from the wall by rotating the body. Again in this position, the distance between acromion and the wall was measured, and the first value was subtracted from the second value and recorded as body rotation value.

The lateral flexion of the body was measured as follows: the participants were first brought to their anatomic position, and the point where the distal tip of the middle finger in hand coincides with thigh was marked. The participants were then asked to make a lateral flexion with their body by moving their hands downwards by sliding them on their thigh, without interrupting the contact between the hands and thigh. In this position, the distal tip of the 3rd middle finger was marked again, and the distance between the first mark and the second mark was measured and recorded as the body's lateral flexion value.

To measure hip abduction, the participants were first brought to a sitting position, and then asked to move their soles adjacent to each other, so as to ensure the maximum abduction in the hip joint. During this movement, the hips are moved into a position of external rotation and the knees to a position of flexion. The participants were then asked to hold their ankles and push their

Figure 4. Measurement of the dorsiflexion and plantar flexion angles of the ankle joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

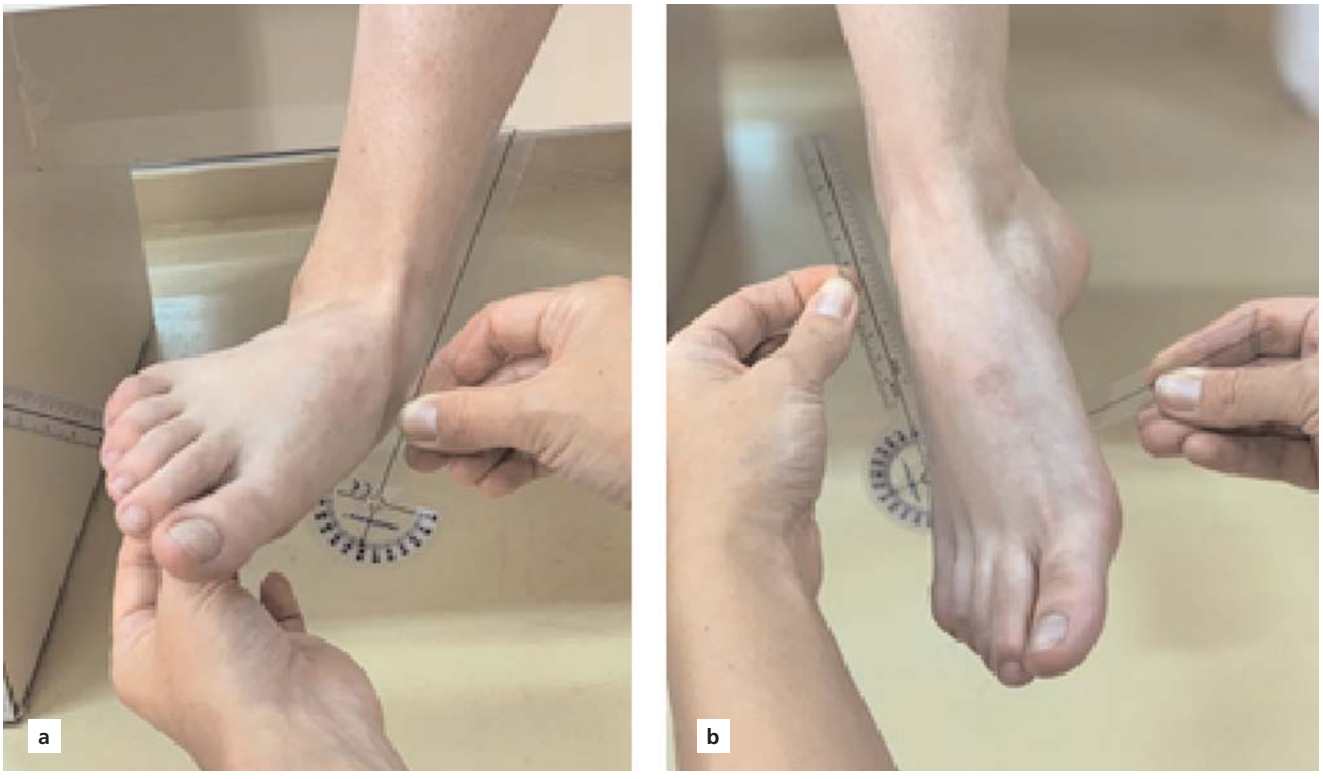

Figure 5. Measurement of the eversion (**a**) and inversion (**b**) angles in the ankle joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

elbows and knees towards the ground as much as they could. The distance between the lateral condoyle and the ground was measured using a tape measure.

Hamstring length was measured as follows: the participants were first brought to a supine position, and asked to perform a hip extension as much as they could while keeping one knee in extension position. To assess hamstring length, the hip was kept in full flexion, and the distance between lateral condoyle and the ground was measured using a tape measure.[7]

Statistical analysis was performed using IBM SPSS Statistics for Windows (Version 25, Armonk, NY, USA). Descriptive statistics were expressed as mean ± standard deviation when the parametric assumptions were satisfied. If these assumptions were not satisfied, the descriptive statistics were expressed as median (minimum-maximum). The descriptive statistics for the categorical variables were given as frequency (n) and percentage (%).

For the continuous dependent variables Student's t test or Mann-Whitney U test was used for comparisons between two groups, depending on whether the dependent variable follows a normal distribution.

For the categorical dependent variables Pearson's chi-squared test or Fisher's exact test was used for testing the independence. The probability of a Type I error (alpha) was chosen as 5% in all tests.

This study was approved by the Başkent University Medical and Health Sciences Research Committee (Project number: KA18/214) and supported by the Başkent University Research Fund.

Table 1
Demographic characteristics of participants.

	Ballet students (min–max)	Non-dancer students (min–max)	p
Age	20 (17–25)	20 (19–26)	0.791*
Height (m)	163.25±5.69	162.57±5.31	0.639†
Weight (kg)	51.4 (43.1–67.3)	57.9 (45.3–91.7)	**0.002***
Body mass index (BMI)	19.1 (15.9–23.5)	21.4 (17.6–32)	**0.001***

*Mann-Whitney U test; †Student's t test.

Results

The demographic results concerning classical ballet students and nondancer students are shown in **Table 1** along with their p values.

While there was no statistically significant difference between the ballet students groups and non-dancer students in terms of mean height (p=0.639) and the median values for age, their medians for weight (p=0.002) exhibited statistically significant differences.The results from the anterior posture analysis concerning the classical ballet students and non-dancer students are shown in **Table 2**.

Being a person is a ballet dancer or not had a statistically significant effect on the presence of hallux valgus

Table 2
Anterior posture analysis of ballet and non-dancer students.

Anterior posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Hallux valgus	(+)	27 (90%)	9 (31%)	**<0.001***
	(–)	3 (10%)	20 (69%)	
Eversion	(+)	2 (6.7%)	3 (10.3%)	0.671†
	(–)	28 (93.3%)	26 (89.7%)	
Inversion	(+)	2 (6.7%)	0 (0.0%)	0.492†
	(–)	28 (93.3%)	30 (100%)	
Tibial torsion	(+)	3 (10.7%)	1 (3.4%)	0.352†
	(–)	25 (89.3%)	28 (96. 6%)	
Genu varum	(+)	20 (66.7%)	3 (10.3%)	**<0.001***
	(–)	10 (33.3%)	26 (89.7%)	
Genu valgum	(+)	0 (0.0%)	5 (17.2%)	0.052†
	(–)	29 (100%)	24 (82.8%)	
Symmetry of hip ASIS	(+)	12 (40.0%)	16 (55.2%)	0.243*
	(–)	18 (60.0%)	13 (44.8%)	
Asymmetry of shoulder	(+)	17 (58.6%)	17 (58.6%)	>0.999*
	(–)	12 (41.4%)	12 (41.4%)	

*Pearson's chi-square test; †Fisher's exact test.

(p<0.001). As a condition where the metatarsophalangeal joint stays in dorsal flexion and the proximal interphalangeal joint remains in plantar flexion, the hallux valgus was not seen in either of the groups of ballet students and non-dancer participants. Whether a person is a ballet dancer or not did not have a statistical effect on keeping the foot in eversion (p=0.671) and inversion (p=0.492) in upright standing position (**Table 2**).

Tibial torsion was not affected statistically by being a ballet dancer or not (p=0.352). Being is a ballet dancer or not was a factor that had a statistically significant effect on the presence of genu varum in the legs (p<0.001) (**Table 2**).

Genu valgum deformity was not seen in the group of classical ballet students, but in five (17.1%) of the non-dancer students. Being a ballet dancer or not was not a statistically significant factor on the presence of the genu valgum deformity (p=0.052), SIAS symmetry (p=0.243) and shoulder asymmetry (p>0.05) (**Table 2**).

The results from the posterior posture analysis regarding classical ballet students and nondancer students are shown in **Table 3**.

A pronation position in the feet was seen in only three of the 30 ballet students, and in 11 of the 29 non-dancer students. Being a ballet dancer or not did not have statistically significant effect on the presence of foot pronation (p=0.012), foot supination (p>0.999), scoliosis (p=0.632) (**Table 3**).

The results from the lateral posture analysis concerning classical ballet students and nondancer students are shown in **Table 4**.

Whether a person is a ballet dancer or not was not a statistically effective factor on the presence of pes cavus in the foot (p=0.483). However pes planus was statistically affected by whether a person is a ballet dancer or not (p=0.041) (**Table 4**).

Genu recurvatum was seen in 53.3% of the ballet dancers and being a ballet dancer or not was statistically significant for the presence of genu recurvatum (p=0.004), but not on the presence of flexion in the knee (p>0.999).

The results from the body flexion and hyperextension analysis on classical ballet students and nondancer students are shown in **Table 5**.

The distrubution for body flexion, as well as the ditribution of body hyperextension showed statistically significant differences between the group of students studying ballet and the other group of students who did not studying ballet (p<0.001).

In terms of lateral flexion, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body (p_{right}<0.001; p_{left}<0.001). In terms of both hip flexion and extension, there was a significant difference between the ballet students and non-dancer students in the measurements taken on two sides of their body (p_{right}<0.001; p_{left}<0.001). In terms of hip abduction, there was a significant difference between the ballet students and non-dancer students in the measurements taken on both sides of their body (p_{right}<0.001; p_{left}<0.001). In abduction measurements, a lower value of measurement means a higher level of flexibility. It is for this reason that hip abduction flexibility was higher in the group of ballet dancers (**Tables 6** and **7**).

In terms of knee hyperextension, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body (p_{right}=0.002; p_{left}=0.004). In terms of plantar flexion, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body (p_{right}<0.001; p_{left}<0.001). In terms of eversion, there was a significant difference between the ballet students and the non-dancer

Table 3
Posterior posture analysis of ballet and non-dancer students.

Posterior posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Pronation of foot	(+)	3 (10%)	11 (37.9%)	0.012*
	(–)	27 (90%)	18 (62.1%)	
Supination of foot	(+)	1 (3.3%)	0 (0%)	>0.999†
	(–)	29 (96.7%)	29 (100%)	
Scoliosis	(+)	10 (33.3%)	8 (27.6%)	0.632*
	(–)	20 (66.7%)	21 (72.4%)	

*Pearson's chi-square test; †Fisher's exact test.

Table 4
Lateral posture analysis of ballet and non-dancer students.

Lateral posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Pes planus	(+)	6 (20%)	13 (44.8%)	**0.041***
	(–)	24 (80%)	16 (55.2%)	
Pes cavus	(+)	0 (0%)	1 (3.6%)	0.483†
	(–)	30 (100%)	27 (96.4%)	
Genu recurvatum	(+)	16 (53.3%)	5 (17.2%)	**0.004***
	(–)	14 (46.7%)	24 (82.8%)	
Flexion of knee	(+)	0 (0%)	1 (3.4%)	>0.999†
	(–)	30 (100%)	28 (96.6%)	
Anterior pelvic tilt	(+)	24 (80%)	17 (58.6%)	0.075*
	(–)	6 (20%)	12 (41.4%)	
Posterior pelvic tilt	(+)	1 (3.3%)	1 (3.8%)	>0.999†
	(–)	29 (96.7%)	25 (96.2%)	
Increase of lumbar lordosis	(+)	22 (73.3%)	18 (62.1%)	0.355*
	(–)	8 (26.7%)	11 (37.9%)	
Decrease of lumbar lordosis	(+)	0 (0%)	2 (6.9%)	0.232†
	(–)	30 (100%)	27 (93.1%)	
Kyphosis	(+)	1 (3.3%)	2 (6.9%)	0.612†
	(–)	29 (96.7%)	27 (93.1%)	
Anterior tilt of head	(+)	12 (41.4%)	19 (65.5%)	0.065*
	(–)	17 (58.6%)	10 (34.5%)	
Posterior tilt of head	(+)	1 (3.3%)	3 (10.3%)	0.353†
	(–)	29 (96.7%)	26 (89.7%)	

*Pearson's chi-square test; †Fisher's exact test.

students in the measurements taken on both sides of their body ($p_{right}<0.015$; $p_{left}<0.007$) (**Tables 6** and **7**).

Discussion

The posture analyses conducted on a group of female conservatory students studying classical ballet and control group of students from Başkent University were compared using the symmetrigraf. Hallux valgus, genu varum, genu recurvatum deformities were more prevalent in ballet students compared to the non-dancer students. Pronation and pes planus in foot were seen in the group of non-dancer students more than ballet students.

Table 5
Flexion and hyperextension of trunk of ballet and non-dancer students.

	Ballet students (min–max)	Non-dancer students (min–max)	p*
Flexion of trunk	21 (5–31)	0 (-28–9)	**<0.001**
Hyperextension of trunk	36 (25–45)	21 (5.5–35)	**<0.001**

*Mann-Whitney U test.

In a study conducted by Iunes et al., there was a statistically significant difference between the group of ballet dancers and the control group in terms of anterior pelvic tilt and pes cavus.[6] In the current study, pes cavus was not seen in the group of ballet dancers. As for anterior pelvic tilt, it was seen in 80% of the group of ballet students and 58.6% of the group of non-dancer students. There was no statistically significant difference between the two groups. It could be the reason of the routine habitude and specific body type and posture of the Turkish woman.

In the study conducted by Sürenkök and Livanelioğlu, it was observed that the values of lumbar lordosis and pelvic tilt were lower in the control group. The reason for this was explained as follows: Among students studying classical ballet dance, it is necessary to reduce lumbar lordosis in order to achieve the ideal posture, which causes a posterior pelvic tilt to occur.[11] In

Table 6
Right side flexibility measurements of ballet and non-dancer students.

Flexibility measurements	Ballet students (min–max)	Non-dancer students (min–max)	p*
Rotation of trunk	16 (7–26)	15 (11–28)	0.772
Lateral flexion of trunk	28 (20–37)	23 (13–38)	**<0.001**
Length of hamstring	45 (25–57)	42.5 (35–50)	0.120
Abduction of hip	4 (0–18)	13 (5–22)	**<0.001**
Flexion of hip	166.5 (131–180)	130 (117–152)	**<0.001**
Extension of hip	37 (22–60)	23 (12–37)	**<0.001**
Flexion of knee	134 (121–147)	132 (118–152)	0.933
Hyperextension of knee	4 (-2–14)	0 (-2–8)	**0.002**
Dorsiflexion of ankle	16.5 (3–32)	17 (4–23)	0.316
Plantar flexion of ankle	89 (78–179)	52 (35–72)	**<0.001**
Inversion of ankle	40 (26–51)	37 (34–47)	0.680
Eversion of ankle	26.5 (17–37)	22 (0–32)	**0.015**

*Mann-Whitney U test.

Table 7
Left side flexibility measurements of ballet and non-dancer students.

Flexibility measurements	Ballet students (min–max)	Non-dancer students (min–max)	p
Rotation of trunk	15 (8–25)	16 (11–30)	0.885*
Lateral flexion of trunk	27.5 (19–39)	22 (15–39)	**<0.001***
Length of hamstring	45.5 (27–60)	44 (37–50)	0.428*
Abduction of hip	4 (0–15)	13 (4–20)	**<0.001***
Flexion of hip	159.73±12.086	128.24±11.618	**<0.001**†
Extension of hip	37 (22–58)	22 (11–40)	**<0.001***
Flexion of knee	135 (120–147)	132 (116–150)	0.539*
Hyperextension of knee	3 (0–12)	0 (-3–8)	**0.004***
Dorsiflexion of ankle	16 (12–35)	17 (3–26)	0.527*
Plantar flexion of ankle	90 (78–180)	55 (38–73)	**<0.001***
Inversion of ankle	39.5 (33–55)	37 (28–52)	0.921*
Eversion of ankle	24.5 (16–33)	20 (0–30)	**0.007***

*Mann-Whitney U test; †Student's t test.

the present study, however, lumbar lordosis and pelvic tilt values did not show any statistically significant difference between the two groups (p>0.05). Also in the study by Sürenkök and Livanelioğlu, genu recurvatum values were higher in the group of ballet dancers compared to the control group.[11] Similarly in the present study, genu recurvatum values were higher in the group of ballet dancers compared to the control group (p<0.05).

According to Klemp et al., hyperextension of the knee is a sign of hypermobility. In our study, there is a statistically significant difference between the group of students studying ballet and the other group of students who did not study ballet in terms of body flexion and hyperextension (p<0.001).[3]

The study of Kim et al. studied the impact of calcaneal posture on the thoraco-lumbar area in the upright standing position. In the said study in which three-dimensional motion analysis was used, it was demonstrated that one-sided and double-sided inversion causes medial and anterior tilt on the pelvis, along with posterior and lateral rotation on the body. It was highlighted that these changes might increase lumbar pain by increasing lumbar lordosis.[12] In the current study, no significant difference was found between the control group and the group of ballet dancers in terms of anterior and posterior pelvic tilt and lumbar lordosis (p>0.05).

It was found that forward flexion (i.e. the flexion of the body) increases through practice and exercising, while dancers with hypermobility are not necessarily more successful, and hypermobility is not necessarily important in their career.[3] In the present study, body flexion and hyperextension values were found to be significantly higher in the group of ballet dancers compared to the control group (p<0.05).

Other biomechanical studies conducted on dancers have concluded that long-term intensive dance training programmes bring about increased flexibility particularly in the lower extremities.[13] In the present study, body flexion; hyperextension and lateral flexion; hip flexion, extension and abduction; knee hyperextension; plantar flexion of ankle and its eversion angles were all found to be higher in the group of ballet dancer both on the right and left sides.

In their study, Wyon et al. divided a group of dancers into three separate groups based on six-week-long mild, medium and high intensity training programmes involving stretching, in order to assess their pre- and post-training lower extremity active and passive joint range of motion. Based on their results, they found an increase in all of the three groups in terms of both active and passive joint range of motion. On the other hand, our study compared the lower extremity active joint range of motion of a group of ballet dancers who danced ballet for a certain period of time (and exercised stretching at adequate levels during this process) with another group of non-ballet-dancing individuals. Based on our results, we concluded that the lower extremity joint range of motion was generally higher in the group of ballet dancers.[14]

The present study has demonstrated that ballet dance requires a certain level of flexibility that can be achieved through stretching exercises during the dance education process; however, inadequate levels of strength and flexibility were found to bring about postural changes.

Conclusion

In the present study that assesses postural differences in individuals studying classical ballet and those who do not, it was demonstrated that classical ballet dance training has an impact on posture. This finding was critical in terms of understanding the relation between posture and injuries in ballet dancers.

In conclusion, based on the information we have obtained, we are of the opinion that any potential injuries can be prevented if posture defects that occur due to ballet dancing are examined in time, and supportive exercises are planned to remedy them.

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ORCID ID:
H. Öktem 0000-0002-2624-122X; C. Pelin 0000-0003-0901-8883;
A. Kürkçüoğlu 0000-0003-4350-4172; M. İzci 0000-0002-8351-0916;
T. Şençelikel 0000-0003-0364-0401

Correspondence to: Hale Öktem, MD
Department of Anatomy, School of Medicine, Başkent University,
Ankara, Turkey
Phone: +90 312 246 66 66 / 1526
e-mail: haleoktem@gmail.com

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A morphometric study of the odontoid process using three-dimensional computed tomography (3-D CT) reconstruction

Ece Alim[1], **Kerem Atalar**[2], **İsmail Nadir Gülekon**[1]

[1]*Department of Anatomy, School of Medicine, Gazi University, Ankara, Turkey*
[2]*Department of Anatomy, School of Medicine, Bülent Ecevit University, Zonguldak, Turkey*

Abstract

Objectives: The aim of this study was to evaluate the morphometric parameters of the odontoid process using 3-dimensional (3D) reconstruction of computed tomography (CT) images and investigate the applicability of using one or two screws for fixing odontoid process fractures.

Methods: CT images of 100 patients (55 males, 45 females) were transferred to the OsiriX program in DICOM format and converted into three dimensional images using the 3D volume rendering feature. Male and female groups were divided into 8–30, 31–50 and over 50 age groups and features of the odontoid process were measured.

Results: In the coronal plane, the minimum external transverse length of the odontoid process (OPmin) was highest in males over 50 year of age with a value of 11.3 mm. In the sagittal plane, the combination of anterior-posterior length of the odontoid process and vertebral body (OPAP) was highest in the males over 50 (14.5 mm). The length of the line taken from the anterior-inferior corner of the vertebral body to the top of odontoid process (LAIT) was measured the highest measured as 45.2 mm in males over 50. These measurements were higher in males than females.

Conclusion: The results of this study showed that it is possible to use a single 4.5 mm or 3.5 mm cannulated screw in the Turkish population. The application of two 3.5 mm screws was found to be appropriate in 76% of males and 62% of females.

Keywords: 3-dimensional reconstruction method; axis; CT; fracture; odontoid process

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Introduction

In the adult human, the vertebral column is composed of 33 vertebrae and is divided into five regions. There are 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal vertebrae.[1] These different types of vertebrae are arranged on top of each other, supported by an intervertebral disc, with fibrocartilaginous structure and muscles, extending from the skull to the pelvis and forming axial support to the body.[2,3] They undertake important functions such as protection of the vertebral column, spinal cord, and spinal nerves, carrying and transferring body weight, and creating a flexible axle for head and body movements.[4–6] The most different part of the vertebral column is the cervical. The neck is a cylindrical structure that contains vital organs, connects the head and the body together.[7]

The odontoid process (dens axis) is a characteristic anatomical element of C2 vertebrae, playing an important role in C1–C2 vertebrae functions. Phylogenetically, the odontoid process extends up to the upper half of the trunk and consists of four different parts; the tip, body, neck and base.[8] It is a critical component of the craniocervical junction. Therefore, detailed information of the embryology and anatomical variations by clinicians performing diagnosis, treatment, and operation in this region is necessary.[9]

Specifically, odontoid process fractures are frequently encountered and treated conservatively or surgically.

Surgical treatment is performed by using posterior C1–C2 fusion or anterior osteosynthesis using plates and screws or by fixing the odontoid process fracture with one or two screws.[8] Each screw application has its own indications, but mainly depends on the anatomical features of the odontoid process and the type of fracture.[10] Odontoid process fractures are approximately 10–14% of all cervical spine fractures.[11] Therefore, understanding of the unique anatomy and architecture of the odontoid process, creation of a specific, pattern of fractures, mechanism of fractures and understanding of the biomechanics of the odontoid process is important for treatment and prognosis. The anatomic structure must be known in advance, especially for anterior and posterior surgical stabilization.[12,13]

Studies on the odontoid process morphology in the Turkish population are limited. In this study, the anatomical features of the odontoid process and the three-dimensional reconstruction technique, which has been proven to be accurate in various applications for spinal surgery, have been measured on computed tomography (CT) images. We believe that our study is clinically important for the calculation of axial diameters and for the feasibility of screwing techniques that can be used in the treatment of fractures due to trauma, has a unique value at this point.

Materials and Methods

This study was performed at the Department of Anatomy of Gazi University School of Medicine and Department of Anatomy of Bülent Ecevit University School of Medicine. Ethical approval was granted by the Local Ethics Committee of Gazi University Faculty of Medicine (approval number: 09.04.2018, 263). CT images of patients who underwent cervical region examination for any reason in the Department of Radiology of Gazi University Hospital were evaluated retrospectively. CT images of patients with pathology or operation history in the cervical region and who could not obtain quantitative data from medical imaging were discluded from the study. Measurements were performed on CT images of 100 patients (55 males, 45 females).

A total of 100 CT images selected for evaluation were transferred to the OsiriX open-source imaging software (free download from http://www.osirix-viewer.com/) in DICOM format. With the 3D volume rendering feature of the OsiriX program, images were converted to three dimensions. Density adjustments were made to best observe the bone tissue. The three-dimensional image obtained was evaluated from the proximal to the distal to the sagittal and coronal surface sections. The length, volume, and angles measured are shown in **Table 1**. The images showing the measurements performed on the CT images are shown in **Figure 1**.

Statistical analysis of the obtained measurement results performed with IBM SPSS Statistics for Windows (Version 19, Armonk, NY, USA). Shapiro-Wilk test was used to determine the consistency of continuous variables to normal distribution. The normality of each parameter was evaluated using Student's t-test and the normal distribution with Mann-Whitney U test. The mean value of standard deviation (SD) was evaluated by the t-test and the value of the test with the minimum, maximum and median values were evaluated with Mann-Whitney U test (**Table 2**).

The study group was divided into three age groups: 18–30, 31–50 and over 50. The median (min-max) values of each age group according to the parameters are given in **Table 3**. Kruskal-Wallis test was used to test the significance of the differences between the averages of

Table 1
Measurements of the odontoid process.

