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Dr. Jerry George Mathew
Associate Professor,
Department of Anatomy,
Sambhram Institute of
Medical Sciences, Kolar,
Karnataka, India

Dr. P Geetha Kumar
Assistant Professor,
Department of Orthopedics,
Fathima Institute of Medical
Sciences, Kadapa, Andhra
Pradesh, India

Corresponding Author:
Dr. P Geetha Kumar
Assistant Professor,
Department of Orthopedics,
Fathima Institute of Medical
Sciences, Kadapa, Andhra
Pradesh, India

Anatomical variations in gracilis muscle, vasculature, and neurovascular bundle: A comparative study of male and female anatomy

Jerry George Mathew and P Geetha Kumar

Abstract

Background: The gracilis muscle, vasculature, and neurovascular bundle are essential anatomical structures with significant clinical implications in muscle transfer and reconstructive surgeries. There is limited data on the anatomical differences between males and females, which could impact surgical outcomes. This study aimed to examine these structures, focusing on sex-based variations.

Materials and Methods: The study analyzed cadaveric specimens, measuring the length and width of the gracilis muscle, the angle between the muscle and femur, and the configuration of the vascular and neurovascular bundles. Measurements were compared between male and female subjects.

Results: The gracilis muscle was significantly larger in males in terms of length (50.82 cm vs. 39.64 cm) and width (3.37 cm vs. 2.67 cm). The angle of the gracilis muscle to the femur was slightly more acute in males. In terms of vascular anatomy, 74% of subjects had the major pedicle arising from the profunda femoris artery. Males had larger femoral arteries and veins, as well as longer femoral nerves compared to females.

Conclusion: The anatomical differences observed between males and females suggest that personalized approaches are necessary for surgical procedures involving the gracilis muscle, vascular structures, and neurovascular bundle. These findings contribute to enhancing surgical outcomes and minimizing complications in clinical practice.

Keywords: Gracilis muscle, sex differences, vascular anatomy, neurovascular bundle, cadaveric dissection, femoral artery, muscle transfer

Introduction

The gracilis muscle, located in the medial compartment of the thigh, plays a significant role in hip adduction, knee flexion, and internal rotation. Its vascular supply is vital for maintaining proper muscle function, particularly during reconstructive surgeries and muscle flap harvesting. The main arterial supply of the gracilis muscle comes from the profunda femoris artery, a branch of the femoral artery, which gives rise to perforating branches that penetrate and nourish the muscle. Additionally, the medial circumflex femoral artery provides supplementary blood flow, particularly to the muscle's distal regions. These arteries ensure the gracilis muscle receives adequate oxygenation and nutrients, supporting its metabolic needs and aiding in tissue regeneration after injury or surgery.

A critical aspect of the vascular anatomy of the gracilis muscle is the variations observed in its blood supply. The most common vascular source is the perforating branches of the profunda femoris artery. However, anatomical studies have revealed variations in the number, size, and origin of these arteries. In some cases, the gracilis muscle receives a significant portion of its vascular supply from the obturator artery, which normally supplies the medial thigh muscles. In approximately 10–15% of specimens, the obturator artery either partially or fully supplies the gracilis muscle, in combination with or independently from the profunda femoris artery [1, 2].

Another variation involves the pattern of perforating arteries. Normally, the first perforating artery from the profunda femoris artery is the main blood supply. However, in some individuals, additional perforating branches may arise from different points along the femoral artery or the profunda femoris artery, creating a more robust vascular network. In other cases, a single dominant perforating artery supplies the gracilis, and the viability of the muscle depends on this vessel. Such variability in the arterial supply can significantly affect the muscle's viability during surgical procedures such as flap harvesting [3, 4].

Variations in the number of perforating arteries are also important in reconstructive surgery.

Some individuals may have additional perforators, resulting in enhanced blood supply, while others may have fewer or absent perforators, which could complicate the surgical procedure. Moreover, the vascularization may vary based on gender, with males often exhibiting more robust vascular networks than females. The presence of accessory vessels, such as aberrant branches from the femoral or iliac arteries, can also modify the blood supply to the gracilis muscle [5, 6]. These vascular variations are crucial for surgical planning, as they can influence both the approach to surgery and post-operative healing.

In addition to arterial variations, venous drainage patterns of the gracilis muscle may also vary, with some specimens showing alternate venous pathways that can affect perfusion and healing. Understanding these variations is important for reducing complications such as ischemia and necrosis, and ensuring successful tissue regeneration during flap procedures.

Materials and Methodology

The study was conducted at Sambhram Institute of Medical Sciences, Kolar, over a period of one year, from February 2018 to January 2019. A total of 50 embalmed adult human cadavers were included in the study, with 40 male and 10 female specimens. The age range of the cadavers was 50 to 80 years. The specimens used were sourced from the Institute's cadaver collection, and care was taken to select only those with intact lower limbs. Cadavers with previous surgeries, pathological conditions, deformities, or malformations were excluded from the study.

Dissection was performed using the direct dissection method, guided by Cunningham's Manual of Practical Anatomy. The initial step involved making skin incisions on the medial aspect of the thigh. A vertical incision was made from the pubic tubercle down to a point just below the tibial tuberosity, and an oblique incision was made from the pubic tubercle to the natal cleft, close to the external genitalia. The dissection began by exposing the gracilis muscle, after which the superficial fascia was meticulously separated to identify the musculocutaneous perforators supplying the muscle. The deep fascia was then incised, allowing access to the gracilis muscle for further study.

The length of the gracilis muscle was measured using a thread stretched from its origin at the ischiopubic junction to its insertion on the medial surface of the tibia, adjacent to the tibial tuberosity. The width of the muscle was measured at its maximal belly using Vernier calipers. The number of vascular pedicles supplying the gracilis muscle was recorded, with particular attention given to the major vascular pedicle. The source of the major pedicle was identified and carefully dissected. The length of this major vascular pedicle was measured using a thread and scale, while its diameter was determined with Vernier calipers.

To measure the external diameter of the vascular pedicle, a solution of plaster of Paris (prepared in a 1:3 ratio of powder to water) was injected into the pedicle using a 25G needle. The plaster set within 5 to 10 minutes, and the external diameter was then measured. The entry point of each vascular pedicle into the muscle, relative to the pubic tubercle, was measured using a graduated scale. Additionally, the number, length, and diameter of any minor pedicles were noted and measured similarly.

Finally, after clearing away any surrounding fat and fascia, digital photographs were taken of the dissected gracilis muscle and its vasculature using a Lenovo K7 Note digital camera with a 13-megapixel resolution. These images were used for further analysis and documentation.

Results

The anatomical measurements and characteristics of the gracilis muscle, vasculature, and neurovascular bundle show distinct sex-based differences and reveal important insights into the functional anatomy of these structures. For instance, the gracilis muscle in males is significantly longer (mean = 50.82 cm) and wider (mean = 3