OPmin	In the coronal plane, the minimum external transverse length of the odontoid process (mm)
OPmax	In the coronal plane, the maximum transverse length of the combination of the vertebral body and odontoid process (mm)
OPAP	In the sagittal plane, the combination of the anterior-posterior length of the odontoid process and vertebral body (mm)
OPL	In the coronal plane, the length between of the apex of the odontoid process and the combination of the odontoid process-vertebral body (mm)
VOL	Odontoid process volume (mm^3)
OPangle	The angle between the line starting from the anterior-superior corner of the vertebral body, ending at the anterior-inferior the corner of the vertebral body and the line between the anterior-inferior corner of the vertebral body to the top of the odontoid process (°)
LAIT	The length of the line taken from the anterior-inferior corner of the vertebral body to the top of the odontoid process (mm)

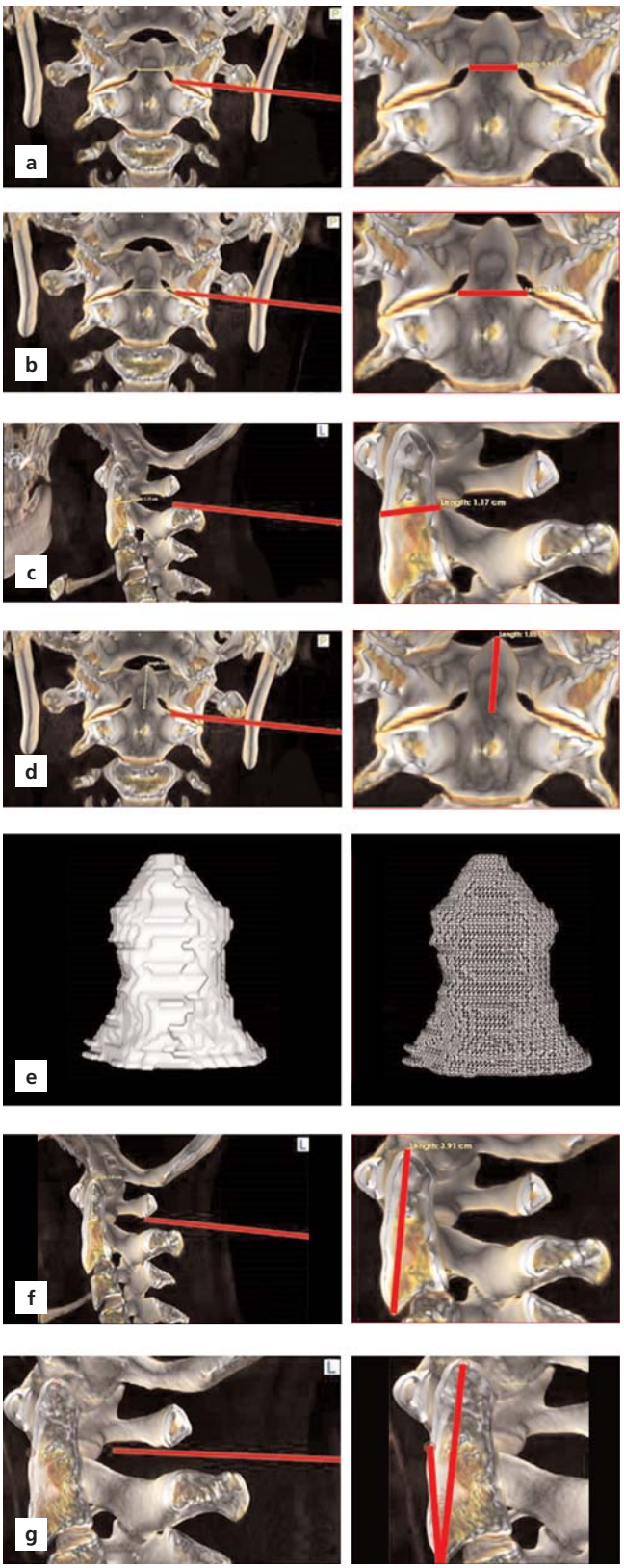


Figure 1. OPmin (**a**), OPmax (**b**), OPAP (**c**), OPL (**d**), VOL (**e**), OPangle (**f**) and LAIT (**g**). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

those who did not show normal distribution among the three age groups, and the one-way analysis of variance (ANOVA) test was used for those with a normal distribution. In all statistical analyses, comparisons with p-values below 0.05 were considered statistically significant.

Results

In this study, data of the anatomical morphology of the odontoid process were measured. From these data, values other than OPangle were higher in males than in females (**Table 4**, **Figure 2**).

Mean values of OPmin in females with respect to age groups were 8.79 mm (7.4–9.9 mm) in the 18–30 year old, 9.26 mm (7.6–10.5 mm) in the 31–50 year old groups, and 9.24 mm (6.9–10.7 mm) in the group over 50.

Mean values of OPmax were 12.31 mm (10.3–14 mm) in the 18–30 year old male group and 12.86 mm (11.3–14.6 mm) in males over 50. Values of both groups were the highest in males. However, mean OPmax was 12.4 mm (9.3–14.5 mm), higher in females in the 31–50 year old group compared to the same age group of males.

According to age groups, OPAP showed higher mean values in males compared to females; 11.78 mm (9.9–13.3 mm) in the 18–30 year old, 11.88 mm (10.1–13.2 mm) in the 31–50 year old group, and 12.17 mm (9.6–14.5 mm) in the group over 50.

OPL values, in males according to age groups were; 15.56 mm (10.6–18.8 mm) in the 18–30 year old group; 15.9 mm (13.2–19.7 mm) in the 31–50 year old group; 16.47 mm (13.2–21.3 mm) in the group over 50. These measurements were higher than those in females. VOL values were higher in males than in females. Mean values of OPangle were 12.52° (9.02–16.5°) in 18–30 year old females; 12.85° (8.4–19.08°) in the female group over 50 and the highest mean value was measured as 12.67° (9.12–20.85°) in the 31–50 year old male group.

LAIT showed higher mean values in males than females and was 38.73 mm (30.5–45.8 mm) in the 18–30 year old group, between 38.82 mm (33.2–45.4) in the 31–50 year old, and 39.49 mm (33.7–45.2 mm) in the over 50 groups.

Discussion

The number of high or medium quality anatomical studies to guide the surgical treatment of non-stable Type II odontoid process fractures is few. A combination of expert opinion, patient and surgeon selection, and the best available information should be made when appropriate treatment is being performed. Knowing the length

Table 2
Comparison of the odontoid process measurements by gender.

	Gender	n	Mean±SD	t-test value	p-value
OPL	Female	45	14.7±1.4		
	Male	55	15.8±1.8	3.097	**0.003**
	Total	100	15.3±1.7		
OPmin	Female	45	9.1±0.9		
	Male	55	9.5±0.7	-2.558	**0.012**
	Total	100	9.3±0.8		
OPmax	Female	45	12±1.4		
	Male	55	12.4±1.1	-1.351	0.180
	Total	100	12.2±1.3		
LAIT	Female	45	36.5±2.3		
	Male	55	38.9±2.8	-4.441	**0.001**
	Total	100	37.9±2.9		
	Gender	**n**	**Median (min-max)**	**Mann-Whitney U test value**	**p-value**
OPAP	Female	45	11.4 (9.5–14.1)		
	Male	55	11.9 (1.2–14.5)	756.5	**0.001**
	Total	100	11.7 (1.2–14.5)		
OPangle	Female	45	11.7 (8.4–19.2)		
	Male	55	10.7 (7.5–20.9)	1035.5	0.162
	Total	100	11.6 (7.5–20.9)		
VOL	Female	45	11.2 (8.3–20.4)		
	Male	55	13.6 (8.3–19.8)	633.5	**<0.001**
	Total	100	12.9 (8.3–20.4)		

and diameter of the odontoid process size is crucial in order to decide the application of one or two screws. When deciding to perform an anterior or posterior surgical procedure, the fracture line, bone quality of the patient and the parameters related to technical factors should be thoroughly mastered.

Knowing the length and diameter due to the diversity of the odontoid process size is very important in order to decide on the application of one or two screws. The decision to perform anterior or posterior surgery is based on the fracture line, the patient's bone quality and the technical factors.[14]

The first studies have shown that the two-screw technique will provide superior mechanical stability.[15] Some odontoid process diameters may not be large enough to accommodate two 3.5 mm cortical screws. The placement of two screws in these patients is difficult and even risky. Although this technical difficulty was not emphasized in the initial reports, there was a need to perform quantitative morphometric studies on the fixation of the odontoid process, possibly due to the use of different techniques applied in different regions.[16,17] There are studies indicating that the anteroposterior diameter of the bread is significantly larger than the transverse diameter.[17,18] In this study, we also observed this result in the groups of females and males (OPAP>OPmin). The transverse diameter of the odontoid process is the smallest diameter and is critical for placing two screws when placed side by side in the coronal or transverse plane.[16] The minimum transverse diameter (OPmin) of the odontoid process to accommodate two 3.5 mm cortical screws should be 9 mm and 8 mm, if no guide is used.[16] A critical value of 9 mm for OPmin is required for the inner cortex of the odontoid process to be left with at least 0.5 mm cortical bone outside the screws and a gap of at least 1 mm between the implants. However, if the inner cortex is not blocked, the intramedullary diameter should be at least 8 mm to accommodate the two screws, considering that the two implants extend to the lateral cortex, with a distance of 1 mm between them.[16] However, in some

Table 3
Comparison by age groups.

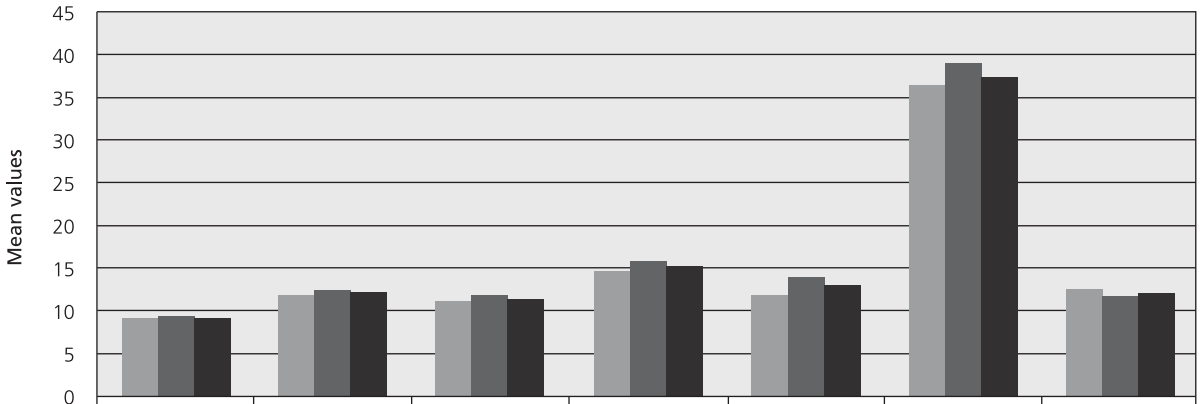
	Age (years)	n	Median (min-max)	Kruskal- Wallis test value	p-value
OPL	18–30	36	15.1 (10.6–18.8)	3.419	0.181
	31–50	39	15 (11.2–19.7)		
	>50	25	15.7 (13.2–19.2)		
	Total	100	15.1 (10.6–19.7)		
OPmin	18–30	36	9.3 (7.4–10.6)	6.158	**0.046**
	31–50	39	9.3 (7.6–10.7)		
	>50	25	9.6 (6.9–10.8)		
	Total	100	9.3 (6.9–10.8)		
OPAP	18–30	36	11.4 (9.7–13.3)	3.348	0.188
	31–50	39	11.8 (1.2–14.1)		
	>50	25	11.8 (9.5–14.5)		
	Total	100	11.7 (1.2–14.5)		
OPangle	18–30	36	11.6 (7.5–17.3)	0.681	0.681
	31–50	39	11.5 (8.8–20.9)		
	>50	25	11.6 (8.1–19.1)		
	Total	100	11.6 (7.5–20.9)		
VOL	18–30	36	12.6 (8.3–19)	0.013	0.994
	31–50	39	13.3 (8.3–20.4)		
	>50	25	13 (9–19.8)		
	Total	100	12.9 (8.3–20.4)		
	Age (years)	**n**	**Median (min-max)**	**One-way ANOVA test value**	**p-value**
OPmax	18–30	36	12.1±1.3	0.261	0.771
	31–50	39	12.2±1.3		
	>50	25	12.3±1.3		
	Total	100	12. ±1.3		
LAIT	18–30	36	37.5±3	0.611	0.545
	31–50	39	37.7±2.7		
	>50	25	38.3±2.9		
	Total	100	37.8±2.9		

studies, less than 9 mm of external anteroposterior diameter was determined.[16,17]

When the information given above and OPmin we have obtained are evaluated together; 62% of females, 76% of males and 70% of the total group had a suitable odontoid process for two 3.5 mm cortical screws. It has been reported that 95% of the Caucasian population,[16] 67% of the Malaysian population,[17] 65% of the Brazilian population[14] and 89.1% of the Greek population[19] are suitable for two 3.5 mm screws. The minimum value of the OPmin we obtained in males was in the 18–30 year old group and was 7.8 mm in females; in the group over 50, this was 6.9 mm. This value was higher than the smallest value (5.59 mm) observed in the Malaysian and Caucasian populations, smaller than the smallest value (9.10 mm) measured in the Greek population.[16,17,20] There are large differences in cortical thickness between populations and in some studies measurements were made on axial slices.[19,21]

Table 4
Average values of measurement parameters for females, males and total group.

Measurement	Females (n=45)	Males (n=55)	Total (n=100)
OPmin (mm)	9.1	9.5	9.3
OPmax (mm)	12	12.4	12.2
OPAP (mm)	11.2	11.94	11.5
OPL (mm)	14.7	15.9	15.3
VOL (mm^2)	11.9	13.9	13
LAIT (mm)	36.5	38.9	37.5
OPangle (°)	12.6	11.8	12.14



	OPmin (mm)	OPmax (mm)	OPAP (mm)	OPL (mm)	VOL (mm^2)	LAIT (mm)	OPangle (°)
Females	9.1	12	11.2	14.7	11.9	36.5	12.6
Males	9.5	12.4	11.94	15.9	13.9	38.9	11.8
Total group	9.3	12.2	11.5	15.3	13	37.5	12.14

Figure 2. Graphic showing the changes in the mean values of the measurement parameters of the females, males and total groups.

In our study, the mean LAIT parameter was 38.9 mm (30.5–45.8 mm), higher in males than in females (**Table 2**). These results show similarities with the results of Korres et al.[19] It has to be noted that the length of the screws used is different from the superoinferior length of the axis. This is because the screw entry point is not on the center of the vertebral body, but on the lower edge. In addition, the top end of the screw must not reach the end of the odontoid process. As a result, the applied screw should be 1–3 mm shorter than the LAIT.[21,22]

In a study conducted on a Greek population, OPL was measured as 17.28 mm (13.24–22.91 mm) in all groups, 17.66 mm (13.24–22.91 mm) in males and 17.07 mm (14.11–21.44 mm) in females. In our study, POU lengths were 15.3 mm in all groups (10.6 to 21.3 mm), 15.9 mm (10.6 to 21.3 mm) in males and 14.7 mm (11.2–19.1 mm) in females. Accordingly, OPL was lower in the Turkish population studied compared to the Greek.[19]

Conclusion

The results of this study showed that it is possible to use a single 4.5 mm or 3.5 mm cannulated screw in the Turkish population. The application of two 3.5 mm screws is appropriate in 76% of males and 62% of female populations. The results obtained from this study emphasize the importance of knowing the actual size of the odontoid process before the proper management of the anterior screwing technique in odontoid process fractures and it is believed that it provides reliable results based on the 3-dimensional reconstruction method.

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ORCID ID:
E. Alim 0000-0002-4686-0677;
K. Atalar 0000-0003-1239-1144;
İ. N. Gülekon 0000-0002-9352-5118

Correspondence to: Ece Alim, MD
Department of Anatomy, School of Medicine,
Gazi University, Ankara, Turkey
Phone: +90 541 982 0606
e-mail: ece.alim06@gmail.com

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Retrospective radiologic analysis of accessory spleen by computed tomography

Sinem Akkaşoğlu[1], Emre Can Çelebioğlu[2], Selma Çalışkan[1], İbrahim Tanzer Sancak[3]

[1]*Department of Anatomy, School of Medicine, Ankara Yıldırım Beyazıt University, Ankara, Turkey*
[2]*Department of Radiology, School of Medicine, Ankara University, Ankara, Turkey*
[3]*Department of Radiology, School of Medicine, TOBB University, Ankara, Turkey*

Abstract

Objectives: The aim of this study was to define the incidence and classify locations of accessory spleen using CT in a large Turkish population and to compare our findings with earlier studies performed in other populations.

Methods: A total of 930 patients were included in the study and evaluated retrospectively using CT. The CT images were obtained using Philips Ingenuity 128 slice computerized tomography device.

Results: 930 patients (413 females, 44.4%; 517 males, 55.6%) who underwent CT imaging for various indications were included in this study. Out of these, 55 had an accessory spleen (5.9%), and four had polysplenia. Most common location of accessory spleen was hilum (49.9%) followed by the gastrosplenic ligament (21.81%), infrasplenic area (18.18%), pancreatic tail (3.64%), splenorenal ligament (3.64%) and suprasplenic area (3.64%).

Conclusion: Accessory spleen is a common variation encountered in the abdominal cavity. Most and least common locations of this variation should be well known to prevent radiologic misdiagnosis and surgical complications.

Keywords: accessory spleen; radiologic anatomy; splenosis

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Introduction

Ectopic splenic tissue can be found in the body in two different types; accessory spleen and splenosis. Accessory spleen is a congenital anomaly which presents with nodule of splenic tissue apart from main body of spleen.[1,2] It results from the failure of fusion of splenic buds in dorsal mesogastrium in the fifth week of fetal life.[1,2] Splenosis is an acquired condition due to autotransplantation of splenic tissue during surgical intervention or traumatic rupture of spleen, caused by the spread of splenic tissue after a splenic injury.[3]

It is possible to differentiate accessory spleen from splenosis by means of histology. Accessory spleens have capsule, hilum and trabeculae. The smooth muscle and elastic elements seen in a real splenic capsule are not visible in splenosis nodules. Splenosis nodules are also lack of hilus with vessels.[3] They are supplied by newly formed arteries which penetrate the capsule.[4] Also different from accessory spleens, Malpighian follicles and central arterioles are not visible in splenosis nodules.[2,3]

Accessory spleens are most commonly found near the splenic hilum, in the gastrosplenic ligament, splenorenal ligament, splenocolic ligament, pancreatico-splenic ligament, greater omentum, gastrohepatic omentum, mesentery, around the tail of pancreas, anywhere along the splenic vessels, and rarely in gonads.[2,5,6]

Accessory spleen is usually an incidental finding with no clinical significance. Although asymptomatic, it can be of clinical importance for differential diagnosis of tumors. Knowledge of accessory spleen is essential for radiologists to prevent misdiagnosis. Accessory spleens may present with complications such as torsion, hemorrhage, spontaneous rupture, hematoma, bowel obstruction or cyst formation which acquires surgical approach. Surgeons must keep this variation in mind during operations. Besides, they have to know the most common

Figure 1. CT scan of accessory spleen at splenic hilus. Accessory spleen (**arrow**); spleen (**star**).

Figure 2. CT scan of accessory spleen at the gastrosplenic ligament. Accessory spleen (**arrow**); spleen (**star**); stomach (**diamond**).

locations for this anatomical variation for proper treatment.[2]

In this study, we aimed to define and classify locations of accessory spleen in a large population by CT and compare our results with earlier studies performed in other populations.

Materials and Methods

A total of 930 patients (413 females, 44,4%; 517 males, 55.6%) were included in the study and retrospectively evaluated by CT. Patients with any surgical or other trauma history for differential diagnosis of splenosis nodules from accessory spleen in radiologic images were excluded fromn the study.

The CT images of the cases were obtained from the archive system of TOBB ETU University. CT examinations were obtained with Philips Ingenuity 128 slice computerized tomography device (Philips Medical Systems, Cleveland, OH, USA). Patient dose parameters were adjusted automatically by the device. 0.8 mm slice thickness and a pitch value of 1 were used. All abdomen CT scans include an area from sub diaphragmatic level to femoral heads to view entire abdominal area with or without an oral and/or intravenous contrast media. 300/100 ml or 350/100 ml non-ionic iodinated contrast materials were used.

Ethical permission was received by TOBB ETU Faculty of Medicine Clinical Research Ethics Committee (number: KAEK 118/051).

Descriptive statistics were used to get the frequency of each variation category of location.

Results

Out of 930 patients, 55 had accessory spleen (5.9%). The mean age of the patients possessing an accessory spleen was 40 (range: 19–90) years. Out of the 55 patients with accessory spleen 34 (61.82%) were males and 21 (38.18%) were females. Four of the 55 patients had polysplenia (7.27%).

The mean diameter of the accessory spleens was 14 (range: 3–20) mm.

Twenty-seven (49.9%) of the accessory spleens were located in hilum (**Figure 1**), 12 (21.81%) in gastrosplenic ligament (**Figure 2**), 10 (18.18%) in infrasplenic area (**Figure 3**), 2(3.64%) in pancreatic tail (**Figure 4**), 2

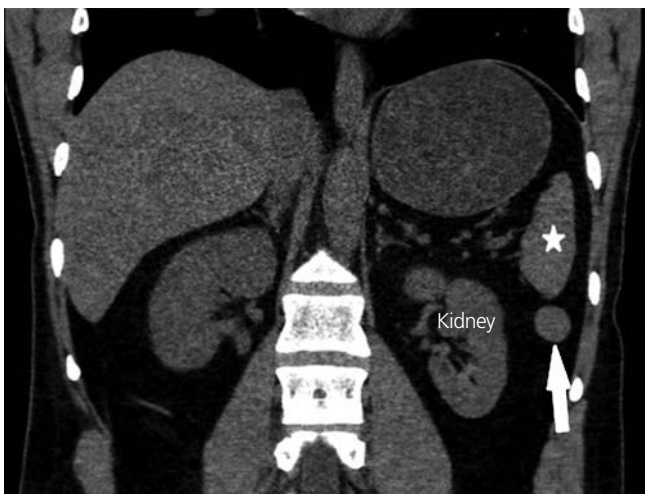

Figure 3. Coronal CT scan of accessory spleen below spleen level. Accessory spleen (**arrow**); spleen (**star**).

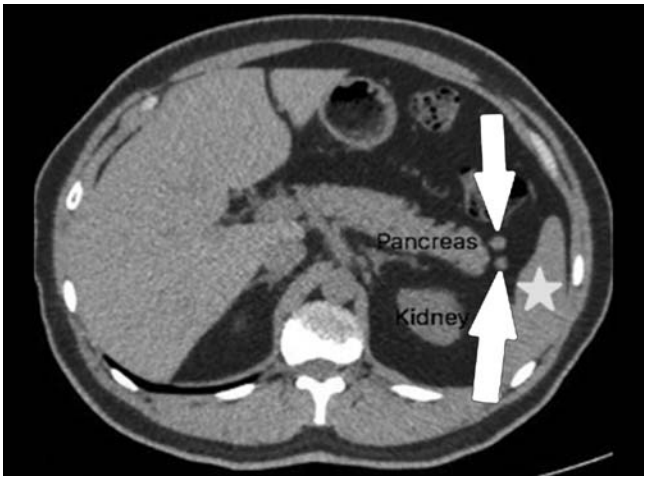

Figure 4. Transverse CT scan of accessory spleen at pancreatic tail. Accessory spleen (**arrow**); spleen (**star**).

Figure 5. CT scan of accessory spleen at splenorenal ligament. Accessory spleen (**arrow**); spleen (**star**).

(3.64%) in splenorenal ligament (**Figure 5**) and 2 (3.64%) in suprasplenic area (**Table 1**).

Discussion

Mesenchymal condensation develops within the dorsal mesogastrium of the lesser sac at the end of the fourth week of fetal life. This condensation differentiates to form spleen during the fifth week.[7] Spleen functions as a hematopoietic center until late fetal life and retains this function even in adult life.[8] Smaller splenic condensations called accessory spleens may develop in proximity of primary spleen.[7,9] Their size varies from 0.5 to 3.75 cm in diameter. The most common locations are the hilum and the anterior aspect of spleen. Spleen initially forms nears the urogenital ridge and gonads may become fused to splenic tissue. On rare occasions splenogonadal fusion leads splenic tissue to be pulled down into pelvic cavity.[10]

Table 1
Locations of accessory spleen.

Location of accessory spleen	n	%
Hilum of spleen	27	49.09
Gastrosplenic ligament	12	21.81
Splenorenale ligament	2	3.64
Tail of pancreas	2	3.64
Suprasplenic area	2	3.64
Infrasplenic area	10	18.18
Total	55	100

Accessory spleen is usually an incidental finding with no clinical significance. Although it is asymptomatic it can be of clinical importance for differential diagnosis of tumors. Accessory spleen in an unusual location can resemble a metastatic lymph node or tumor in pancreas, adrenal gland, kidney, stomach, intestine or even in testis.[2,11] Knowledge of accessory spleen is essential for radiologists to prevent misdiagnosis.

Splenectomy is a curative treatment option in hematologic diseases such as hereditary spherospherocytosis and chronic immune thrombocytopenic purpura.[12] Surgeons must keep accessory spleen in mind at the time of splenectomy because therapeutic effect depends on the complete removal of splenic tissue. Besides they have to know most common locations of this anatomical variation for proper treatment. Because once they are left behind during the first surgery they will undergo hyperplasia and cause recurrence of these diseases.[2,12,13] Preoperative radiologic examinations before splenectomy would help to indicate the accessory spleens during surgery.

Accessory spleen is usually asymptomatic, but it may present with complications such as torsion, hemorrhage, spontaneous rupture, hematoma, bowel obstruction or cyst formation which acquires surgical approach.[2,11,14,15] Beside the common locations it must be kept in mind that accessory spleens may be multiple but rarely more than six.[16] On the other hand, splenosis presents as numerous nodules (as many as 400) in the abdominal cavity.[2,4] Multiple accessory spleens must be evaluated during the surgery to prevent recurrence of the aforementioned complications.

Accessory spleen is not looked for during abdominal operations except splenectomy.[1] Hence, it is difficult to indicate the real incidence. On the other hand, radiologic diagnosis of this variation is difficult because of the fatty tissue entirely surrounding the accessory spleen or its' appearance similar to lymph node.[1] Detailed preoperative radiologic evaluation will achieve detection rates and prevent recurrence and complications in patients who have splenectomy indication. Radiologic studies with expanded patient series will also be valuable to indicate the real incidence.

It has been reported in the textbook of Snell's Anatomy that 10% of the normal population has accessory spleen.[17] Mortele et al.[18] reviewed 1000 CT scans retrospectively and found accessory spleen in 15.6% of patients from USA; Romer et al.[19] reviewed 1,735 CTs and found the incidence as 11% incidence in Switzerland. Chaware et al.[20] reported the incidence in India as 4.5%. Yıldız et al.[21] reported accessory spleen incidence in a Turkish population as 10–30%. In this study, the accessory spleen was present in 5.9% of our cases and this can be considered as lower than these earlier reports.

The youngest case reported in the literature was 17 and the oldest 67 years old.[22] The youngest case observed in the present study was 19 years old, while the oldest was 90. The most common locations in the literature were splenic hilum (75%) and tail of pancreas (20%).[22] In the present study, 49.09% of the accessory spleens were in hilum. The most common location indicated in the present study is consistent with the previously published data.

Romer et al.[23] and Szold et al.[24] reported the mean diameter of accessory spleen in a range from 10 mm to 35 mm. Unver Dogan et al.[25] and Kang et al.[26] measured the mean diameter as 16 mm and 15 mm respectively. In the present study, we measured the mean diameter of the accessory spleen 14 mm which is in consistent with the aforementioned studies.

Bora et al.[27] reported accessory spleen was more frequent in males (52.27%) than in females (47.73%). Vikse et al.[28] also analyzed gender distribution of this variation and declared it more common among females (15.4%).

This study has some limitations such as missing of past medical history. Future prospective studies with larger sample size may provide more exact information of incidence and will enable the researchers to question the clinical symptoms.

Conclusion

Studies on radiological scans, surgery series and autopsy series will be useful for determining the incidences in different populations. This study presents important knowledge to surgeons, radiologists, anatomists and oncologists about the incidence and locations of accessory spleen in Turkey.

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ORCID ID:
S. Akkaşoğlu 0000-0002-3371-4734; E. C. Çelebioğlu 0000-0002-1580-7064; S. Çalışkan 0000-0002-5839-3172; İ. T. Sancak 0000-0003-1968-7714

Correspondence to: Sinem Akkaşoğlu, PhD
Department of Anatomy, School of Medicine,
Ankara Yıldırım Beyazıt University, Ankara, Turkey
Phone: +90 553 477 67 85
e-mail: snm222@hotmail.com

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Hibiscus ameliorates salt-induced carotid intima-media thickness in albino rats

Fidel O. Gwala, William O. Sibuor, Beda O. Olabu, Anne N. Pulei, Julius A. Ogeng'o

Department of Human Anatomy, School of Medicine, University of Nairobi, Nairobi, Kenya

Abstract

Objectives: The carotid intima-media thickness (CIMT) is a known biomarker of clinical and subclinical cardiovascular events and evaluation of therapeutic action. Excessive salt directly causes changes in the common carotid intima and media layers and has been linked to hypertensive disease resulting to changes on vascular structure. *Hibiscus sabdariffa* is a traditional herbal drink with antihypertensive effects. The anatomical aspects of its effects however, are largely unknown. This study therefore, investigated the effects of hibiscus extract on CIMT in rats fed with a high-salt diet.

Methods: Young albino rats *(Rattus norvegicus)* were divided into three groups: (A) high-salt diet alone, (B) high-salt diet and *Hibiscus sabdariffa* extract and (C) control group fed a normal diet for 8 weeks. Specimens from carotid arteries of rats were fixated and processed for paraffin embedding. Seven-micrometer thick sections were stained with Hematoxylin and Eosin stain and examined under light microscopy. Morphometric measurements were taken to determine the CIMT.

Results: High-salt diet increased CIMT from 497.86 µm to 697.85 µm in 8 weeks. In *Hibiscus sabdariffa* extract fed rats, the CIMT decreased to 542.85 µm ($p<0.05$) by week 8.

Conclusion: *Hibiscus sabdariffa* extract ameliorates salt-induced increase in CIMT in rats in a time-dependent manner. This implies that *Hibiscus sabdariffa* products may have therapeutic value in salt-induced vascular morbidity.

Keywords: carotid intima-media thickness; hibiscus; salt diet

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Introduction

Excessive salt intake has been reported to increase blood pressure and plays a role in damaging cardiovascular structure and causing dysfunctions such as endothelial dysfunction and kidney disease progression.[1,2] It is also associated with greater risk of cardiovascular and cerebrovascular diseases including atherosclerosis and stroke.[3,4] These pathological processes increase risk of cardiovascular morbidity and mortality.[5,6] Direct anatomical implications of high sodium consumption in particular result in vascular hypertrophy and collagen deposition and increased carotid intima-media thickness (CIMT).[7] CIMT is a good surrogate marker of subclinical atherosclerosis and progressive cardiovascular disease.[8] There is considerable high-salt intake and burden of cardiovascular disease morbidity and mortality worldwide, especially in middle and low-income countries.[5,9] Despite this, adherence to conventional treatment regimens such as elective dietary salt restriction has faced difficulties. With more than 50% non-compliance rates, the emergence of alternative therapies creates more attractive treatment options.[10]

Hibiscus sabdariffa extract reduces blood pressure in a dose dependent manner[11,12] and has possible therapeutic effects on oxidative stress, lipid profile and atherosclerosis.[13] It is used primarily as a traditional remedy for hypertension.[10] Furthermore, because of the reported safety for long term administration of *Hibiscus sabdariffa* extract (HSE) as an antihypertensive,[14,15] it provides an effectively manageable diet-imposed therapy that is low on cost and easily available. Among the salt-induced structural changes, CIMT is a particularly potent indicator of vascular disease with predictive staging, diagnostic and follow up prognostic value.[16,17] It could as well be used to evaluate the therapeutic effectiveness of HSE in partly reducing cardiovascular disease risk.[18]

Data on structural effects of *Hibiscus sabdariffa* on blood vessels is critical in elaborating the mechanisms. However, the effect of HSE on salt-induced changes in CIMT has not been reported before. This study therefore examined the effects of HSE on salt-induced changes in CIMT.

Materials and Methods

This study was performed on 24 two-month old albino rats *(Rattus norvegicus)* obtained from the Department of Biochemistry of University of Nairobi. Ethical approval for the study was obtained from the Bio-Safety, Animal Use and Ethics Committee, Faculty of Veterinary Medicine, University of Nairobi, approval number: FVB/BAUE/ 2017/130. The rats were randomly selected by simple random sampling and marked 1-24. The numbers were then fed into a random number generating software. From this, 8 random numbers were obtained for each of the 3 groups (A–C). The rats were randomly assigned into baseline (n=2), experimental (n=16) and control (n=8) groups. At experiment weeks 2, 5 and 8, six rats from the two experimental group and two rats from the control group were euthanized. Group A was fed a diet containing 8% sodium chloride, Group B 8% sodium chloride and HSE by gavage and Group C (control group) was fed on standard pellets. Feeding was evaluated by a feed efficiency ratio to determine how much food each rat consumed. Water was provided *ad libitum*.

Dry dark-red calyces of *Hibiscus sabdariffa* were purchased from the local market. The technicians at the Herbarium of the Department of Botany, University of Nairobi, facilitated identification of the plant material. Thirty grams of the calyces were brewed in 200 ml of boiled water and allowed to stand for 30 minutes. The resulting mixture of calyces and brewed extract was then filtered and the solution evaporated to dryness giving a dark red powder (yield: 55%). The dry extract was stored at 4°C to keep it from growing mould[12] and dissolved in distilled water at room temperature and administered orally by gavage.

Standard iodized salt (sodium chloride) was purchased from the local supermarket. Seventy-seven grams of sodium chloride (NaCl) were added to 923 g of standard rat chow. One kilogram of standard rat chow contained 0.3% NaCl. The standard rat chow and NaCl were then mixed thoroughly to get an 8% NaCl diet.[19]

On tissue harvesting, the animals were anaesthetized by halothane and perfused with 10% formalin solution. After perfusion, the common carotid arteries (CCAs) were harvested by extending the midline body incision up to the neck region and reflecting the skin flaps laterally. The right CCA was identified at its junction with the brachiocephalic trunk and the right subclavian artery and the left were identified branching from the arch of the aorta. The whole length of the artery was harvested on both sides up to just before the bifurcation into internal and external carotid arteries.

Whole CCAs were fixed in 10% formal saline for at least 24 hours. 1 mm long samples obtained from the middle of the specimen were dehydrated in increasing grades of alcohol, cleared in toluene and embedded in paraffin wax. Seven-micrometer thick sections were deparaffinized in xylene, rehydrated and stained with Hematoxylin and Eosin. The slides were examined with a light microscope.

Photomicrographs of the sections were taken using a Canon digital camera (12 megapixels) mounted on a photomicroscope. These photographs were processed using the Fiji-ImageJ (NIH, Bethesda, MD, USA) software for morphometric and stereological analysis. The c-IMT was determined through four random points. Five different 7 µm sections were sampled from each animal by simple random sampling. Photomicrographs were taken from each section and examined at a magnification of ×400. Four random points were traced on the wall of the CCA over the intimal-media zone in the photomicrograph of each section (**Figure 1**). The average measure of CIMT was then calculated from the four points as shown follows:

$$IMT = (IMTa+IMTb+IMTc+IMTd)/4$$

Results

The CCA displayed three distinct histological layers characteristic of a typical elastic artery: an innermost tunica intima, tunica media and an outermost tunica adventitia The CIMT was 282.26 µm at week 0. It increased in all the groups across the total duration of the study (**Figure 2**). The increase was a statistically significant from week 2 to week 8 (**Figure 3a**) in the control group, being 368.23 µm at week 2 and 512.98 µm at week 8. A similar statistically significant increase was observed in the experimental groups. In the high-salt group, the mean CIMT increased from 497.86 µm in week 2 to 697.85 µm in week 8 (**Figure 3b**), whereas in the high-salt with HSE group it increased to 542.85 µm by the 8th week (**Figure 3c**). The CIMT was most marked by the 8th week. Concurrent administration of HSE with high-salt loading led to a less pronounced increase in CIMT compared to the high-salt group alone during the entire study period (**Figure 3c**). At the 8th week, the difference among the three groups was statistically significant (**Figure 2**).

Discussion

High dietary salt intake induced notable increase in CIMT, similar to that reported in earlier studies.[20,21] Safar et al.[20] demonstrated an increase in CIMT alongside the arterial wall in rats fed a high-salt diet. It was also suggested that high urinary sodium levels resulted from high-salt diets such as from processed foods. Similarly, a positive correlation between urinary sodium levels and CIMT was established.[7,21,22]

The potential blood pressure independent cardiovascular disease risk under a high-salt diet may be related to cardiovascular functional and structural changes. This could be through alterations in shear stress and endothelial function.[23,24] Such alterations can cause vascular hypertrophy and collagen accumulation[23] which increase CIMT. Vascular smooth muscle cells undergo modulation of growth, proliferation, hypertrophy and even apoptosis through effects of various isoforms of TGF-β.[25] In addition, TGF-β down regulates proteolytic extracellular matrix (ECM) molecules such as matrix metalloproteinases (MMPs). In particular, MMP-2 and -9 are thought to be specifically involved in collagen breakdown in the CCA[22] and their hindrance by TGF-β could contribute immensely to increased collagen deposition in the tunica media. These findings are consistent with the association of high sodium intake with greater presence of carotid atherosclerosis.[21]

On the contrary, when HSE was concurrently administered with a high-salt diet, it decreased the amount of intima-media thickening. Attenuation of high-salt-induced thickening in the intima and media of the aorta was similarly demonstrated using garlic extract.[26] Like garlic, a variety of plant extracts show potential to reduce intima-media thickening[27] particularly *via* inhibition of angiotensin converting enzyme (ACE). *Hibiscus sabdariffa*, similarly, has been reported to demonstrate ACE inhibiting properties.[10] This reduces release of angiotensin II which plays a major role in vascular smooth muscle cells hypertrophy. Previous histopathological experiments reveal that HSE reduces foam cell formation and inhibits vascular smooth muscle cell migration and calcification in blood vessels of rabbits.[28] Hibiscus significantly reduced severe atherosclerosis in the aorta of the rabbits and thus, showing anti-atherosclerotic activity.

In vitro, *in vivo* and clinical studies have provided evidence of hypolipidemic and anti-hypertensive effects of HSE which are linked to its antioxidant activities, inhibition of ACE, vaso-relaxant, antiatherogenic, anti-inflammatory and endothelial stabilizing properties.[11,29–31] Its potent antioxidant properties[32] include scavenging reactive oxygen species and stimulating nitric oxide synthase (NOS) as described by Olalye and Rocha.[33] The reverse is seen in endothelial dysfunction where nitric oxide reduction and reactive oxygen species production contribute to intima media changes.[34] The lesser collagen

Figure 1. Estimation of common carotid wall thickness. **AT:** adventitia thickness; **IMT:** intima-media thickness. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

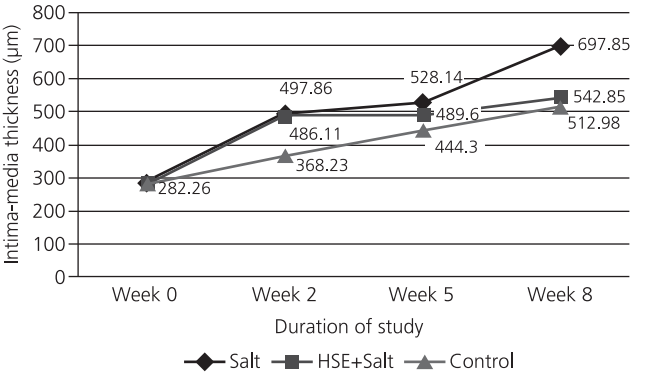

Figure 2. Line graph showing trends in intima-medial thickness in control and experimental groups.

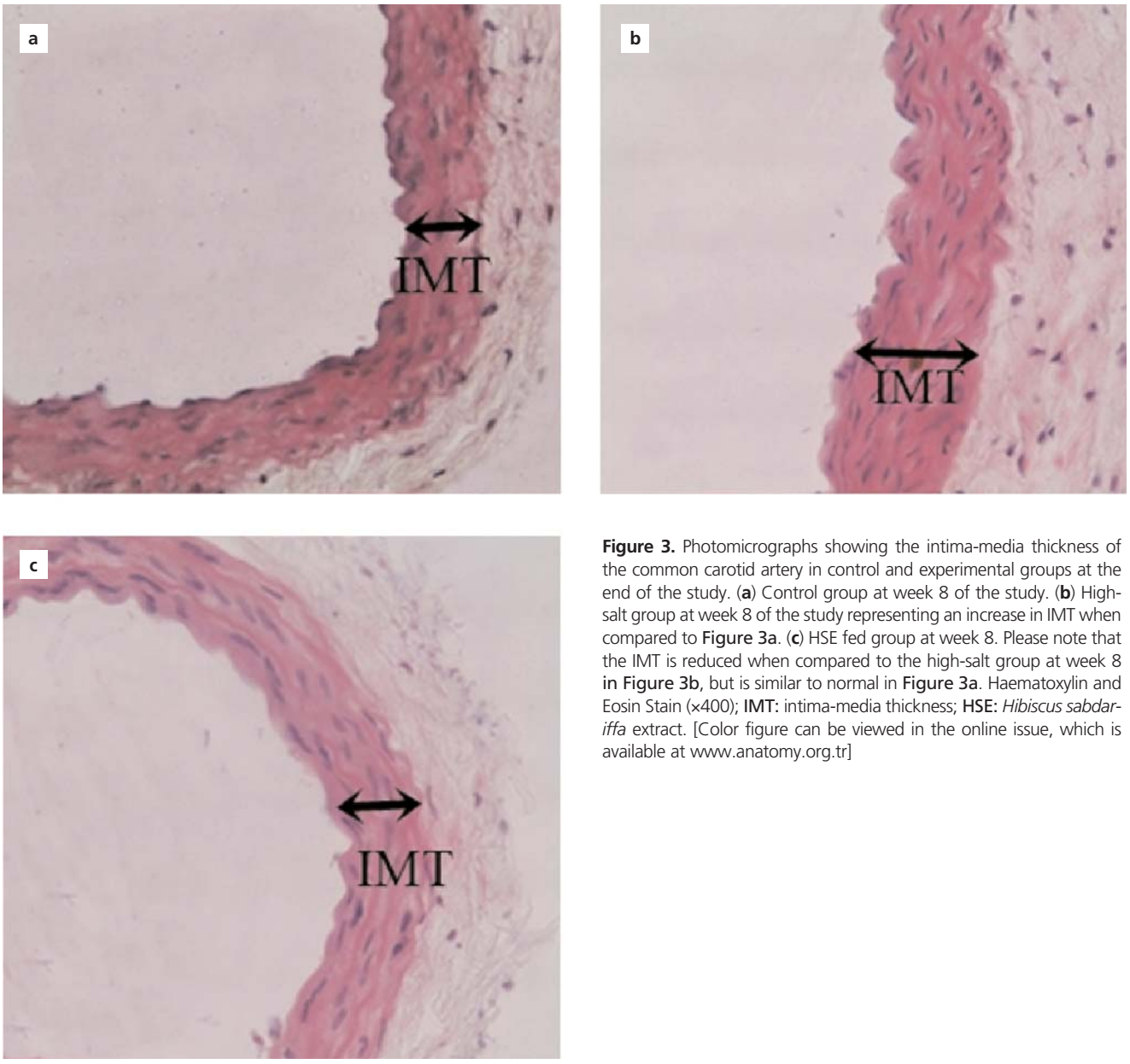

Figure 3. Photomicrographs showing the intima-media thickness of the common carotid artery in control and experimental groups at the end of the study. (**a**) Control group at week 8 of the study. (**b**) High-salt group at week 8 of the study representing an increase in IMT when compared to **Figure 3a**. (**c**) HSE fed group at week 8. Please note that the IMT is reduced when compared to the high-salt group at week 8 **in Figure 3b**, but is similar to normal in **Figure 3a**. Haematoxylin and Eosin Stain (×400); **IMT:** intima-media thickness; **HSE:** *Hibiscus sabdariffa* extract. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

deposition and lower intima-medial thickness demonstrated in the current study therefore could be attributed to these antioxidant and other properties.

Experimental work shows that HSE has a huge potential for pharmaceutical and nutraceutical application.[35] Hibiscus polyphenolic isolate (HPI) has been shown to suppress proliferating cell nuclear antigen (PCNA) level and MMP-2 activation. In addition, expression of connective tissue growth factor (CTGF) was prominently suppressed by HPI.[36] Hibiscus also inhibits neointimal formation by suppressing cell proliferation, migration, apoptosis and oxidation. Accordingly, this further demonstrates the utility of HSE in reducing CIMT and therefore reducing the risk of cardiovascular disease. Moreover, attenuation of carotid intima-media thickening as well can be a good indicator for treatment.[17]

Conclusion

This study reveals that the *Hibiscus sabdariffa* extract ameliorates salt-induced increase in carotid intima–media thickness in rats in a time-dependent manner. This implies that hibiscus products may have therapeutic value in salt-induced vascular morbidity. We recom-

mend further studies on isolation of various components of hibiscus to elucidate the role in cardiovascular protection further.

Acknowledgement

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ORCID ID:
F. O. Gwala 0000-0003-3910-2832; W. O. Sibuor 0000-0003-2886-1016; B. O. Olabu 0000-0003-0782-8006; A. N. Pulei 0000-0003-2437-8596; J. A. Ogeng'o 0000-0001-5918-9184

Correspondence to: Fidel O. Gwala, BSc
Department of Human Anatomy, School of Medicine, University of Nairobi, P.O. Box: 30197 – 00100, Nairobi, Kenya
Phone: +254 706 661 250
e-mail: gwalafidel@gmail.com

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Is femoral artery calcification a sign of mortality in elderly hip fractures?

Özhan Pazarcı, Cihat Ekici, Kemal Yazıcı, Seyran Kılınç, Hayati Öztürk

Department of Orthopaedics and Traumatology, School of Medicine, Cumhuriyet University, Sivas, Turkey

Abstract

Objectives: It is important to determine the risks of mortality in elderly patients with hip fractures. The aim of this study was to investigate the effect of femoral artery calcification on mortality risk in patients with cemented partial hip prosthesis.

Methods: The study included 145 patients (≥65-years-old) with cemented partial hip prosthesis operated following hip fracture. Patients were divided into two groups: Group (1) included those without femoral artery calcification, and Group (2) with femoral artery calcifications observed on direct radiography. Age, gender, duration of hospitalization, time of death and follow-up duration, ASA score, anesthesia type, fracture type, complication and time of operation for patients were compared between two groups.

Results: After exclusion of certain patients due to lack of necessary information in their documents, a total of 116 patients were investigated. The mean age of patients was 81.52±6.82. Mean follow-up duration was 35.39 (range: 0–76) months. Three out of 116 patients died after some complications during surgery. Mean time of death after surgery was 21.21 months in Group 1 and 23.86 months in Group 2 (p=0.628).

Conclusion: The results of this study showed that femoral artery calcification in patients with cemented prosthesis due to hip fracture at advanced age had no effect on mortality. However, there is a need for advanced studies with larger patient groups.

Keywords: arterial calcification; hip fracture; mortality

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Introduction

Vascular calcification is an important marker of atherosclerosis and a result of chronic inflammatory processes. Histopathologically, widespread arterial calcification is associated with coronary artery stenosis. Aortic calcification is accepted as a sensitive marker for atherosclerosis.[1] Osteoporosis and atherosclerosis are commonly found in these patients.[2] Arterial calcification in some regions is associated with fracture risk.[3]

In elderly patients, hip fracture and associated complications are public health issues.[4] According to a United States of America based data, 250,000 hip fractures are observed in cases above the age of 65 years each year.[5] The annual mortality rate of those with hip fracture reaches up to 30%.[6] Patients operated due to hip fracture have many factors that affect mortality and duration of admission, so it is important to define which factors are associated with mortality.[7] Cemented hemiarthroplasty is a reasonable alternative to a fixation device for the treatment of intertrochanteric fractures.[8]

Better understanding of the mechanisms behind vascular calcification will open the way for studies which may be beneficial for cardiovascular and bone health. In our study, the aim was to determine whether femoral artery calcification on hip AP radiographs affects mortality in hip fracture cases.

Materials and Methods

The study included patients treated in our clinic due to hip fractures during 2015 and 2016. The study received local ethics committee permission from Cumhuriyet University (approval number: 2018-12/08). In order to eliminate the effect of treatment type on mortality in the study group, 145 patients of 65 years and older with

cemented hemiarthroplasty were included in the study. After excluding patients with no available medical history or radiography, a total of 116 patients were included in the study. Patient information was retrospectively assessed. Direct hip AP radiographs were evaluated by two orthopedists together. Group 1 (n=90) was defined as patients without femoral artery calcification, while Group 2 (n=26) was defined as patients with femoral artery calcification (**Figure 1**). Differences in terms of parameters such as age, sex, duration of admission, operation time, follow-up duration and death time between the groups were investigated. Additionally, information on American Society of Anesthesiologists (ASA) score, comorbid diseases, complications, type of anesthesia, fracture type, operation within the first 48 hours or not and whether the patient survived was evaluated. All patients had cemented partial hip prosthesis operation performed with anterolateral (Watson-Jones) approach in supine position.

Statistical analysis was performed by Statistical Package for Social Sciences (SPSS for Windows, version 21.0, Chicago, IL, USA). Chi-square test and Fisher's exact test were used for comparison of categorical data. Kolmogorov-Smirnov normality analysis was made for comparison of numerical variables. The survival analysis of exitus patients were investigated with the Kaplan-Meier test.

Results

A total of 116 patients were included to the study (mean age: 81.52±6.82). Of these patients, 49 were males (42.2%) and 67 were females (57.8%). Mean hospital stay was 11.77±6.81 days. Mean time to operation of patients was 4.95±3.5 days. While 31 patients (26.7%) were taken for operation in the first 48 hours, 85 patients (73.3%) had operation after the first 48 hours. Mean follow-up duration was 35.39 (range: 0–76) months. According to ASA scoring, the distribution of patients was as follows: ASA I: 4 patients, ASA II: 56, ASA III: 51 and ASA IV: 5 patients. In total, 98 patients were operated under general anesthesia, while 18 patients under spinal anesthesia. 73 patients had fractures in the femur intertrochanteric region, while 43 patients had femur neck fractures. Complications were observed in 3 out of 116 patients (2 cases with infection, 1 with implant failure).

There were no differences observed between the groups in terms of gender, ASA score, anesthesia type, fracture type, complications, and surgery within the first 48 hours (**Table 1**). Additionally, there were no differences between the groups in terms of age, duration of admission, and operation time. With similar follow-up durations, there was no significant difference observed in the mean death duration between the groups (**Table 2**).

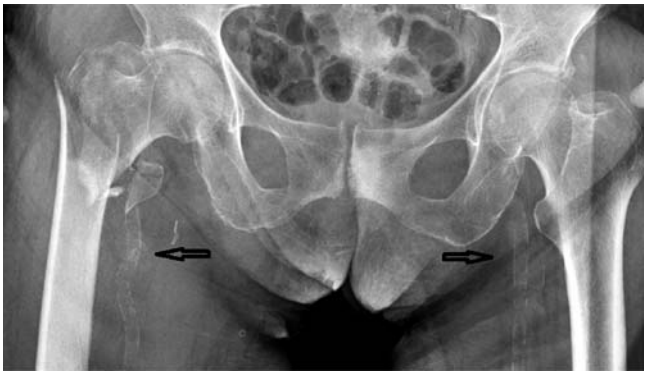

Figure 1. Hip AP radiography of a 90-year old female patient with femoral artery calcification (**arrow**). (Multifragmentary pertrochanteric fracture, AO classification 31A2.2)

68 patients died during the follow-up period of our study (**Figure 2**). Fifty of these patients - 4 males (35.29%) and 26 females (38.23) - were in Group 1 (73.52%); 18 patients - 10 males (14.70%) and 8 females (11.76%) - were in Group 2 (26.47%). Deaths were related to advanced age and existing comorbidities. There was no correlation between death and arterial calcification between the groups. At least one or more chronic comorbidities were seen in 90%.

Discussion

The strongest aspect of this study is the presentation of mean 32-month follow-up outcomes of cases with hip fracture both with and without femoral artery calcification. Arterial calcification, cardiovascular diseases and osteoporosis were reported to be related to each other in previ-

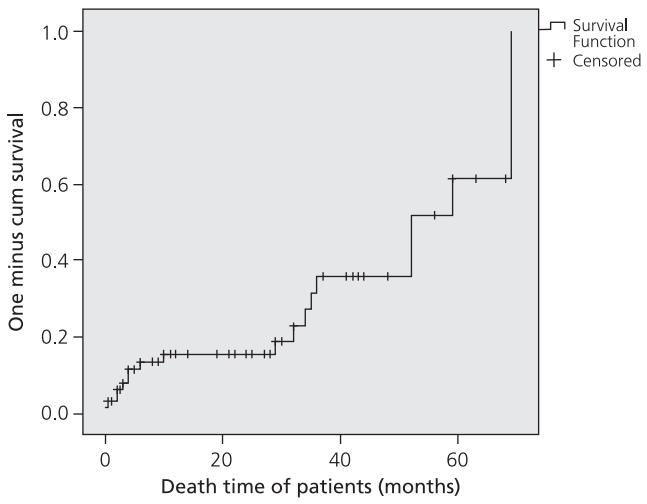

Figure 2. Kaplan-Meier one minus survival curves showing the cumulative death time of patients after hip surgery.

Table 1
Mortality risk factors compared between groups.

		Femoral artery calcification				
		Absent (Group 1) (n=90)		Present (Group 2) (n=26)		
Variables	Category	Count	Row N %	Count	Row N %	p-value
Gender	Males	37	75.51	12	24.49	0.647
	Females	53	79.10	14	20.90	
ASA	1	2	50.00	2	50.00	0.098
	2	45	80.36	11	19.64	
	3	41	80.39	10	19.61	
	4	2	40.00	3	60.00	
Type of anesthesia	General	76	77.55	22	22.45	0.983
	Spinal	14	77.78	4	22.22	
Fracture type	Intertrochanteric	55	75.34	18	24.66	0.45
	Femur neck	35	81.40	8	18.60	
Complication	None	87	77.68	25	22.32	0.781
	Infection	2	66.67	1	33.33	
	Revision	0	0.00	0	0.00	
	Other	1	100.00	0	0.00	
Operation in first 48 hours	Yes	27	87.10	4	12.90	0.138
	No	63	74.12	22	25.88	

ous studies.[9] However, these studies included assessment of aortic calcification.[10] Our study is important in terms of evaluating patients with femoral artery calcification on direct hip radiographies in terms of mortality.

The main effect of vascular calcification in bone is osteoporosis and fragility fracture due to reduced bone turnover.[11,12] Aortic calcification is not only associated with lower bone mass but also a higher incidence of new osteoporotic fractures.[13,14] Peripheral artery calcification is associated with low bone volume and coronary artery calcification.[15,16] No statistically significant difference in mortality rates between two groups was found in our study.

The effect of implant choice for hip fracture on mortality rates of patients was previously investigated by early studies. Cemented or cement-free partial hip prosthesis or proximal femoral nail (PFN) may be used in patients with intertrochanteric fracture.[17] The present study included patients that have been treated with cemented hemiarthroplasty, whereas patients treated with the others were excluded. Internal fixation may also be appropriate for elderly patients with impaired mobility, but further studies are required on this group before definite conclusions can be made.[18]

Another superior aspect of our study is the length of the follow-up duration. Mean mortality time of patients in both groups was more than twenty months. The mortality in the first year varies from 10–30% being the most common period.[19,20] In this study, there was no statistically significant difference in mortality rates after partial hip prosthesis among patients with femoral artery calcification compared to the control group. There were also no statistically significant differences observed between the groups when compared in terms of sex, ASA score, anesthesia type, fracture type, complications and time to surgery between the groups. Advanced age, male sex, cognitive impairment, psychiatric illness, living with a caregiver, having more than two comorbidities, cardiovascular disease, renal disease or any malignancy have been suggested to be associated with high mortality rates in hip fracture patients.[21] In our series, the mean age of the patients was over 80 years (**Table 2**). Especially for such elderly patients with hip fractures, it is necessary to well define factors that are associated with increased mortality rates to predict life expectancy and to prevent

Table 2
Comparison of patient information in Group 1 (n=90) and Group 2 (n=26) patients.

	Group 1 Mean±SD	Group 2 Mean±SD	p-value
Age (years)	80.95±6.93	83.5±6.14	0.094
Duration of admission (days)	11.65±6.2	12.19±8.72	0.771
Operation time (days)	5±3.78	4.8±2.29	0.806
Death time (months)	21.21±18.52	23.86±23.17	0.628
Follow-up duration (months)	36.19±23.04	32.63±24.46	0.495

complications.[22] This study is important in terms of showing that femoral artery calcification has no effect on increased mortality risk in elderly with hip fractures. Nevertheless, this study has some limitations. Among these are the retrospective nature of the study and the rather limited number of the patient group.

Conclusion

This study showed that femoral artery calcification in elderly patients with cemented prosthesis has no effect on mortality. However, there is a need for advanced studies with larger patient groups.

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ORCID ID:
Ö. Pazarcı 0000-0002-2345-0827; C. Ekici 0000-0002-8153-9416;
K. Yazıcı 0000-0001-9539-8848; S. Kılınç 0000-0003-0144-0916;
H. Öztürk 0000-0003-3273-5565

Correspondence to: Özhan Pazarcı, MD
Department of Orthopaedics and Traumatology, School of Medicine, Cumhuriyet University, Sivas, Turkey
Phone: +90 346 258 06 38
e-mail: dr.pazarci@gmail.com

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Dimensional assessment of the tensor fasciae latae muscle in fetal cadavers with meningomyelocele for flap surgery

Orhan Beger

Department of Anatomy, School of Medicine, Mersin University, Mersin, Turkey

Abstract

Objectives: The tensor fasciae latae (TFL) muscle may be preferred for the closure of superficial dorsal layers in patients with meningomyelocele (MMC). This study aimed to display the algebraic anatomy of TFL in fetal cadavers with MMC compared to that in normal fetuses.

Methods: Seven formalin-fixed fetuses with MMC (4 males and 3 females) aged from 18 to 27 weeks of gestation were dissected. A digital caliper (for the length and width of TFL) and digital image analysis software (for the surface area of TFL) were used to perform morphometric measurements. The numerical values of this study were compared with the calculated data obtained from the regression formula of a previously published article, considering fetal cadavers at the same gestational week.

Results: No statistically significant difference was observed between the quantitative values related to TFL sizes in terms of side and gender ($p>0.05$). Considering the calculated data obtained from the regression formulas, TFL dimensions in fetal cadavers with MMC did not statistically differ from normal fetuses without any malformations ($p>0.05$). TFL sizes including length, area, and width in some fetuses with MMC were smaller (3 fetal cadavers) or larger (1 fetal cadaver) than those of normal fetuses described previously.

Conclusion: TFL sizes including length, width and surface area in fetal cadavers with MMC were found similar to normal fetuses, statistically. Taking into account the individual differences related to TFL dimensions, whether MMC influences lower extremity muscle morphology should be examined in future studies. This anatomical knowledge related to TFL in fetuses with MMC should be taken into account when designing flap size.

Keywords: fetus; flap; meningomyelocele; regression; tensor fasciae latae

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Introduction

Meningomyelocele (MMC) causes important problems (e.g. sexual disability, urinary or fecal incontinence, hindbrain herniation, and hydrocephalus) associated with the central nervous system. It is generally repaired immediately after birth within 24 to 48 hours in order to eliminate the effects of environmental factors such as infection, desiccation and heat.[1–6] However, based on the "two-hit hypothesis (the first-hit: the interruption of the neurulation in early pregnancy, and the second-hit: the destructive effect caused by intrauterine environment in the remaining period)", some surgeons recommend intrauterine MMC repair before 26 weeks of gestation to remedy "second-hit"-induced damage.[1-3,7–13] In addition, MMC repairs *in utero* decrease ventriculoperitoneal shunt dependence, prevent the progression of spinal cord damage, and improve neurological functions.[1–3,8,11] In this context, prenatal MMC repair has appealed more and more surgeons.[1–3,7–13]

Following the repair of the neural parts of the spinal cord, superficial dorsal layer renovations are performed with myocutaneous and muscular flaps such as latissimus dorsi and gluteus maximus.[5,7–10,14] Morphometric features of these muscles used in MMC repair have recently become an area of interest for anatomists to determine if there is a dimensional change in fetuses with MMC.[15] On

the other hand, the tensor fasciae latae (TFL) flaps can be preferred in the treatment of MMC.[16,17] In this regard, due to the fact that there is no previous study on the algebraic anatomy of TFL including its length, width and surface area in fetuses with this pathology, the main aim of this study was to determine of the morphometric features of TFL in fetuses with MMC compared to normal fetuses.

Materials and Methods

After approval of the Clinical Research Ethics Committee of Mersin University School of Medicine, seven formalin-fixed fetuses with MMC (4 males and 3 females) with 18 to 27 weeks of gestational age were dissected. Skin and fascia were removed to display TFL in the lateral decubitus position were dissected under a surgical microscope (Carl Zeiss f170, Carl Zeiss Meditec AG, Jena, Germany). Taking into account the former study by Beger et al.,[18] the following parameters of TFL were measured: surface area, anterior and posterior border lengths, and width.

Fetal cadavers with MMC in the current study were previously used to display the morphometric features of the latissimus dorsi, thoracodorsal artery and nerve compared to normal fetuses.[15] The shrinkage percentage in the tissues on account of fixative solution was determined as less than 1% by Cutts;[19] therefore, the effect of 10% formalin on numerical data was underestimated. Using a digital caliper (0.01 mm precision, Mahr, 16 ER, Göttingen, Germany), the measurements including TFL length and width were performed. A digital camera (Nikon d3300, Nikon, Tokyo, Japan) was used to photograph TFL with a millimeter scale in the same position under the same environmental conditions (**Figure 1**). Utilizing a digital image analysis software (ImageJ, NIH, Bethesda, MD, USA, https://imagej.nih.gov/ij/, 1997–2018), the surface area of TFL was calculated by photograph analysis.[15,18,20] The averages of three repeated measurements were given in the tables. ANOVA with repeated measurements and post hoc RIR Tukey tests were used to assess intra-observer reproducibility of dataset. Length of the right foot of fetuses was measured to determine the gestational weeks of specimens. Student's t-test was used to compare the sides (paired samples t-test) and gender (independent samples t-test). The calculated data obtained from the regression formulas of Beger et al.'s[18] study considering fetuses at the same gestational week were compared to the measurements of this study including the length, width and surface area of TFL. Statistical significance level was set as $p<0.05$.

Results

The demographic data of age, foot length, and gender, numerical values of this study, and the calculated data

Table 1

Demographic (age, number, foot length and gender) and morphometric (length, width and surface area of TFL) data related to fetuses.

Fetuses	Fetus 1	Fetus 2	Fetus 3	Fetus 4	Fetus 5	Fetus 6	Fetus 7
Age	18	19	20	22	23	26	27
Foot length	25.43	28.66	29.57	34.61	39.02	46.47	48.11
Gender	Male	Female	Female	Male	Male	Male	Female
Surface area (mm^2) (R/L)	**20.10**[a]/44.30	53.15/57.50	72.88/**87.01**[b]	80.49/115.77	114.01/90.31	**95.48**[a]/**84.99**[a]	154.34/157.90
Calculated values (mm^2)*	33.85	48.27	62.69	91.52	105.94	149.19	163.61
Average values (mm^2)†	58.45±19.35	58.45±19.35	58.45±19.35	94.14±22.46	94.14±22.46	150.92±33.19	150.92±33.19
Length of anterior margin (mm) (R/L)	11.06/14.08	11.40/13.89	15.03/16.21	14.16/15.78	17.32/17.07	16.58/16.45	18.56/19.51
Calculated values (mm)*	12.09	13.01	13.90	15.72	16.63	19.36	20.27
Average values (mm)†	13.09±2.67	13.09±2.67	13.09±2.67	16.24±2.15	16.24±2.15	19.45±2.94	19.45±2.94
Length of posterior margin (mm) (R/L)	10.04/9.78	10.37/11.32	11.72/**16.14**[b]	**10.33**[a]/12.05	13.40/12.88	**9.82**[a]/**10.73**[a]	13.72/13.75
Calculated values (mm)*	9.55	10.33	11.11	12.67	13.45	15.79	16.57
Average values (mm)†	10.70±2.81	10.70±2.81	10.70±2.81	12.89±2.38	12.89±2.38	16.37±2.67	16.37±2.67
Width (mm) (R/L)	**2.79**[a]/**4.48**[a]	5.30/6.17	6.21/7.15	6.39/7.38	8.01/7.70	**7.52**[a]/**7.48**[a]	10.84/9.79
Calculated values (mm)*	5.14	5.73	6.33	7.52	8.11	9.90	10.49
Average values (mm)†	5.95±1.28	5.95±1.28	5.95±1.28	7.85±1.68	7.85±1.68	9.91±0.96	9.91±0.96

L: left; R: right. *The calculated data obtained from the regression formulas of Beger et al.'s[18] study considering fetuses at the same gestational week. †Average values of Beger et al.'s[18] study considering fetuses at the same gestational month. [a]Values smaller thanthe range of Beger et al.'s[18] fetuses for the same month. [b]Values greater than the range of Beger et al.'s[18] fetuses for the same month.

obtained from the regression formulas of Beger et al.'s[18] study are shown in **Tables 1** and **2**.

No statistically significant difference was found between the measurements repeated for three times (p>0.05), indicating that the reliability of intra-observer repeatability was successful. No statistically significant difference was observed between the quantitative values in terms of side and gender (p>0.05). Considering the calculated data obtained from the regression formulas of Beger et al.'s[18] study, TFL dimensions in fetal cadavers with MMC did not statistically different from normal fetuses (**Table 2**) (p>0.05). TFL surface area in a 26-week-old fetus was bilaterally smaller than that of value range reported by Beger et al.[18] The area on the right side of an 18-week-old fetus was smaller than the value range, while the area on the left side of a 20-week-old fetus was larger than the value range (**Table 1**).

The posterior border length of TFL in a 26-week-old fetus was bilaterally smaller than that of value range reported by Beger et al.[18] The length on the right side of a 22-week-old fetus was smaller than the value range, while the length on the left side of a 20-week-old fetus was greater than the value range (**Table 1**). TFL widths in 18-week-old and 26-week-old fetuses were bilaterally smaller than that of value range reported by Beger et al.[18] (**Table 1**).

Table 2
Comparison of the average values of the cases with the calculated data obtained from Beger et al.'s[18] study.

Parameters	Current study	Calculated values*	p	Change %
Surface area (mm^2)	87.73±38.89	93.58±49.64	0.556	-%6.25
Length of anterior margin (mm)	15.48±2.39	15.85±3.12	0.540	-%2.33
Length of posterior margin (mm)	11.86±11.89	12.78±2.68	0.399	-%7.20
Width (mm)	6.94±2.02	7.60±2.04	0.123	-%8.68

*The calculated data obtained from the regression formulas of Beger et al.'s[18] study considering fetuses at the same gestational week.

Discussion

The most and heaviest form of the spina bifida is MMC, which might cause ventriculoperitoneal shunt dependence, hindbrain herniation, high mortality rate, hydrocephalus, neurological disability, sexual dysfunction, and Arnold-Chiari II malformation.[1–4] MMC repairs *in utero* may prevent these negative conditions, although it carries risks such as fetal death or premature birth.[1,2] Therefore, some surgeons recommend MMC repairs *in utero* due to the neurodevelopmental outcome of children following fetal MMC closure.[1–3,11] After the repair of the neural part, superficial dorsal layer closure can be performed with different muscular flaps such as the latissimus dorsi and gluteus maximus.[7–10,14,15] Posma[17] recommended the use of TFL flaps in the repairs of MMC. Phillips and Lindseth[16] studied 47 patients with MMC and stated that the external oblique, the adductors and

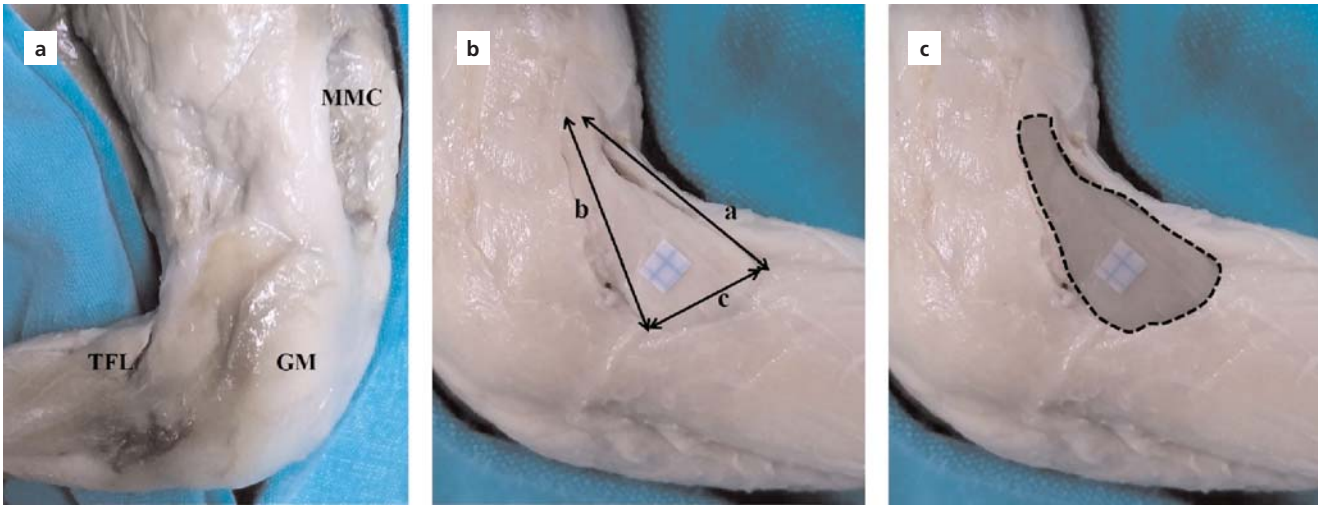

Figure 1. (**a**) The tensor fasciae latae (TFL) and gluteus maximus (GM) muscles, and meningomyelocele (MMC); (**b**) Anterior (a) and posterior (b) margin lengths and (c) width of the tensor fascia lata; (**c**) Surface area of the tensor fascia lata. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

TFL (triple transfer) were used to close the superficial dorsal layer of 41 patients. They used the external oblique and the adductors (double transfer) in six patients, due to insufficient dimension of TFL.[16] Beger et al.[18] studied the algebraic anatomy of TFL in 50 normal fetal cadavers aged from 18 to 30 (mean 22.94±3.23) weeks of gestation and reported that its morphometric features were important for neurosurgeons and pediatric surgeons during the neonatal MMC treatment. However, no study conducted on the quantitative properties of TFL in fetuses with MMC was found in the literature.

The regression equations related to the dimensions (e.g. length, width and surface area) of different muscles such as the latissimus dorsi were calculated to estimate their size in normal fetuses.[18,20] In our previous studies conducted on seven fetal cadavers with MMC, the morphometric features of the latissimus dorsi, thoracodorsal artery and nerve were compared with the estimations of the regression equations.[15,20] We found that the surface area, length and width of the latissimus dorsi in fetuses with MMC were 3–10% smaller than normal fetal cadavers and concluded that this reduction should be taken into account when designing flap sizes.[15,20] From this anatomical perspective, we suggested that the anatomical variations in dimensions of the muscles used as flap in MMC repairs should be displayed.[15] In the current study, the algebraic anatomy of TFL in fetal cadavers with MMC were evaluated to estimate its size using the calculated values obtained from the regression formulas of Beger et al.'s[18] study considering fetuses at the same gestational week. Therefore, the dimensions of TFL including its length, width and surface area in fetal cadavers with MMC were found similar to normal fetuses statistically. Considering the study of Phillips and Lindseth,[16] small TFL observed in some patients with MMC may be due to individual differences. According to the previously reported data range, the reason why individual differences do not achieve statistical significance may be the small number of cases or the variable level of disruptions that may affect muscle morphology in the nerve tissues due to MMC. These should be further investigated in larger series.

Conclusion

The findings of this study showed that the dimension of TFL in fetuses with MMC were similar to normal fetuses, statistically. Considering the individual differences related to TFL dimensions, whether MMC influences lower extremity muscle morphology should be examined in future studies.

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ORCID ID:
O. Beger 0000-0002-4932-875

Correspondence to: Orhan Beger, PhD
Department of Anatomy, School of Medicine, Mersin University, Mersin, Turkey
Phone: +90 324 361 06 83 / 1092
e-mail: obeger@gmail.com

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Fingerprint pattern similarity: a family-based study using novel classification

Eric O. Aigbogun Jr.[1], **Chinagorom P. Ibeachu**[2], **Ann M. Lemuel**[1]

[1]*Department of Anatomy, Kampala International University, Western Campus, Ishaka, Uganda*
[2]*Department of Anatomy, College of Health Sciences, University of Port-Harcourt, Rivers State, Nigeria*

Abstract

Objectives: Establishing that certain traits are inherited can be assessed from the extent of morphological similarity of the offspring and their parents. This study, evaluated the pattern similarity of the fingerprint of offspring to that of their parents using a novel classification.

Methods: Fifty families (comprising of father, mother and a child) without ethnic considerations were recruited and digital fingerprints were obtained. The fingerprints; arch (A), loop (L), and whorl (W) were identified and a novel classification (A, L, W, AL, AW, and LW) for heredity study as described by Aigbogun et al.(2018) was adopted. Chi-square analysis was used to test distribution differences, while a pedigree tree was designed for the offspring's similarity to the parents.

Results: In this study, loop (L) was consistently predominant both as single (>60%) and combined distribution (>75%), followed by whorl (<25%) and then arch (<22%); although not entirely consistent for the whorl (W) and arch (A). The distribution except the ring finger (χ^2=24.891; P=0.036) was not statistically significant (p>0.05). From the pedigree tree, the possibility that the offspring displayed patterns similar to that of the parental combinations was 84% for the thumb, 76% for the index finger, 84% for the middle finger, 88% for the ring finger, and 92% for the little finger.

Conclusion: Morphological evidence from this study suggests that fingerprints are more genetically determined than environmentally influenced; however, the pattern in which they are inherited seemed closer to co-recessivity with complex expressivity.

Keywords: family; fingerprint pattern; human; inheritance; novel classification

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Introduction

The argument about the heritability of certain traits including fingerprints in humans has been on for years. Geneticists have established that nearly all traits in the offspring are shared genetic information from the parents;[1] however, the nature in which these traits are expressed are to a great extent dependent on how they are inherited and the susceptibility to exogenous interference, such as diseases, mutation, and environment.[2,3] Establishing the fact that certain traits are inherited in a particular fashion provide the basis for predicting the outcome of an offspring and vice versa. The hereditary implication of fingerprints has drawn attention from geneticists for a long while, because it is believed that they hold valuable information capable of explaining various familial characteristics and diseases.[4–10]

The ridge-like impressions noticeable on all the fingers are called fingerprint (friction ridges) and its study is called dermatoglyphics.[11,12] Although the number, shape, indentations, and spacing of the ridges varies from one individual to another,[13–16] it is suggested that the ridge patterns are partly genetically determined and environmentally influenced;[17–19] hence, fingerprint is believed to be a multifactorial trait.[20]

Scientific evidence regarding the fingerprint pattern similarity in families using the qualitative attributes is relatively scarce, because most studies utilized the quantitative methods,[19,21–23] and the available classifications did not provide enough scientific basis for its use in family-based studies. This study, therefore, evaluated the fingerprint pattern similarity between the parents and offspring using a novel classification technique.

Materials and Methods

The study adopted a cross-sectional design, which involved the collection of the digital fingerprint from 50 randomly-selected families in Rivers State, Nigeria to estimate the pattern similarity of the offspring to that of the parents using novel classification.

Stratified random sampling was adopted for the study. This considered the concentration of residential areas with mainly civil servants and employees of higher institutions, which made it easier to get a complete sample population (family size), explain the study, and get consent. Volunteer families were conveniently sampled from across various residential areas in Port Harcourt, Rivers State, Nigeria. The study did not take into consideration the ethnicity of the families; however, the study utilized only families of Nigerian descent. The criteria for selection included families with at least father, mother and a child, and no clinical or medical history of congenital abnormalities. Incomplete families (single parents or no child), family with a history of adoption, and damaged anatomical parts of choice were all excluded from the study. In a situation where a family had more than a child, to reduce sample bias, simple paper balloting was used to determine which offspring participated in the study. The age of the participating families was a selection criterion only for infant children (less than 2 years), but when fingerprint obscurity was noticed in the parent, the family was excluded; however, when it affected an offspring and the family had more than one, the next offspring was chosen as a replacement.

Digital fingerprints were obtained using the HP Scanjet 300 Flatbed Photo Scanner as described by Aigbogun et al.[24] The palm of the hands was wiped thoroughly, before placing on the screen of the scanner. A little pressure was applied when the palm was placed on the surface of the scanner, for adequate contact with the fingers. Only the primary fingerprint details were required; therefore, the palm and all five digits were taken together in one scan as illustrated in **Figure 1**. After each print, sterile tissue wipes were used to clean the glass-scanning surface to prevent contamination. The digit prints were read directly from the picture (**Figure 1**) and the print patterns entered into an excel sheet, which was tabulated and stratified by families. The study utilized the three general classification types; arch (A), loop (L) and whorl (W) for all digits of the right (R) and left (L) hand.[25]

This study adopted Aigbogun et al. classification to organize the fingerprint patterns and distributions.[26] In this technique, when considering hereditary of fingerprint pattern, it is assumed that both right and left digits are a unit. For easy identification, the study considered the alphabetic positions as follows: A (both hands arch), L (both hands loop), W (both hands whorl), AL (arch-loop combinations on either hand), AW (arch-whorl combinations on either hand), and LW (loop-whorl combination on either hand).[26]

Using the Excel Sheet, each trait (pattern combination) of the parents (as a single group) were tabulated against the possible combination outcome (by crosses) of their offspring and a pedigree tree drawn for all parental

Figure 1. Digital hand print obtained using the HP 300 flatbed scanner (zoomed in to capture fingerprint type).[24] [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Table 1
The distribution of dermatoglyphic pattern on the thumb and test of association.

		Thumb (1D)			Chi-square analysis			
Side	**Group**	**A**	**L**	**W**	**Df**	**χ^2**	**p**	**Inference**
Right	Father	4 (8.0)	38 (76.0)	8 (16.0)				
	Mother	9 (18.0)	35 (70.0)	6 (12.0)	4	3.34	0.503	NS
	Offspring	10 (20.0)	33 (66.0)	7 (14.0)				
	Total	**23 (15.3)**	**106 (70.7)**	**21 (14.0)**				
Left	Father	8 (16.0)	36 (72.0)	6 (12.0)				
	Mother	14 (28.0)	30 (60.0)	6 (12.0)	4	5.594	0.232	NS
	Offspring	16 (32.0)	25 (50.0)	9 (18.0)				
	Total	**38 (25.3)**	**91 (60.7)**	**21 (14.0)**				

A: arch; **Df:** degree of freedom; **L:** loop; **NS:** non-significant; **W:** whorl; **χ^2**: chi-square value.

combinations and offspring outcome. Statistical Package for Social Sciences (SPSS for Windows, version 23.0, Armonk, New York, USA) was used for chi-square analysis to present distribution and analyse association (confidence level set at 95%, and $p<0.05$ was considered significant). The percentage conformance of offspring to parental combinations was calculated.

The study obtained ethical clearance (with reference number UPH/R&D/REC/026) from the University Ethics Committee of the Post-Graduate School of the University of Por Harcourt; after review by the Departmental Post-Graduate Board. Participating families (the parents, on behalf of the families) provided a written and signed informed consent after a clear explanation of the research purpose, procedure and benefits. The study adhered to all statutory and regulatory requirements for human participation in research(es).

Results

The distribution of the fingerprint patterns (stratified by the family components), and the Chi-square test of distributional differences of the patterns on both hands (right and left) are shown in **Tables 1–5**. The parental combinations of the fingerprint patterns and outcome in offspring (conformity; as straight black lines and nonconformity; as dotted red lines), as well as percentage predictability of the outcome for each finger are shown in **Figures 1–5**.

The loop pattern dominated in all fingers; thumb (1D) [R; 70.7%, L; 60.7%], index (2D) [R; 55.3%, L; 59.3%], middle (3D) [R; 68.7%, L; 70.7%], ring (4D) [R; 66.0%, L; 69.3%], little (5D) [R; 66.0%, L; 69.3%]. The distribution of the fingerprints on the right and left fingers were not statistically significant ($p>0.05$) in the family strata, except for the right ring finger ($\chi^2=10.549$; $p=0.032$) (**Tables 1–5**).

Table 2
The distribution of dermatoglyphic pattern on the index finger and test of association.

		Index (2D)			Chi-square analysis			
Side	**Group**	**A**	**L**	**W**	**Df**	**χ^2**	**p**	**Inference**
Right	Father	11 (22.0)	27 (54.0)	12 (24.0)				
	Mother	7 (14.0)	32 (64.0)	11 (22.0)	4	3.550	0.470	NS
	Offspring	14 (28.0)	24 (48.0)	12 (24.0)				
	Total	**32 (21.3)**	**83 (55.3)**	**35 (23.3)**				
Left	Father	8 (16.0)	32 (64.0)	10 (20.0)				
	Mother	13 (26.0)	29 (58.0)	8 (16.0)	4	2.371	0.668	NS
	Offspring	14 (28.0)	28 (56.0)	8 (16.0)				
	Total	**35 (23.3)**	**89 (59.3)**	**26 (17.3)**				

A: arch; **Df:** degree of freedom; **L:** loop; **NS:** non-significant; **W:** whorl; **χ^2**: chi-square value.

Table 3
The distribution of dermatoglyphic pattern on the middle finger and test of association.

		Middle (3D)			Chi-square analysis			
Side	**Group**	**A**	**L**	**W**	**Df**	**χ^2**	**p**	**Inference**
Right	Father	5 (10.0)	33 (66.0)	12 (24.0)				
	Mother	6 (12.0)	37 (74.0)	7 (14.0)	4	3.166	0.530	NS
	Offspring	9 (18.0)	33 (66.0)	8 (16.0)				
	Total	**20 (13.3)**	**103 (68.7)**	**27 (18.0)**				
Left	Father	6 (12.0)	33 (66.0)	11 (22.0)				
	Mother	4 (8.0)	39 (78.0)	7 (14.0)	4	6.734	0.151	NS
	Offspring	11 (22.0)	34 (68.0)	5 (10.0)				
	Total	**21 (14.0)**	**106 (70.7)**	**23 (15.3)**				

A: arch; **Df:** degree of freedom; **L:** loop; **NS:** non-significant; **W:** whorl; χ^2: chi-square value.

Table 4
The distribution of dermatoglyphic pattern on the ring finger and test of association.

		Ring (4D)			Chi-square analysis			
Side	**Group**	**A**	**L**	**W**	**Df**	**χ^2**	**p**	**Inference**
Right	Father	4 (8.0)	26 (52.0)	20 (40.0)				
	Mother	5 (10.0)	39 (78.0)	6 (12.0)	4	10.549	**0.032**	S
	Offspring	4 (8.0)	34 (68.0)	12 (24.0)				
	Total	**13 (8.7)**	**99 (66.0)**	**38 (25.3)**				
Left	Father	1 (2.0)	33 (66.0)	16 (32.0)				
	Mother	4 (8.0)	39 (78.0)	7 (14.0)	4	7.767	0.100	NS
	Offspring	6 (12.0)	32 (64.0)	12 (24.0)				
	Total	**11 (7.3)**	**104 (69.3)**	**35 (23.3)**				

A: arch; **Df:** degree of freedom; **L:** loop; **NS:** non-significant; **S:** significant; **W:** whorl; χ^2: chi-square value.

Table 5
TThe distribution of dermatoglyphic pattern on the little finger and test of association.

		Little (5D)			Chi-square analysis			
Side	**Group**	**A**	**L**	**W**	**Df**	**χ^2**	**p**	**Inference**
Right	Father	3 (6.0)	41 (82.0)	6 (12.0)				
	Mother	2 (4.0)	46 (92.0)	2 (4.0)	4	2.576	0.631	NS
	Offspring	3 (6.0)	42 (84.0)	5 (10.0)				
	Total	**8 (5.3)**	**129 (86.0)**	**13 (8.7)**				
Left	Father	3 (6.0)	43 (86.0)	4 (8.0)				
	Mother	5 (10.0)	42 (84.0)	3 (6.0)	4	1.902	0.754	NS
	Offspring	5 (10.0)	39 (78.0)	6 (12.0)				
	Total	**13 (8.7)**	**124 (82.7)**	**13 (8.7)**				

A: arch; **Df:** degree of freedom; **L:** loop; **NS:** non-significant; **W:** whorl; χ^2: chi-square value.

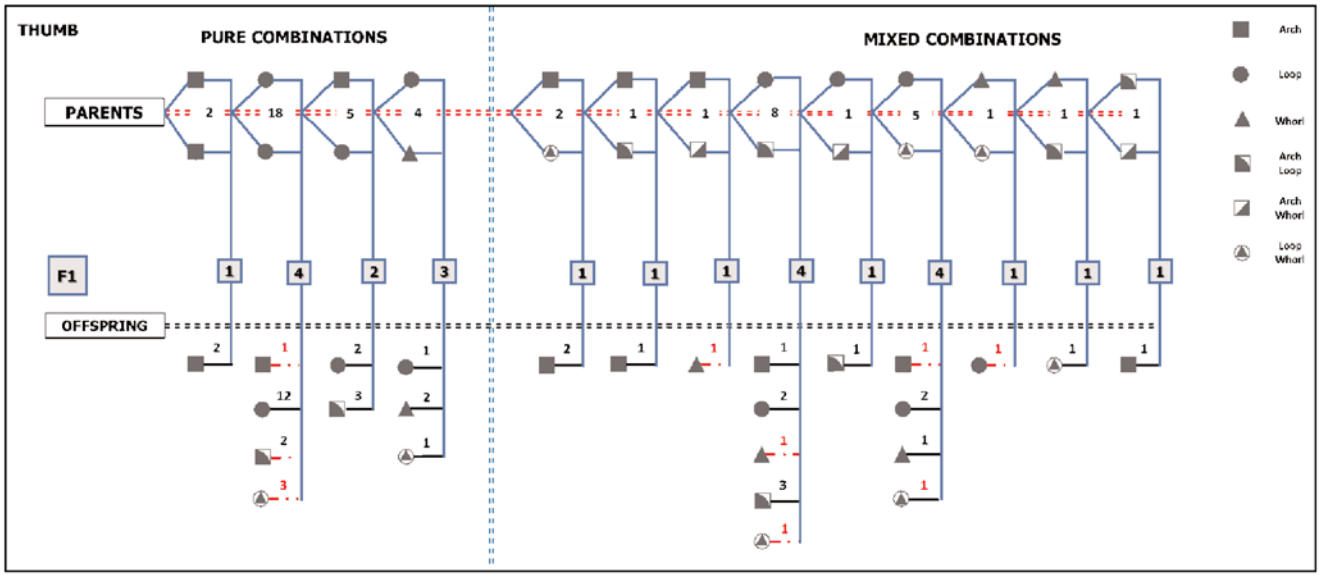

Figure 2. Pedigree tree and offspring patterns from parental combinations on the thumb (offspring conformity to parental combination; black color: yes, red color: no; [39/50=78% possibility of inheritance]). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

From the cross-match, the study showed that only the index and ring fingers presented all possible combinations for the patterns (A, L, W, AL, AW, and LW), while on other fingers (thumb, middle and ring), the pattern AW was absent (**Figures 2–6**). The parental combination on the thumb (1D) displayed 13 patterns, with the offspring presenting a 78% conformance (39 matching outcomes of the 50 offspring fingerprint and 11 outcomes not matching parental combinations; **Figure 2**). The parental combination on the index finger displayed 14 patterns, with 76% conformance (38 matching and 11 outliners; **Figure 3**), while the parental combination on the middle finger had 11 patterns and 84% conformance (42 matching and 8 outliners; **Figure 4**). The parental combination on the ring finger displayed 9 patterns with 88% conformance (44 matching and 6 outliners; **Figure 5**), whereas, the

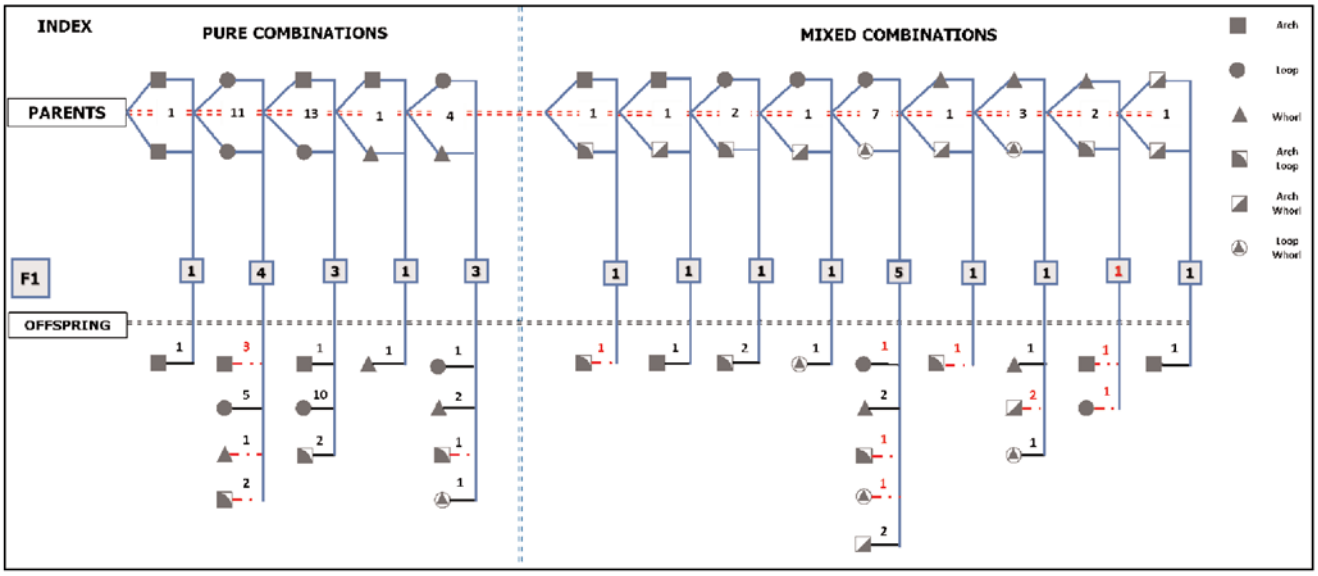

Figure 3. Pedigree tree and offspring patterns from parental combinations on the index finger (offspring conformity to parental combination; black color: yes, red color: no; [38/50=76% possibility of inheritance]). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

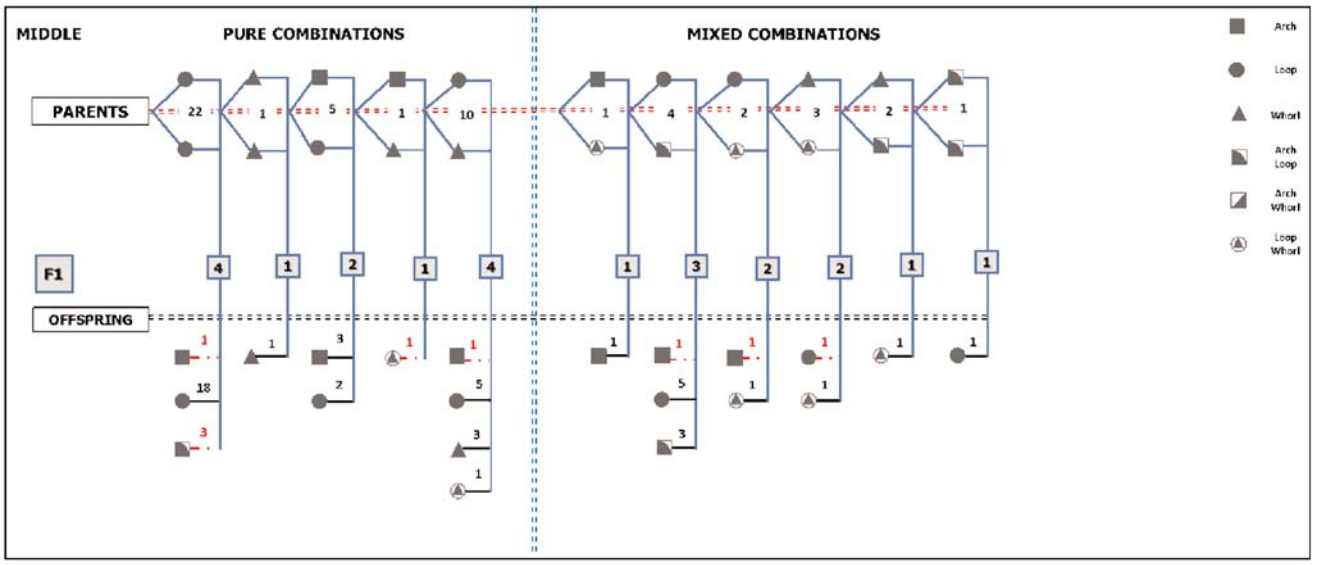

Figure 4. Pedigree tree and offspring patterns from parental combinations on the middle finger (offspring conformity to parental combination; black color: yes, red color: no; [42/50=84% possibility of inheritance]). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

parental fingerprint combinations on the little finger presented 5 patterns and 92% conformance (46 matching and 4 outliners; **Figure 6**).

Discussion

This study investigated fingerprint combination patterns using a novel classification technique designed for evaluating pattern similarity between parents and their offspring. We observed that loop (L) consistently remained the predominant fingerprint, followed by whorl and then arch; although not generally consistent with whorl (W) and arch (A), because the left index finger had more arch patterns. Eboh,[27] Meril et al.,[28] and Ujaddughe et al.[29] reported similar findings of a higher proportion of loops and arches on left fingers, but whorl on the right.

When the distribution across the family members was compared, there was no difference indicating that

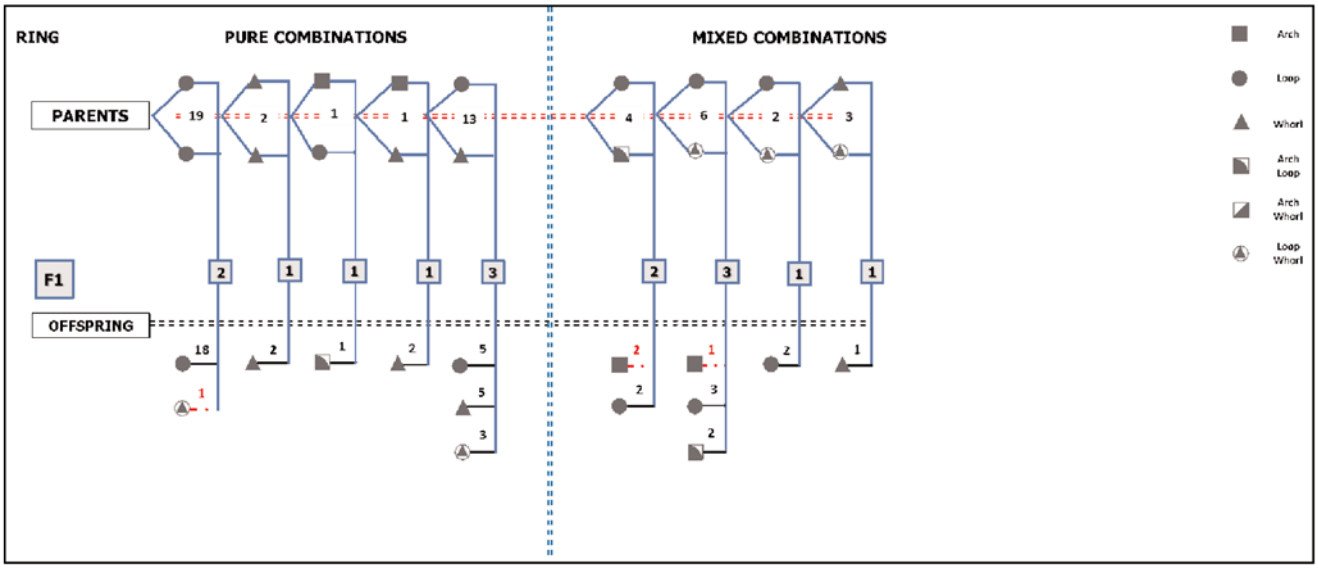

Figure 5. Pedigree tree and offspring patterns from parental combinations on the ring finger (offspring conformity to parental combination; black color: yes, red color: no; [44/50=88% possibility of inheritance]). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

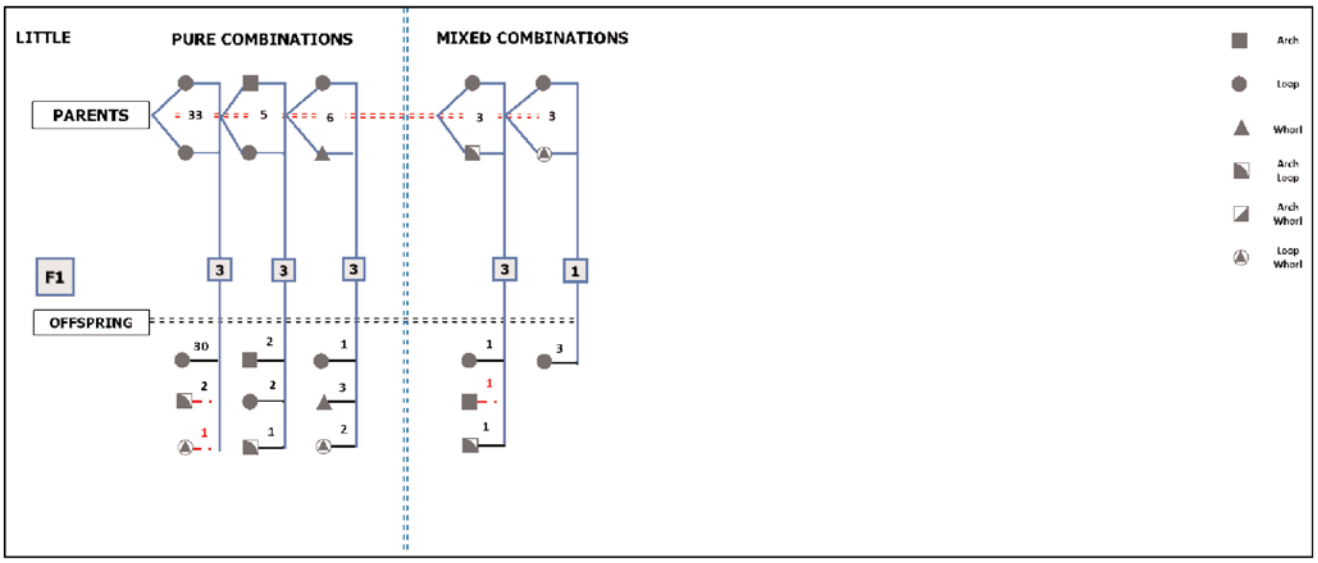

Figure 6. Pedigree tree of offspring patterns from parental combinations on the little finger (offspring conformity to parental combination; black color: yes, red color: no; [46/50=92% possibility of inheritance]). [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

the displayed patterns were generally similar in both parents and the offspring. The total distribution of the pattern on the fingers of parents and offspring was not significant. Thus, the distribution of the fingerprint pattern (types) was a representation of the parental combination.

In evaluating the possibility of inheriting fingerprints, we observed that in the offspring population, the index and ring finger presented all 6 combinations, with an exception to AW, which was absent in all digits of the offspring. However, when present, it was non-conformant to parental combination; thus, suggesting that AW pattern is rarely inherited irrespective of the presentation in the parents. When the parental combination was cross-matched with offspring outcome, the possibility that the offspring presented an accurate pattern from the parental combinations was 78% for the thumb, 76% for the index finger, 84% for the middle finger, 88% for the ring finger, and 92% for the little finger. Observing the various parental combinations in the study population (crossing the fingerprint types of parents in a table for an insight into its possible inheritance pattern), the outcome of some of the fingerprint patterns suggested that the offspring indeed inherited those patterns in an explainable fashion.[30] The findings are suggestive of the possibility of alternated inheritance of these fingerprint patterns, such that parents could display a loop on the right and an arch on the left whereas their offspring will present with arch on the right and loop on the left (alternated inheritance). When both fingers are considered as a single unit, then it is possible that the trait is expressed with a non-side-specific bias like inherited birthmarks, which is often non-location specific.[26]

The findings in this study buttress the fact that fingerprint is a multifactorial trait - that it is genetically determined as well as environmentally influenced.[18–20] Furthermore, as a trait, having three fundamental types (A, L, and W) with several variations, the way offspring will inherit the pattern is not expected to be simple co-dominance as observed in the ABO blood group. This assertion is in line with the report of Hartl and Jones,[31] with the argument that multifactorial traits cannot be studied by means of the simple dominance-recessive pattern because the effects of the segregation of alleles of one gene may be concealed by effects of other genes, and environmental effects may cause identical genotypes to have different phenotypes.

The findings in this study suggest that fingerprint is a tri-allelic non-codominant trait, with a complex phenotypic expression as observed in reduced penetrance. Reduced penetrance exists probably as a result of discrepancies in allelic expression, copy number variation (CNV), or additional genetic variants with modulating influence.[32] Traits that express reduced penetrance follow an autosomal dominant mode of inheritance; although it is also reported to exist in autosomal recessive traits.[33] This is not surprising as studies have suggested that the loop prints have two variants; ulnar and radial forms.[18,25,34] These forms could be a result of mutation of the loop pattern which produced different phenotypic outcomes, which to a large extent depends on

the effect of the allele present.[32] Grundy et al.,[35] Rossetti et al.,[36] Vujic et al.,[37] and Schaaf et al.[38] explained that in certain conditions with an autosomal dominant inheritance, two non-penetrant alleles may express recessivity while copying the normal dominant form of the trait. This study observed that when the parents' pattern had arch (A) and whorl (W) in combination with the loop (L), the offspring almost always expressed L, which happened to be the predominant trait in the studied population. These findings highlight the possibility that the offspring pattern is to a large extent determined by the parental combinations.

Conclusion

The findings of this study reinforce the argument that fingerprints are more genetically determined than environmentally influenced, and that the print patterns are truly passed from parents to offspring. However, the pattern in which it is inherited is rather more complex than the simple Mendelian or co-dominant pattern.

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ORCID ID:
E. O. Aigbogun Jr 0000-0001-8230-2771;
C. P. Ibeachu 0000-0001-9191-9650;
A. M. Lemuel 0000-0002-6998-1439

Correspondence to: Eric O. Aigbogun Jr, PhD
Department of Anatomy, Kampala International University, Western Campus, Uganda
Phone: +256 781 691 191
e-mail: eric.aigbogun@kiu.ac.ug

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Contribution of 3D modeling to anatomy education: a pilot study

Hale Öktem[1], Tuğçe Şençelikel[2], Ece Akçiçek[3], A. Sena Koçyiğit[3], U. Sena Penekli[3], Sezin Sungur[3], Beste Tanrıyakul[3], Başak Naz Ulusoy[3]

[1]*Department of Anatomy, School of Medicine, Başkent University, Ankara, Turkey*
[2]*Department of Biostatistics, School of Medicine, Başkent University, Ankara, Turkey*
[3]*Term III Student, School of Medicine, Başkent University, Ankara, Turkey*

Abstract

Objectives: Traditional anatomy education involves theoretical lectures and practical applications, including examination of cadavers and models. In recent years, new technologies in biomedical fields have included three-dimensional (3D) modeling techniques that enable rapid creation of a 3D computer version of physical models. Such 3D modeling can be used as an active educational tool that enables students to better understand organs and how these organs are positioned relative to one another in anatomy education. The aim of this study was to analyze how the active role and involvement of students in 3D modeling contributes to anatomy education and 3D thinking.

Methods: In this study, 29 Term II students studying in the Başkent University School of Medicine were enrolled with 3D modeling training based on an anonymized CT sample. In addition to defining anatomic structures observed in the sections, 3D images of the common carotid artery, thyroid gland and trachea were obtained using the TT3D-BMMP software, and the position of these structures relative to one another was evaluated. The results of the anatomy quizzes given before and after the 3D modeling training were statistically evaluated.

Results: A statistically significant difference was found between the results of the quizzes administered before and after the training ($p<0.001$). However, no statistically significant difference was found between male and female students in terms of the quiz results before training, while a significant difference was found in the quiz results after training.

Conclusion: We believe that sectional and radiological identification and recognition of anatomical structures by the students through 3D modeling will facilitate their anatomy education and be beneficial in terms of clinical practices in the future.

Keywords: 3D modeling; anatomy; education

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Introduction

As the oldest field of medicine, anatomy examines the normal shape and structure of the body, the organs that form the body, and the structural and functional relationships between these organs. The primary educational tools used in anatomy education include theoretical books, atlases, plastinated or embalmed cadavers, and digital pictures.[1–5]

Spatial ability is important in learning anatomy. Understanding the spatial and visual relationships of anatomical structures with one another forms the basis of the anatomy training.[6] Furthermore, modern technology offers various solutions in at least acquiring certain types of resources. Among the new technologies that have been introduced in the recent years into the biomedical fields for research, practice and education purposes are the fast prototyping techniques used in three dimensional (3D) printing.[7] With using 3D software, students can visualize visceral organs and determine variations of these organs.[8,9]

This study was an oral presentation at the XXI Students Symposium of Study Modules, May 22–24, 2019, Ankara, Turkey.

Moreover, in certain faculties of medicine, reaching the resources used in anatomy education can be difficult not only due to a lack of financial resources, but also for ethical, legally and cultural reasons. It is considered that the new opportunities provided by modern technology can create a path for overcoming these difficulties.[7]

Anatomical models are important during academic education, and are also used today in clinic practice as well.[10] With the use of 3D modeling technology in clinics, it becomes possible to perform modeling specifically for a single patient, and to intervene on the patient in the most suitable manner by developing the necessary strategies for surgery.[11]

A 3D modeling can quickly create a 3D computer version of a physical model. In the recent years, 3D modeling applications have started to be used in medicine, medical education, diagnosis, surgery planning and bone reconstructions.[12]

Moreover, 3D anatomy software is beneficial for the students' self-learning. This software is also relevant for the courses on cadaver dissection, which are provided under the guidance of instructors. The development of a computer-based anatomy education supports students in adapting and implementing their anatomy knowledge in real life.[13] The 3D modeling and the two-dimensional radiological imaging methods (such as cross-sectional anatomy, MR and CT) that students practice during their basic medical education allow them to gain prior experience in clinical applications.

The objective of this study was to evaluate the contribution of 3D modeling on the active role and involvement of students in anatomy education and on their ability to imagine in three dimensions. Furthermore, in the light of the results, it can give an idea about whether computer based education system should be included in medical curriculum.

In this study, 3D modeling of thyroid gland was performed. The thyroid gland is the largest endocrine gland located in the anterior part of the neck, below and lateral to the thyroid cartilage, consisting of an isthmus with two lateral lobes on the right and left. The isthmus neighbors the second and third tracheal rings on their anterior side, while the sternohyoid, sternothyroid and omohyoid muscles are located in front of the isthmus. The thyroid gland is supplied by superior and inferior thyroid arteries. Recurrent laryngeal nerves pass under the medial surface of the lateral lobes.[14] The anatomical neighborhood of the gland to the inferior thyroid artery and laryngeal nerve is important for complications that may occur during thyroid surgery.[15,16]

Materials and Methods

Our study was conducted with a total of 29 Term II students, including 17 women and 12 men from Başkent University School of Medicine. All of the students were given an anatomy quiz (the first quiz) 15 days after taking the theoretical anatomy lecture of endocrine organs. Then 29 students were trained with 3D modeling using the TT3D-BMMP method, and asked to perform a 3D modeling of the thyroid gland and the neighboring trachea and common carotid artery. They were not informed about a second quiz.

An anatomy quiz (the second quiz) that included the same questions was administered again 30 days after the modeling training was performed and the modeling activities were carried out. The anatomy quiz consisted of ten questions with ten slides that contained two dimensional atlas pictures, atlases, and cadaver and radiologic sections. In each slide, a question was asked about a structure. The post-exam assessment was performed by giving one point for each question. The scores of the exams prior to and after the training (the first and second quizzes) were statistically evaluated.

TT3D-BMMP software was used for the 3D modeling training. This software was developed by Dr. Erhan Kızıltan from Department of Biophysics in Başkent University School of Medicine. The students first performed the manual segmentation of the thyroid gland, common carotid artery and trachea from 60 sections of 1.5 mm thickness found in the CT scan of an anonymous patient (**Figures 1–3**).

Before and during the modeling training, standard information was given to the students regarding the structures observed in the sections. The structures segmented by the TT3D-BMMP software were distinguished by the students. A 3D mesh-structure (mesh) was formed, and then visualized with the GMESH software. The post-processing applications which were performed with this software was freely and easily available. The relation between the anatomical structures were also evaluated in three dimensions with the post-processing applications and compared in terms of appearance and size with ideal atlas images.

Descriptive statistics in the study were given as mean ± standard deviations. The difference between the exam results before and after the training was analyzed using the paired sample t test. By separately evaluating the exam results before and after the training, the difference between the gender groups was analyzed using the Mann-Whitney U test. In the analysis, the type I error probabil-

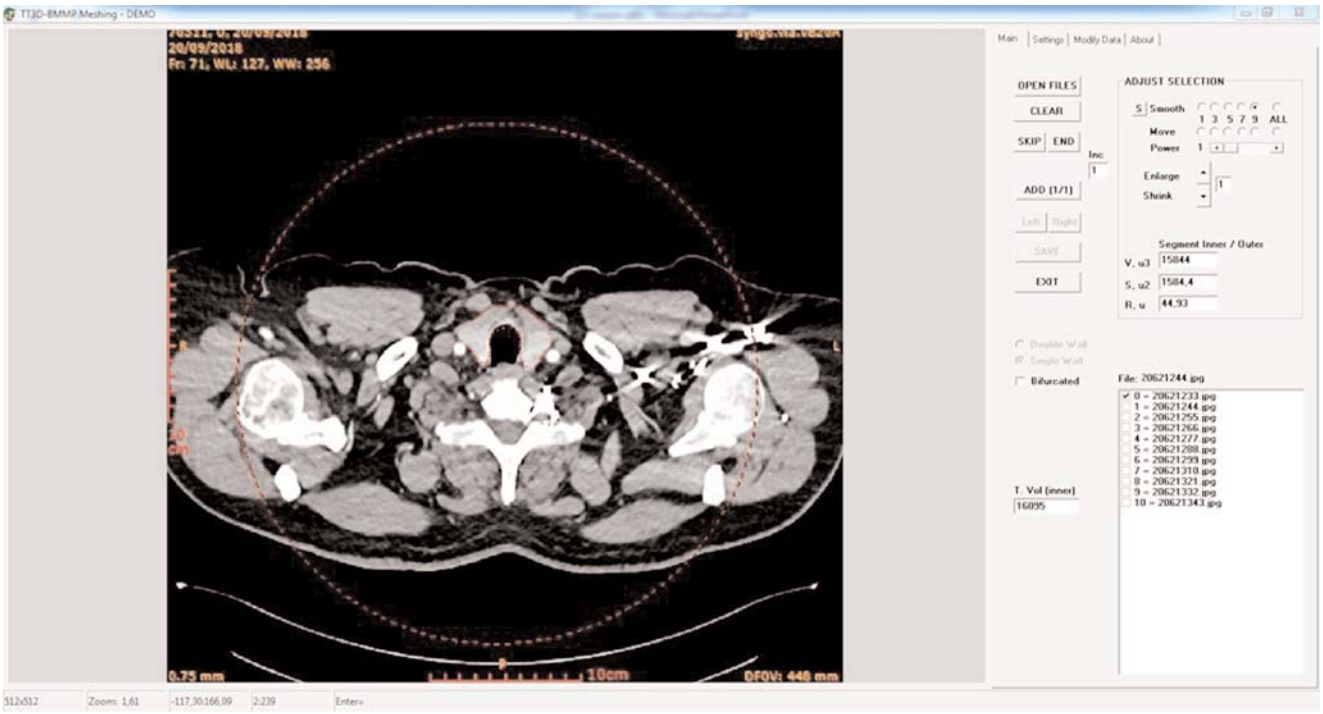

Figure 1. Segmentation of the thyroid gland.

ity was determined as 0.05. All analyses were performed using IBM SPSS Statistics for Windows (Version 25, Armonk, NY, USA). This study was approved by the Başkent University Medical and Health Sciences Research Committee (Project number: KA19/72) and supported by the Başkent University Research Fund.

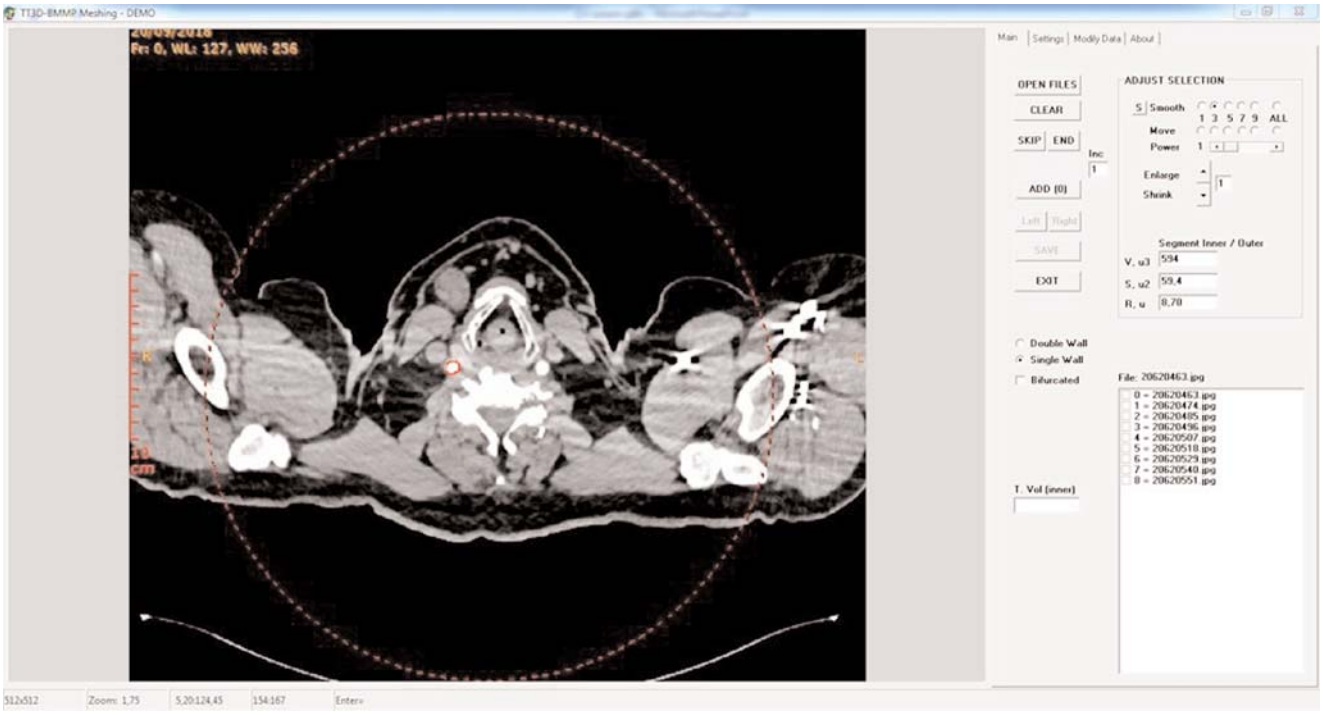

Figure 2. Segmentation of the common carotid artery.

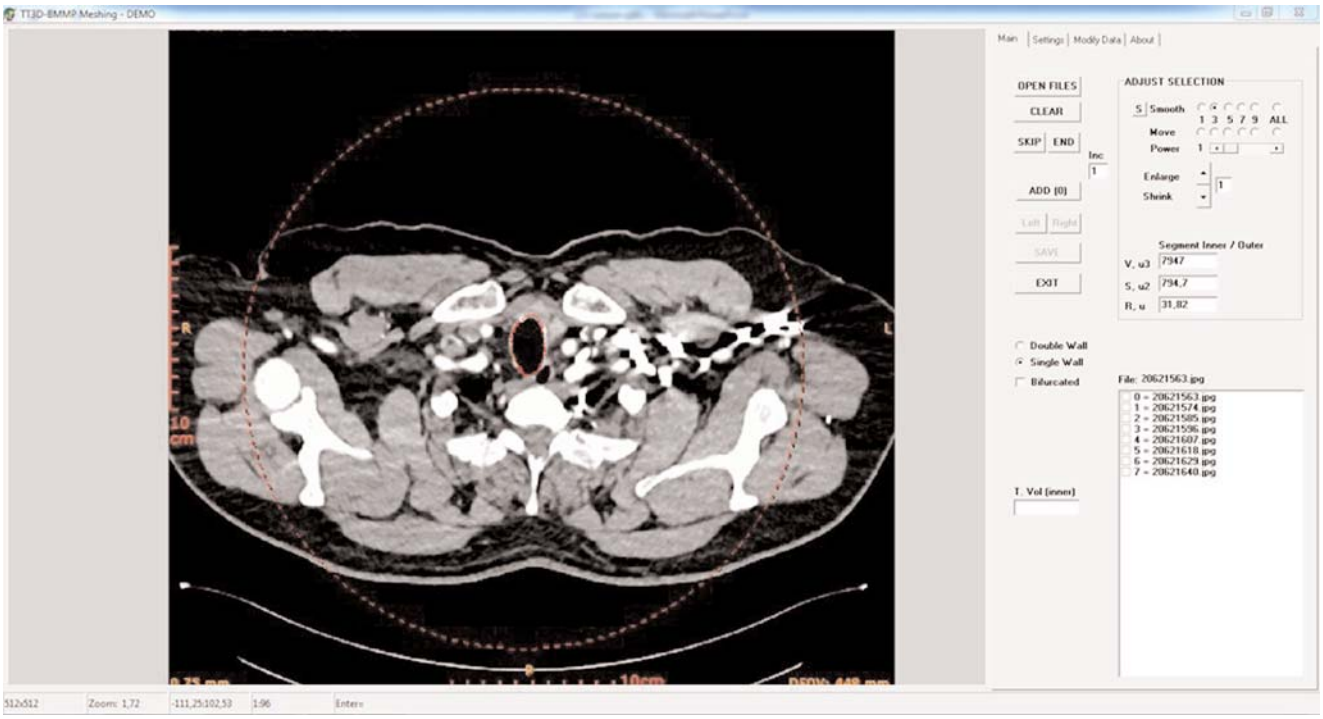

Figure 3. Segmentation of the trachea.

Results

Segmentations of the thyroid gland, trachea and common carotid artery were performed by the students using the TT3D-BMMP software, and mesh models were also prepared. One physical model was produced as a sample (**Figures 4** and **5**).

The models were visually compared with radiography images and ideal atlas images in terms of appearance and scale. The anatomy quizzes given before and after the 3D modeling training were evaluated based on ten points, with each question having a value of one point. Descriptive statistics of the quizzes given before (first)

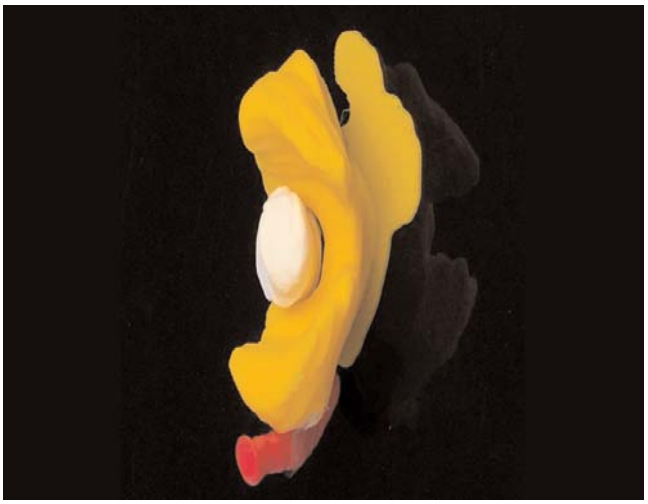

Figure 4. Superior view of 3D model of thyroid gland, common carotid artery and trachea. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

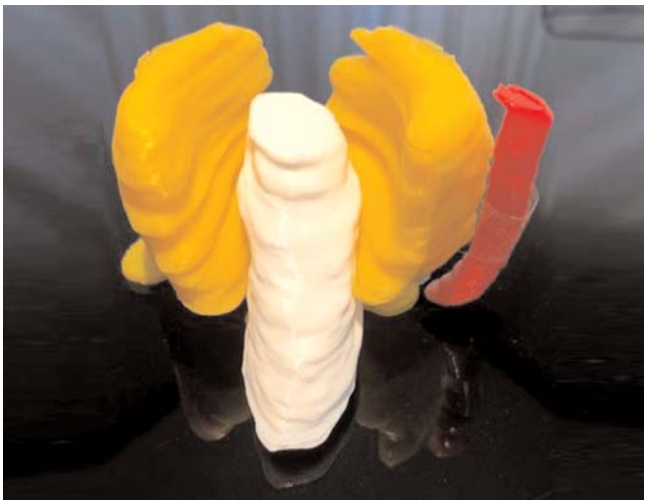

Figure 5. Posteror view of 3D model of thyroid gland, common carotid artery and trachea. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Table 1
Descriptive statistics of quiz given before and after the 3D modeling training using paired sample t-test.

Anatomy quiz	Mean±SD	p
First quiz	5.14±1.66	<0.001
Second quiz	7.10±1.37	

and after (second) the 3D modeling training are shown in **Table 1**.

A statistically significant difference was found between the first quiz given before the 3D modeling training and the second quiz given after the training (p<0.001). While the average score in the exam before the training was approximately 5 points, the average exam score increased to approximately 7 points after the training.

When the exam results were evaluated between the gender groups, no statistically significant difference was found between male and female students in terms of the first quiz results (p=0.873), while a significant difference was found in terms of the second quiz results (p=0.007) (**Table 2**).

Discussion

The results of this study showed that 3D modeling can be an effective method in anatomy education by allowing students to recognize structures in repeating segments and form 3D structures. Models printed with 3D modeling can also be used as materials in anatomy education. These models are also important in that they are individualized training materials and show variations.

Traditional learning model can be summarized as a 2D → 3D → 2D model. Information learned in such a manner makes it difficult to remember 3D structures correctly, and may even cause structures to be learned erroneously and deficiently. As was the case in this study, the 3D structures formed from consecutively repeating 2D sections through the integration of 3D modeling into 2D education has allowed for a more accurate and lasting learning.[17]

Table 2
Evaluation of first and second quiz results among genders using Mann-Whitney U test.

	First quiz median (min–max)	Second quiz median (min–max)	p
Women (n=17)	5 (1–8)	7 (4–9)	0.873
Men (n=12)	5.5 (2–7)	8 (7–9)	**0.007**

In a study by Vorstenbosch et al.[6] on spatial intelligence, students with high mental rotation test scores were also found to be more successful in the anatomy exam. Although men scored higher than women in both mental rotation tests, no significant gender-related increase was observed between the two tests. Similarly in this study, while the increase in the scores for men in the second exam after receiving the training was statistically significant (p=0.008), the increase in the score between the two exams was not found to be statistically significant for women (p=0.879).

Jamil et al.[18] found that the scores of men were higher than women in both tests, and a significant increase was identified in the scores of both women and men. Although this study's objective was not to evaluate the difference between genders, it can be stated based on the obtained data that a statistically significant difference is present between the scores obtained in the two tests by male students.

Certain studies in the literature have aimed to provide training through a 3D model. In this study, our aim was to have the students learn anatomy by making 3D modeling from 2D sections. For example, in a previous study conducted on a 3D generated model, a comparison was made between groups that received traditional 2D education and 3D model education, and no difference was found between the two groups in terms of contribution to anatomy education.[19]

In another study by Lim et al.[20] on 3D models, the cadaver samples group, the 3D models group and a group that combined the two were compared. While a significant improvement was observed in the results of the 3D model group no significant difference was observed in the other two groups. The use of 3D models instead of cadaver models does not create a disadvantage, and the results even demonstrate that the use of 3D model is more effective in anatomy education.

The development of spatial intelligence contributes to anatomy education, and anatomy education similarly contributes to the development of spatial intelligence in students. This mutual interaction positively affects the visual approach of the students towards their anatomy knowledge, making it easier for them to learn anatomy.

According to a study by Jamil et al., 97% of students found the use of 3D modeling software in education more effective as compared to plastic models.[18] The use of 3D modeling in medical education will ensure greater visualization of dynamic processes in the mind, and allow for more effective use in both diagnosis and treatment in future.[21]

The low number of participants can be considered as a limiting factor of the present study. Since participation to the study was on a voluntary basis, the intense course schedule of medical students limited their participation in the study. The inability to distinguish nerves, certain small veins and certain muscles from soft tissues in every section when using different radiologic methods constitutes one of the difficulties of 3D modeling.[19] This study represents a preliminary study; further studies are required for revealing its contribution to life-long learning.

Conclusion

By using such a 3D modeling program as a part of active education, students will improve themselves in evaluating the sectional images 3D manner. Such a program will make the students familiar to the localizations of different anatomical structures in the human body and their relations with each other. With the addition of 3D education into the curriculum, our aim was to increase the success of students in the anatomy class.

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ORCID ID:
H. Öktem 0000-0002-2624-122X; T. Şençelikel 0000-0003-0364-0401; E. Akçiçek 0000-0003-0592-351X; A. S. Koçyiğit 0000-0002-6481-9168; U. S. Penekli 0000-0003-1516-1707; S. Sungur 0000-0003-3201-4602; B. Tanrıyakul 0000-0002-0335-1522; B. N. Ulusoy 0000-0002-8351-0916

Correspondence to: Hale Öktem, MD
Department of Anatomy, School of Medicine, Başkent University, Ankara, Turkey
Phone: +90 312 246 66 66 / 1526
e-mail: haleoktem@gmail.com

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Anatomy education in Ethiopia - the effect of school background on medical school performance

Abebe Ayalew Bekel, Dawit Habte Woldeyes, Yibeltal Wubale Adamu, Mengstu Desalegn Kiros, Shibabaw Tedila Truneh, Belta Asnakew Abegaz

Department of Human Anatomy, College of Medicine and Health Sciences, Bahir Dar University, Bahir Dar, Ethiopia

Abstract

Objectives: In Ethiopia, western modern education has been introduced in 1908, though there has been traditional education starting from the entrance of Christianity in Ethiopia in the sixth century. Currently, there are thousands of government and private schools in the country. The objective of this study is to identify who scores well in anatomy in the university; students coming from government or private schools?

Methods: A cross-sectional study design was used to assess the effect of high school background on medical students' performance in anatomy among 120 randomly selected students at Bahir Dar University College of Medicine and Health Sciences.

Results: Anatomy is given for medical students as separate course in regional approach for ten months after they complete premed courses as five hours lecture and one hour practical session per week. Students than take an exam with theoretical and practical parts, after completion of each region. Out of 120 randomly selected students about 64% joined the university from government schools and the rest were from private schools. From the government school group, only 17% of the students scored low. However, out of the total private school students 40% were low scorers. There was a statistically significant correlation between school background and medical student performance in anatomy (p=0.007). The odds of private school students performance in anatomy was 3.22 times lower than those of government school students (p=0.007)

Conclusion: Students graduated from government high schools perform better in academics than students graduated from private schools.

Keywords: government school; performance; private school

Anatomy 2019;13(2):122–125

Introduction

In Ethiopia, western modern education has been introduced in 1908, though there is traditional education starting from the entrance of Christianity in Ethiopia in the sixth century. Currently, there are thousands of government and private schools in the country. Different types of disciplines are taught in various universities with an aim to produce professional clinicians and teachers for medical and allied disciplines.[1] These universities admit their students from both private and government schools that scored the cut point result for admission to higher education. Most of students with the highest score join the medical education as Ethiopian ministry of education announces every year.

Medical training at the Bahir Dar University, College of Medicine and Health Sciences is currently a six years program which is divided into preclinical stage and clinical stage. The preclinical stage encompasses pre-medicine, pre-clinical I and pre-clinical II. The clinical stage is divided into clinical I, clinical II and final year (internship) training. The actual medical training begins in the preclinical departments where the students study the basic medical science subjects, including anatomy, embryology, histology, biochemistry and physiology.[2,3] Anatomy is a very important but difficult subject in medical science. The study of anatomy is one of the most relevant aspects of the pre-clinical training. A sound knowledge in the subject is essential if the medical practitioner

Table 1
Cross-tabulation of school background and students performance.

School type	High performance	Low performance	Total	p-value
Government	64	13	77	
Private	26	17	43	0.007
Total	90	30	120	

is going to accurately define and successfully treat the patient.[4]

During these stages of study students fail more in anatomy than in histology, embryology, biochemistry and physiology, knowing predictors of academic failure and success is important for medical schools that are trying to ensure high completion rates and develop support mechanisms for students with inadequate performance.[5] A recent study showed that those who perform poorly in the early years of medical school, for whatever reason, might be at an increased risk for subsequent professional misconduct.[6]

Despite a multitude of social, academic, and emotional stressors, most students successfully cope with a complex new life role and achieve academic success. Other students are less able to successfully manage this transition and, sooner or later, decide to withdraw themselves, or face dismissal by the medical school.[7]

In Ethiopia, the effect of student's school background on medical students' performance in Anatomy has not been assessed yet. Hence, the objective of this study is to identify who scores well in anatomy; students coming from government or private schools? Accordingly, the result of this particular research will help policy makers to give possible suggestions and decisions to the concerned bodies.

Materials and Methods

A cross sectional study design was used to assess the effect of student's school background on medical students' performance in Anatomy at Bahir Dar University College of Medicine and Health Sciences, Bahir Dar, Ethiopia. To carry out this study 120 randomly selected students were used, who join medical school for the first time after completion of 12th grade.

After informed verbal consent was taken from participants, data was collected using a structured questionnaire. The data obtained were checked for clarity and consistency before analysis, IBM SPSS Statistics for Windows (Version 22.0, Armonk, NY, USA) was used for statistical analyses and values of $p<0.05$ were considered statistically significant. Descriptive statistical analysis was performed. Logistic regression was used to assess the correlation between student's school background and medical students' performance in anatomy.

Results

A total of 120 students, in the age range of 19-21 years, were randomly selected to assess the effect of student's school background on medical students' performance in anatomy at the Bahir Dar University College of Medicine and Health Sciences. Out of the total study subjects, 81 (67.5%) were males and 39 (32.5%) were females. From the randomly selected study participants,

Table 2
SPSS output of logistic regression showing the strength of correlation between school type and performance of students.

						95% CI for Exp (B)	
Variables	B	SE	Wald	Significance	Exp (B)	Lower	Upper
School type	1.169	.436	7.199	.007	3.219	1.37	7.561
Constant	-1.594	.304	27.452	.000	.203		

B: unstandardized beta; **CI:** confidence interval; **SE:** standard error.

77 (64.2%) of them joined the university from government schools and 43 (35.8%) from private schools; 90 (75%) were high scorers, whereas 30 (25%) of them were low scorers. Of the total of government school students 64 (83%) scored high and 13 (17%) scored low. 26 (60%) of the private school students were high scorers whereas the remaining 17 (40%) were low scorers. The odds of private school students performance in anatomy was 3.22 times lower than those of government school students (p=0.007) (**Tables 1** and **2**).

Discussion

Anatomy is given for medical students as separate course in regional approach in parallel with histology, embryology, biochemistry and physiology for ten months after they complete pre-med courses. During this period, the students study anatomy with five hours lecture and one hour practical session per week and take an exam after the completion of each region. The exam has both theoretical and practical parts. The theoretical part usually has multiple choices, true/false, matching; fill the blank spaces, and easy questions. The practical part is carried out on cadavers to assess student's skill of dissection. Finally, at the end of the 10th month, they take the final exam which has written and oral parts. The written exam has multiple choice questions from all regions. The oral exam is on models and cadavers and is done by external examiners who come from other universities. After all these activities, students' performance in anatomy is evaluated using the summation of these exams. If student scores more than or equal to 70, it is considered as high score and less than 70 is low score in the context of our university.

The study sought to establish the relationship between student's school background and medical students' performance in anatomy. Private school students have higher test scores than government school students in higher education entrance exam. However, the opposite is true in the university. Most of high scorers are students from government schools. This is supported by our current study which depicted that from the total of government school students only 17% of them are low scorers. Conversely, from the total of private school students, 40% of them are low scorers. Hence, there is statistically significant correlation between student's school background and medical students' performance in anatomy (p=0.007) (**Tables 1** and **2**). The odds of private school students' performance in anatomy was 3.22 times lower than that of government school students (p=0.007) (**Table 2**). This is supported by a study done in Australia which describes that students who graduated from private schools do less well during their first year at university than other students.[7] This variation can be due to the fact that private schools have better infrastructure required for the physical and mental development of the child. They can help with the required facilities for the students to learn their lessons in a better way.[8] This attributes also seen in a study conducted in India and Spain.[9,10]

Having these advantages over government schools, private school students score more than government school students in higher education entrance exam. However, as these students join the university, they have equal opportunities in resource allocation with the government school students. Consequently, most students from the government schools score more than those from the private schools in the university as this study shows. The ministry of education of Ethiopia has to use this study as input and equip government schools with materials and experienced teachers to enable more students to join the university from government schools.

Conclusion

The study investigated the relationship between students' school background and medical students' performance in anatomy. The findings of this study show that students who graduated their high school from government schools perform better in academics than students graduated from private schools.

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ORCID ID:
A. A. Bekel 0000-0002-5853-2953; D. H. Woldeyes 0000-0002-4922-9928; Y. W. Adamu 0000-0002-9307-4548; M. D. Kiros 0000-0002-7120-4671; S. T. Truneh 0000-0003-0849-0772; B. A. Abegaz 0000-0002-6345-2018

Correspondence to: Abebe Ayalew Bekel, MSc
Department of Human Anatomy, College of Medicine and Health Sciences, Bahir Dar University, P. O. Box: 79, Bahir Dar, Ethiopia
Phone: +251 918 040 350
e-mail: abe3a16b@gmail.com

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Mystery of Anatomy: Robert Knox

Şenay Gül[1], **Serap Şahinoğlu**[2]

[1]*Faculty of Nursing, Hacettepe University, Ankara, Turkey*
[2]*Department of Medical History and Ethics, School of Medicine, Ankara University Ankara, Turkey*

Abstract

Anatomy has been an integral part of medical education for thousands of years. From the past to the present, the corpses on the dissection tables have often been the bodies of people dismissed by the community, such as dead prisoners or the homeless. While dissection studies continued in a similar manner until the early nineteenth century, the works of Robert Knox, an anatomist from Edinburgh, played an important role in the emergence of the Anatomy Act, one of the most striking developments in the field of anatomy. Robert Knox was a scientist not only interested in anatomy but also art. His contributions to anatomy and his work in the field of art failed to attract sufficient and necessary attention due to murders of innocent people committed by William Hare and William Burke. They murdered these people in order to ensure the supply of cadavers to anatomists and physicians and compromised Robert Knox as a knowing participant. This study aims to bring Robert Knox's contributions to anatomy and art to light by considering the period in which he lived, the Industrial Revolution.

Keywords: anatomy; anatomy act; art; dissection; Robert Knox

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Introduction

Especially after the Renaissance, the human body sparked the curiosity of physicians and artists who went to great lengths to explore it. All these efforts accelerated anatomical studies, which have been essential for the development of medicine since that time. Intellectuals of the period turned away from scholastic philosophy and began to question the conviction of the Church that the human body was sacred. Human dissection played a key role in the development of medicine and anatomy. The Industrial Revolution in Britain, which took place in the eighteenth and nineteenth centuries, deeply influenced modern medicine with increasingly growing interest in anatomy and dissection. However, the difficulty in obtaining cadavers led to the seeking of alternative solutions. Initially, the bodies of executed prisoners were being dissected, but this was not enough. Therefore, physicians and researchers turned to new solutions, such as grave robbing, and the use of corpses for their anatomical studies.[1–3]

This study will discuss Robert Knox's professional life, the difficulties that he had in obtaining cadavers, the relationship between anatomy and art, and the impact of the Industrial Revolution on medical developments. Robert Knox worked as a physician and anatomy teacher at the University of Edinburgh, School of Medicine. Despite difficulties in supplying cadavers, he managed to work on dissections and exhibit the corpses that he had dissected in order to immortalise them. Undoubtedly, another important aspect of this study is the Anatomy Act of 1832, which removed the legal obstacles to anatomical study and dissection Robert Knox had difficulty to obtain cadavers, and therefore, resorted to what we would now consider illegal ways. One's life is best understood when the period in which one lived is taken into account. The methods used to obtain cadavers at that time are illegal and unethical today; however, this

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study prioritised the historical dimension of the phenomenon in question.

A Brief History of Anatomy and Dissection

Anatomy is the first branch of science that has been evolving from ancient times and taught to medical science.[1] Our curiosity about the human body dates back to ancient times. The dissection of human bodies is as old as the direct exploration of human anatomy. However, physicians in Ancient Greece avoided dissecting cadavers because they regarded the human body as sacred and honourable.[2] Dissecting cadavers was a regular practice in Alexandria between the fourth century B.C. and fourth century A.D. However, it was not practiced until the sixteenth century due to the prohibitions of the Catholic Church.[3–5]

Corpses dug up by grave robbers and those of executed prisoners were the only source of bodies for anatomists, from those who performed the early dissections in Alexandria in 300 B.C. to the anatomists of the seventeenth century in Britain.[6] The three most prominent anatomists of the Medical School of Alexandria were Praksagoras, Herophilos and Erasistaratos.[3] Herophilos (335–280 B.C.) was the student of Praksagoras and regarded as the first scientist to dissect the human body.[3,7] Herophilos is considered to be the founder of anatomy, because he dissected human and animal cadavers and contributed significantly to the science of anatomy of that era.[8] Although this environment of freedom enjoyed by Herophilus and Erasistratus did not last long, it was not completely over.[4] For example, Galenus (A.D. 128–200) went to Alexandria for medical education and dissected monkeys and pigs as it was then forbidden to dissect the human body at that time.[3,7] His greatest mistake was that he extrapolated his findings on the anatomy of animals to the human anatomy.[2,7] Galenus refrained from dissecting the human body probably due to the prohibitions of and his close ties with the Church.

The Church's ban on the dissection of human corpses, which was based on its teachings on the sanctity of the human body in the Middle Ages, also caused people to approach dissection with feelings of discomfort and suspicion. Human cadavers were hard to obtain, and therefore, physicians and students had to work on anatomical models and drawings, which were inadequate, however. They needed human cadavers to dissect and study anatomy.[2]

Human dissections started to be carried out towards the end of the Middle Ages in Europe.[4,5] Back then, numerous Arabic medical texts were translated into Latin,[2,5] such as *Kitāb Kāmil al-Şina 'ah al-Tibbiyah (Complete Book of the Medical Art)* - also called *al-Kitāb al-Malikī (Royal Book)* by 'Alī ibn *al-'Abbās al-Majūsī (Haly Abbas)*, *al-Kitāb al-Hāwī fī al-Tibb (Comprehensive Book on Medicine)* by Abū Bakr Muhammad ibn Zakariyyā al-Rāzī (Rasis or Rhazes) and *Kitāb al-Qānūn fī al-Tibb (Canon of Medicine)* by Ibn Sīnā (Avicenna). Those works played a key role in the development of medicine from the end of the eleventh to the beginning of the fifteenth century. The detailed anatomical information in the Great Arabic medical compilations such as Ibn Sīnā's *Kitāb al-Qānūn fī al-Tibb (Canon of Medicine)* and Ibn Rushd (Averroes)'s *Kitāb al-Kulliyāt (The Book of General Principles)* provided new insights and aroused interest in the subject.[2]

At the end of the twelfth century, the educators of the Salerno School of Medicine performed animal dissections in their lectures, yet once a year or less. Frederick II decreed that medical schools be allowed to dissect one human body once every five years. In 1299, Pope Boniface VIII promulgated a bull referred to as *Detestande Feritatis (of Detestable Cruelty)* prohibiting the dissection of the human body for any but a limited number of forensic reasons.[2,3,5]

Some interventions used to be carried out on cadavers for various reasons. For example, dead bodies that were to be brought back to their home countries to be buried used to be embalmed in the middle of the fourteenth century. Cadavers were also dissected to remove internal organs, determine the cause of death, investigate suspicious deaths or epidemics, check for specific signs on the bodies of deceased saints or investigate whether someone died due to witchcraft or natural causes.[2–5]

Mondino de Luzzi (1275–1321) was the first after Herophilos to dissect cadavers to study anatomy.[2–5,9] Henri de Mondeville (1260–1316), who was the surgeon of Philip IV and Louis X of France, states in his book entitled La *Chirurgie* (1312) that one must obtain special permission from the Roman Church to remove the internal organs of cadavers.[5]

Difficulties in dissection practices continued until Andreas Vesalius (1514–1562). Vesalius published his masterpiece *De Humani Corporis Fabrica Libri Septem* (On the Fabric of the Human Body in Seven Books) in 1543 based on his dissection practices.[2,3,5,8] His work on human dissection helped him find errors in anatomy books. He highlighted the significance of observation by

stating, "*If anyone wishes to observe the works of Nature, he should put his trust not in books on anatomy but in his own eyes…*".[3,10,11] Vesalius's work presented his successors with the errors of the Galenus anatomy. He played a key role in the development of the science of anatomy by pointing at the dissection tables.[5,8,9]

Another important point in the development process of anatomy is the spaces where dissection studies are performed. After the sixteenth century, physicians built anatomical theatres not only to perform human dissection for their own research but also to stage public displays. One of those anatomical theatres was a mobile theatre at the University of Montpellier in France. The first stationary theatre was built in 1584 in Padova.[5] In the 1600s, human dissections turned into a form of spectacle, which allowed professors to show their skills. It was, however, more of a spectacle than empirical investigation.[2]

Nevertheless, spectators developed distaste for those public displays because they thought that dissection rendered both the individual and social personality of those who were dissected unrecognisable and stripped them of their right to burial. This negative attitude towards dissection began to change with an increased interest in science in the eighteenth century. In Europe, anatomy progressed, and the decline in capital punishment especially in some countries led to a shortage of cadavers for medical schools.[12]

The Murder Act on the use of bodies of executed prisoners for anatomical studies and research was passed in 1751 in Britain. It had two objectives: (1) to prevent horrific murders and denial of burial to offenders and (2) to create a legal basis to supply corpses for anatomical research.[11] The government also increased the number of criminals to be executed in order to supply human bodies for anatomical research.[13] Despite all these efforts, the number of cadavers supplied to medical schools was insufficient due to the rapid increase in the number of medical and anatomical studies. Some European countries enacted laws that allowed medical students to dissect the bodies of prisoners, mental patients who committed suicide and paupers who died in hospitals.[12] Back then, paupers seeking medical care had to sign a secret contract that stipulated that they pay the physician the "thing" that they owed to the hospital. The "thing" referred to the "body" to be used for medical and scientific research.[1]

However, the situation was a bit different in Britain, where laws on the use of unclaimed bodies were not accepted until the beginning of the nineteenth century.[2] Something had to be done to stop the murders committed by Bishop and Williams in London and by Burke and Hare in Edinburgh to supply cadavers to medical schools.[13,14]

In 1828 in Britain, a government committee, set up under the leadership of the neuroanatomist Herbert Mayor, reported the problems of anatomists, and the Anatomy Act was adopted in 1832, which decreed that the bodies of unclaimed paupers who had died in elderly care homes and hospitals be given to licensed anatomists for dissection. The "unclaimed" were those whose bodies had not been claimed within forty-eight hours after death. The Act changed the paradigms of cadaver acquisition for anatomical research. While the Law did not allow the use of bodies of executed prisoners for dissection in accordance with human rights and dignity, it made the donation of such cadavers possible.[13,15,16] The Act established the legal basis for the supply of cadavers for anatomical research. The poor began to sell the bodies of their deceased relatives to medical schools. In addition, cadaveric donation ushered a new era in the field of medicine.[6] The Law remained in force until the Human Tissue Act was adopted in 2004.[16]

The legalisation of the use of unclaimed bodies and those of executed prisoners for dissection paved the way for the development of anatomical research in many countries.[17–19] The Anatomy Act was the first regulation passed by the British government on this subject with not only social but also political and economic ramifications. The Act also made it possible for medical education as well as the field of medicine to proceed in a coherent, reproducible and scientific way. The next section will address Robert Knox, both an anatomy teacher and artist, who played a key role in the passing of the Anatomy Act.

The Life and Works of Robert Knox

Robert Knox was born in 1791 in Edinburgh during the Industrial Revolution (**Figure 1a**).[20] His works on dissection made significant contributions to anatomy and the training of numerous medical students. Knox began his medical education at the Edinburgh School of Medicine in 1810 and failed the anatomy class taught by the Professor of Anatomy, Alexander Monro II. To pass anatomy, Knox attended the anatomy class of Dr. John Barclay, who had an international reputation in the field. Knox graduated from the Edinburgh Medical School in 1814 and worked at St. Bartholomew's Hospital in London for one year. He served as an army surgeon in

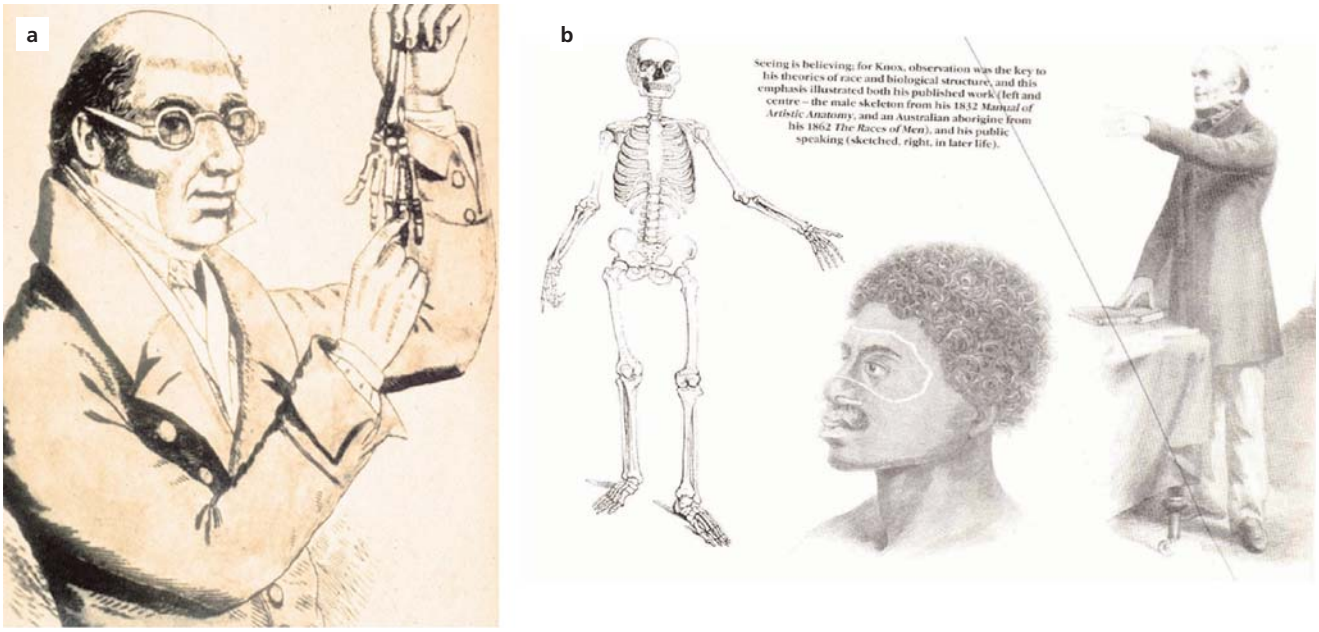

Figure 1. Robert Knox (**a**)[20], some of his illustrations (**b**)[20]. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Brussels, and his first task was to deal with the wounded of the Battle of Waterloo.[21–24]

The Industrial Revolution, which took place in the United Kingdom from around 1760 to 1830 and marked the beginning of modern age, signifies a shift from an agrarian to an industrial economy especially with the invention of the steam engine in 1775 by James Watt.[25,26]

The spirit of scientific research and innovation of the Industrial Revolution prompted scientists to unlock the secrets of the human body, which is the most perfect and complex of all machines. The human body was subject to a level of scrutiny that it had never before experienced, and its secrets began to be disclosed.[27] Numerous contagious diseases were transferred across the oceans due to colonialism and slavery, which gained momentum with the Industrial Revolution.[1] During that period, Knox visited South Africa and conducted an extensive study on the history and anthropology of the Cape of Good Hope. He devoted a large part of his life to study and develop ethnological theories on the anatomical features of African people (**Figure 1b**).[20] After serving as an army officer until 1820, he turned to a different career path and became an educator. In 1821, he began to live in Paris, which was then the center of contemporary anatomical debates, and met Etienne Geoffroy Saint-Hilaire and Georges Cuvier (Georges-Léopold-Chrétien-Frédéric-Dagobert- Baron Cuvier), two giants of comparative anatomy. Knox became familiar not only with the theories of Cuvier and Saint-Hilaire on comparative anatomy but also with the new ideas of racism and colonialism.[23,24]

After Knox returned to Edinburgh in 1822, he started to work in the Chair of Anatomy of the School of Medicine at the University of Edinburgh upon the proposal of Dr. John Barclay. He published his studies on the treatment of necrosis, bone regeneration, pericarditis and tapeworm in the Edinburgh Medical Journal between 1821 and 1823.[21–24]

Knox proposed a plan for a museum of anatomy to exhibit the comparative anatomical samples, which had been collected by Dr. John Barclay for more than twenty years. After the adoption of the plan in 1825, Knox was appointed as the founding executor of the Museum of Comparative Anatomy in 1826 and remained in that post until 1831.[21–24] The same year, following the death of John Barclay, Knox started to teach anatomy and surgery to about 300 students in the Department of Anatomy of the Edinburgh School of Medicine. He also performed a large number of dissections during that period. During the 1827–28 academic year, Knox taught 504 students, including nobles, jurists, artists and writers, in Britain's largest anatomy class.[9]

Knox was Edinburgh's most successful and independent anatomy teacher.[21–22] With his scientific articles published in Lancet and Medical Gazette magazines, he con-

tributed significantly to medicine, anatomy, comparative anatomy and zoology. His work entitled "*Contributions to Anatomy and Physiology*" attracted the attention of many scientists. His lectures on anatomy, physiology and pathology published in the Medical Times were very useful to many medical students. He also published his lecture notes on "Human Anatomy for Artists" inspired by his own experience and Leonardo Da Vinci. Emphasising that zoology should be used for anatomical studies; Knox also gave lectures on ethnology.[22]

In the following years, Knox got involved in a scandal that ruined his life and had to leave Edinburgh.[9] This will be discussed in more detail in the next section. His license to teach anatomy was withdrawn, and he stayed in London until the end of the 1840s, writing more on anatomy. He also started a new career as a wandering lecturer, in which he taught lectures on ethnology and race and published works on anatomy that were useful not only for physicians, but also for artists and zoologists.[23]

He tried to give a new direction to race studies and devoted many years of his life to recording most information on physical and the bone structures and nervous systems of different races and embarked on long journeys for doing so. He was also interested in human history. During his years in Africa, he objectively examined human relations as well as the wild, social and intellectual life using scientific methods. To him, race was everything, and literature, art and civilisation developed around it.[20]

Knox witnessed the kinship of races and the solidarity and ties between peoples. He argued that patriotism, social spirit and the preservation of national life depended on the homogeneity of the race. According to him, racism played a critical role in the rapid rise of Napoleon Bonaparte to power.[22] *The Races of Men* (1850) is regarded as the highlight of Knox's career.[13,20,21,28] Biddiss argues that Knox and Hitler's views of race were different from each other. Knox examined race in a scientific and systematic way to contribute to the knowledge of comparative anatomy. Interestingly, Knox, the founder of scientific racism, was alleged to be an anti-colonialist since he began working in South Africa.[20,28]

Robert Knox's scientific works (1825–1850) contributed to the development of racism in Europe. In general, it does not come as a surprise when someone who is interested in medicine is also interested in race. What is surprising is that race studies did not attract the attention of those who were involved in medicine. Knox's views of racism were rarely addressed or mostly misunderstood by social scientists. Before him, no one established a nexus between race and anatomy. His works made sure that the significance of the nexus between these two notions was recognised by medical students, across the country and abroad.[22]

Knox's career ended as an under-paid anatomist at the Brompton Cancer Hospital in London British authorities barred Knox from employment at Edinburgh University, and he was unable to perform his profession in London until the Medical Act was passed in 1858. He was appointed Honorary Member of the London Society of Ethnology in 1860 and First Member of the first anthropological Society of Paris in 1861. Although he sought an academic position in Britain during that period, it was to no avail.[13,20,21,24,28]

Robert Knox died at his home on December 9, 1862 and was cremated and buried at a funeral attended by his former students on December 29, 1862. Knox's grave was simply forgotten. In 1966, Sir John Bruce and Professor Eric Mekie, two of Knox's successors at the Surgical Clinic of the University of Edinburgh, had his grave cleaned up and had a fine memorial placed upon the site.[13,20]

The Burke and Hare Murders

Robert Knox is known as anatomist who bought the corpses of the victims of murderers William Burke and William Hare from Edinburg.[23] Before the Anatomy Act came into force in 1832, anatomists were only allowed to dissect the cadavers of executed prisoners. In the 1700s, there were few students of anatomy and many criminals sentenced to death. Therefore, medical students and teachers did not lack for cadavers. Along with the softening of laws and development of medical education, the number of cadavers supplied to medical schools became more and more insufficient. Therefore, digging up corpses was a practical solution to the problem.[22,23,28,29]

However, Burke and Hare's method of obtaining cadavers was much more dramatic. They knew of grave robbers and would have robbed graves themselves; however, they found it too hard and dangerous. One day, an old man who had been renting a room from Hare died. The deceased man had no relatives, and Burke and Hare thought that they could sell his corpse to anatomists for a high price. They had only heard of Alexander Monro III (1773–1859). Monro III was not only a physician but also a renowned anatomy teacher who had 40,000 students throughout his life. Hare and Burke went to

Surgeon's square to sell the cadaver to Monro. There, they ran into Knox's students who told them that Dr. Knox would pay more than Dr. Monro would. Therefore, the two men handed over the corpse to the students. If Burke and Hare had not run into Knox's students that evening, it would have been Alexander Monro III that would have been charged with these crimes, and Knox might not have written books on anatomy, anthropology and ethnology. Satisfied with the fortune they had made, Hare and Burke thought about the prospects of the venture and began to kill homeless people. They sold sixteen human cadavers to Knox, who had no idea where they had come from.[2,9,24]

In November 1828, the body of Ms. Docherty was found in Dr. Knox's cellar at Surgeons' square in Edinburgh. Since it was a dissection room, it was not surprising to find a human body there. However, the authorities were suspicious that the cadaver had been brought there by illegal means. Knox had great difficulty obtaining a sufficient number of cadavers for his dissection practices, and therefore he, like his colleagues, did not question where all the bodies were coming from. The forensic investigation into Ms. Docherty's death revealed that the cause of death was strangulation.[14,22,23,28]

This shocking truth brought all of Britain – and of course Knox – into discredit. In hindsight, Knox was not actually responsible for those murders. He was never summoned to court and was never found guilty of any contravention. However, many physicians and the public associated him with those murders.[28] Burke was publicly executed and then dissected by Dr. Monro, and books, wallets and bags were made from his skin and sold on the streets. Hare was released.[30,31]

There is no doubt that all those incidents had a social, legal and ethical dimension. Were the cadavers of paupers and prisoners dissected according to their own wishes, or were they murdered specifically to be dissected? The answers to these and similar questions are probably not positive. This study focused on the historical dimension of the subject matter and excluded the above questions and discussions.

Anatomy and Art

Despite bringing cadavers, dead bodies, and thus death into mind, anatomy is a science that examines the structure and vital functions of normal, healthy and living bodies as well as body parts. Art is a concept and activity that always exists in parallel with life. A human being is at the intersection of art and anatomy. The zeal for the detailed and accurate depiction of human anatomy resulted in a more realistic illustration of the human body.[32]

Anatomy and art actually go together like a horse and carriage. The better we understand the anatomical details of the human body, the more easily and successfully we can assign a meaning to them. Knowing about the proportions of human face, the wrinkles that come with age and gestures and their anatomical details plays a key role in reflecting feelings such as happiness, fear and anxiety expressed mostly by facial gestures.[32]

Renaissance art took on a unique character with the branches of science, especially anatomy and mathematics. Both artists and physicians sought accurate anatomical information. Artists placed a new emphasis on the accurate representation of animals and plants, the scientific use of the perspective and the idea that the human body is beautiful and worthy of contemplation, and therefore, they performed anatomy and dissection studies tolearn about the human body in greater detail.[4]

Leonardo da Vinci (1452–1519) comes to mind when we think about the zeal to illustrate the human body in the most accurate way. His works depicting the human body are based on his anatomical studies. He was a painter, inventor, anatomist, theorist, philosopher, musician and teacher and made significant contributions to art, literature, science and technology. Therefore, he was one of the greatest and most versatile geniuses not only of the Renaissance but also of all time.[5] He ingeniously combined his objective observations of nature with his great love for the reproduction of invisible reality through fine arts and painting. His works have inspired numerous artists for centuries.[33]

The objective of Leonardo da Vinci was to unravel the internal dynamics of all the fields of his interest and to establish a connection among them. His method was to experiment continuously. Da Vinci model was based on the superior composition and interaction between art and science. Studies on the superficial anatomy of the human body led him inevitably to general anatomy, comparative anatomy and physiology. He believed that through dissection and experimentation he could unlock the mystery behind motor movements and even mechanisms that govern life itself. He, therefore, designed models to study the mechanisms of muscles and heart valves. To him, a painter should know and understand the inner structures of the human body. It is stated that he also dissected human bodies to make his drawings.[32]

Scientists had to use drawings when they could not obtain real cadavers for their anatomical studies. Jacopo

Berengario da Carpi's book entitled *Anatomia Carpi* published in 1535 was the first illustrated anatomy book. It contains anatomical illustrations of people in front of a landscape background stripping their skin on the abdomen or chest area with their own hands to show the reader what is inside. It is the first educational tool and work on artistic anatomy. After Berengario, a permanent cooperation was established between artists and anatomists. The former brought an aesthetic dimension to anatomy.[5]

The Renaissance lifted the taboos on the human body, turning it into something that could be explored. During that era, such artists as Leonardo da Vinci, Michelangelo Buonarroti, Raffaello Sanzio da Urbino, and Albrecht Dürer expected anatomists to guide them, and they even dissected cadavers themselves to satisfy their curiosity.[9] Until the beginning of the nineteenth century, painters mostly studied the human body, visited anatomical theatres and read the physicians' books and met them in person.[1]

In conclusion, anatomy is not only a part of medicine but also closely related to art. The illustration of the human body had become important after the sixteenth century. The spirit of the age prompted anatomists to portray the human body and artists to study anatomy. Anatomists not only dissected cadavers but also used their own drawings to teach anatomy. Even today, artists have to learn anatomy. In addition to his studies on anatomy, Robert Knox illustrated the human body and used his drawings in his lectures on anatomy.

Robert Knox's Anatomical and Artistic Works

Artists are influenced by the art movements of the period in which they live. At the end of the eighteenth and the beginning of the nineteenth century, artists adapted to the spirit of the Enlightenment which prioritised reason to comprehend the world and began to imagine more rational and vivid works inspired by antiquity. This new school of thought is referred to as Neoclassicism, also known as 'noble simplicity andcalm grandeur'. The ancient Greek and Roman civilisations became the inspirational sources of artists, and Rome became the centre of Neoclassicism and a meeting point for them. The Enlightenment, the Industrial Revolution, and the collapse of the absolutist feudal system upset the perceptions of God, humanity and the world. Christianity began to lose its grip on society. Of course, this revolution in value judgments resonated with art as well. Religious motifs, which were dominant in the art of painting until the Baroque period, were almost lost. Mythology was replaced by history, and the place of art in society was redefined. Art became a public phenomenon especially after the French Revolution. Artists took on a new role with the opening of the traditional art market to the public. They began to choose their own subject matters and approach them from their own perspective.[34] Before the Industrial Revolution, art and artists were under the strict rules, and therefore, not original and free. The Industrial Revolution destroyed the rigid rules and taboos.[35]

Having also been influenced by the art movements of the era, Robert Knox and other anatomists used more independent and realistic anatomical illustrations, which became a necessity for lectures on anatomy. Knox's views of art are compatible with Neoclassicism. In his book entitled *A Manual of Artistic Anatomy: For the Use of Sculptors, Painters and Amateurs*, Robert Knox stressed that even emotions should be illustrated in a specific way.[23,36]

For Knox, the object of art is to represent 'nature in her finest forms, in her highest manifestations of matter', and to capture perfection and beauty.[22,28] Knox suggested to his students that they study Ancient Greek sculpture and never draw a naked woman without a model of Venus at hand. Knox thought that art and science were in harmony for their broadest purposes, and therefore, encouraged young artists to study anatomy as part of their education. But he also warned: "*Artists must know the human body, but only to the extent that they have an understanding of superficial anatomy and the deeper structures that shape it. Too great a focus on anatomy could divert artists from their higher aims*".[22,23,28] The young artists of the time attended lectures on anatomy at the Royal Academy of Fine Arts and followed courses on anatomy in medical schools to get first-hand knowledge of the human body through dissection.[28]

Knox strove to portray reality exactly as it was until the first photograph was taken in 1826 by Joseph Niepce. His drawings have left their mark on this century. Knox also drew some of the cadavers brought to him for dissection. The most remarkable one was that of Mary Paterson. Knox met Mary Paterson when her body was brought into his dissection room. Knox was especially interested in aesthetic anthropometry and its relationship with the fine arts. That is why he said, upon seeing Mary Paterson's body in the anatomy hall, which she had the most perfect body proportions he had ever seen.[22,28]

He drew Mary Paterson's perfect body so that future students and generations could also see it. Mary

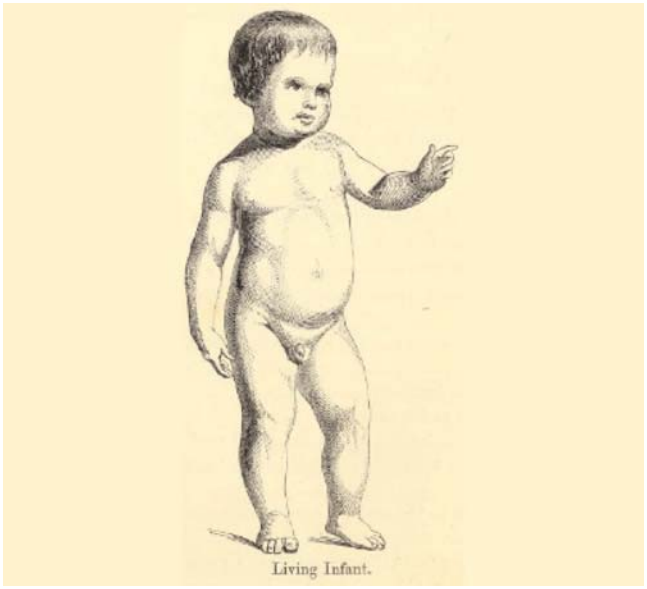

Figure 2. Living infant's body.[36]

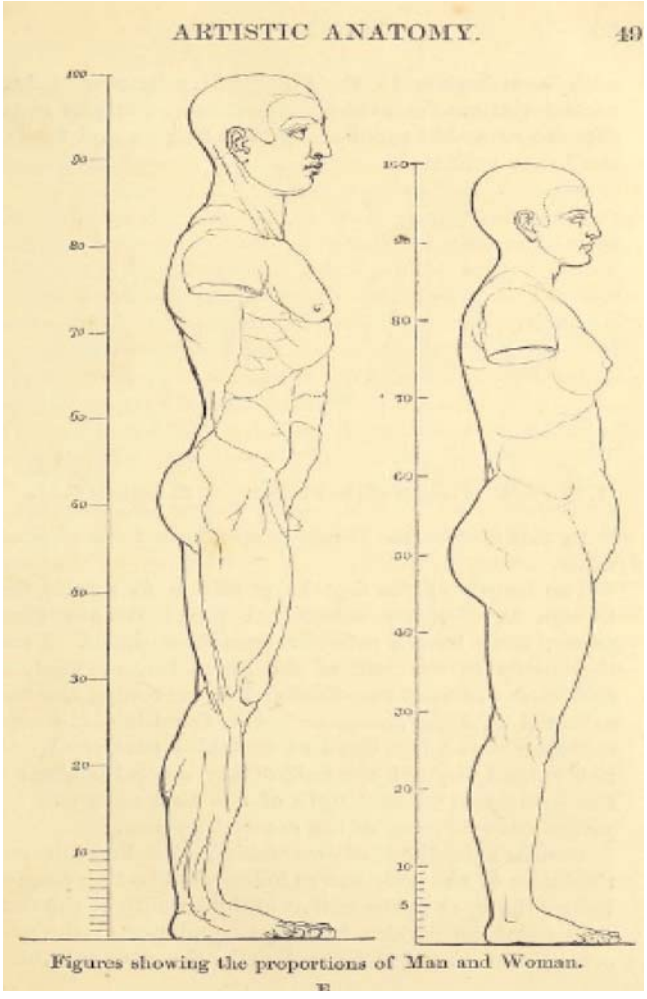

Figure 3. Male and female body proportions.[36]

Paterson's body had become an aesthetic object for artists and intellectuals and was on display until it began to decay. It was then embalmed in a tank full of alcohol and examined in depth after being exhibited for three more months.[22,28]

Knox often made references to Leonardo da Vinci to support his own ideas and argued that da Vinci never mistook the dead for the living. He always drew the dead as the dead and the living as the living.[28] To Knox, old people and infants lacked ideal human forms because the former have wrinkled skin while the latter are underdeveloped (**Figure 2**).[36] Therefore, according to him, women between the ages of seventeen and twenty-seven possessed ideal bodies. To him, beauty was based on proportions and the outer part of the body, which were at their best during the first period of adulthood (**Figure 3**)[36], and the interior of the human body was unaesthetic. Knox stated that the exterior of the human body belonged to art and the internal (organs, etc.) belonged to science.[22,23,28]

Knox compiled his views of artistic issues in his books entitled *A Manual of Artistic Anatomy: For the Use of Sculptors, Painters and Amateurs and Great Artists and Great Anatomists: A Biographical and Philosophical Study* (**Figure 4a** and **b**).[36,37] In the introduction of the latter he told his readers: 'The true relation of anatomy to science, philosophy, and art, has not yet received from thinking men the attention it merits'. In order to overcome this deficiency, Knox wrote this book by taking into account the opinions of Leonardo Da Vinci, Michelangelo, Raphael, Cuvier and Saint Hilaire. However, after the Burke and Hare incident, Knox lost his position in the official history of anatomy, and he was erased from the history of art in Britain in the nineteenth century.[22,28]

Discussion

Science witnessed significant progress especially in the nineteenth century, and scientific advances gained a new impetus with advances in anatomy. We cannot deny the fact that the Anatomy Act played a key role in this process.

Before the Hare and Burke murders, Knox was one of Britain's most famous, unique and influential anatomists. However, Knox's involvement with Burke and Hare left him with financial difficulties and a bad reputation for the rest of his life.[20,24,28] The Anatomy Act was passed after the Hare and Burke murders.

However, Knox's life, career and fame also changed.[38] He was never formally accused, far less convicted of any

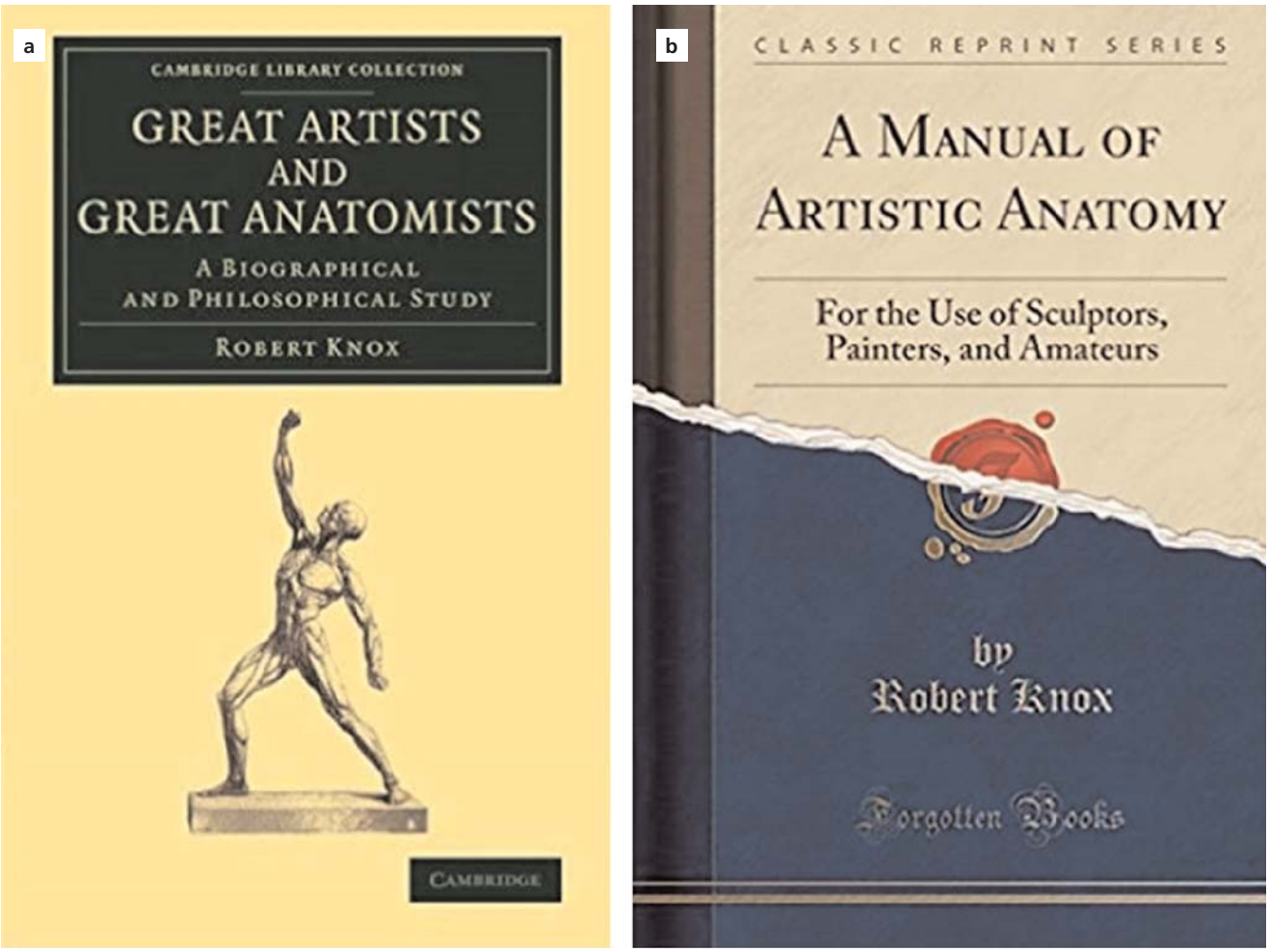

Figure 4. The books of Robert Knox (**a**, **b**).[36,37] [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

crime.[39] He diverted his attention to other fields of science such as ethnology and anthropology.[38]

Knox was a very intelligent and ambitious scientist. As reported by Lonsdale, who was one of Knox's students, Knox and Monro were always compared to each other because both were successful educators. The fact that their students and contemporaries described Knox as a better educator than Monro did nothing but intensify the competition between the two.[22]

Who can or should be the subject of history, of medical history? Robert Knox was left to be forgotten because he was found guilty based on the moral and legal standards of the period in which he lived. Today, finding out what really happened back then is impossible. It is, however, undeniable that Knox's studies on race, dissection, anatomy, ethnology and anthropology, and his views of arts and aesthetics made significant contributions to science, medicine, philosophy and art. He also trained elite physicians, which is his other contribution to medicine.

Knox's life has been the subject of numerous books, articles, plays, films and television series, all of which have allowed us to get to know him as an anatomist who had been excluded from the history of medicine. However, the current enthusiasm for Knox has more to do with the mystery and horror of the Hare and Burke murders arousing people's curiosity rather than Knox's contributions as an artist and scientist.

Conclusion

Robert Knox was found guilty based on the moral and legal standards of the period in which he lived. However, undoubtedly, he was both an accomplished anatomist and an avant-garde figure who made significant artistic contributions to anatomy.

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ORCID ID:
Ş. Gül 0000-0002-8808-5760;
S. Şahinoğlu 0000-0003-4462-2402

Correspondence to: Şenay Gül, PhD
Faculty of Nursing, Hacettepe University,
06100, Sıhhiye, Ankara, Turkey
Phone: +90 312 305 15 80
e-mail: senaygundogmus@gmail.com

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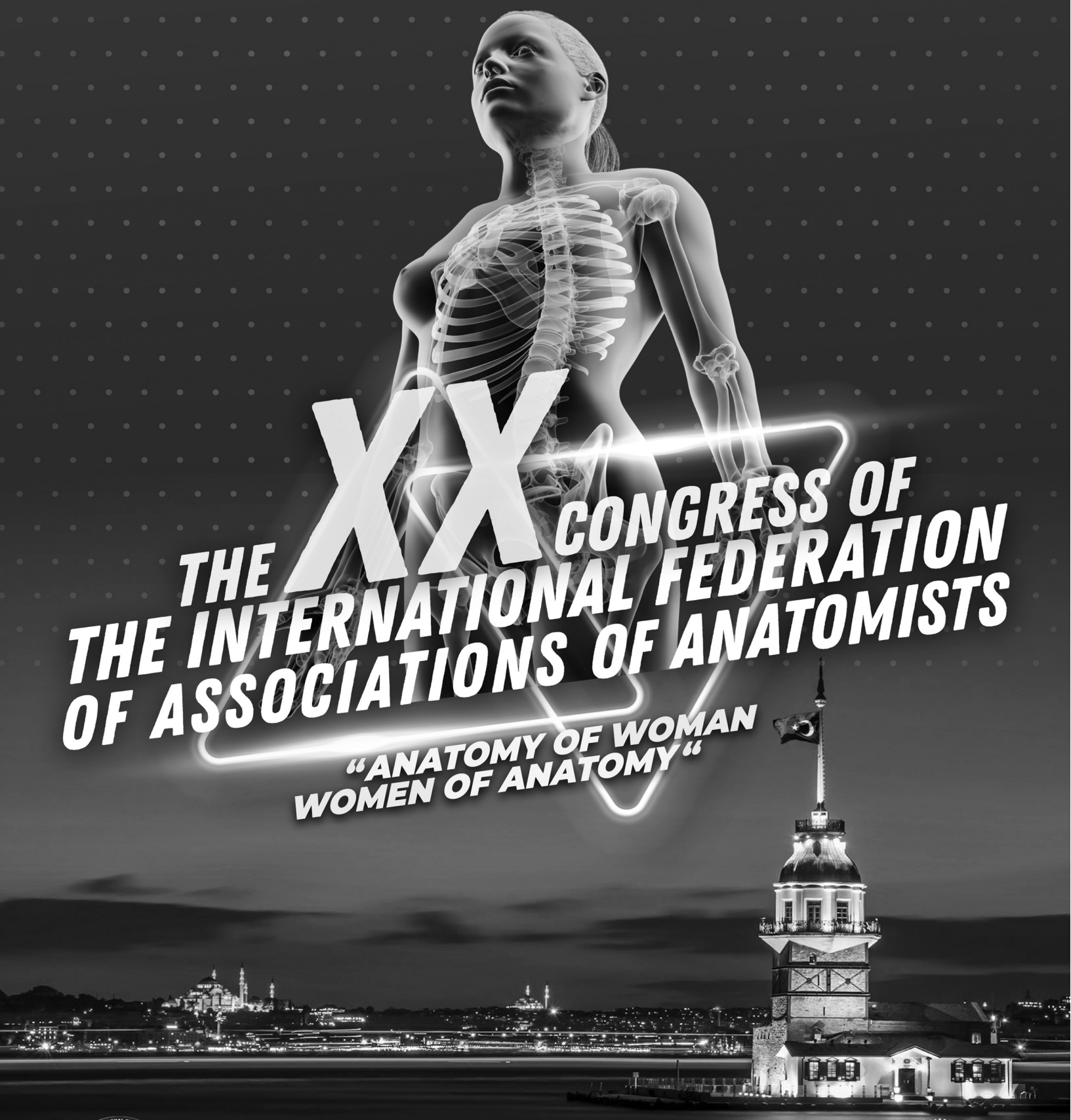

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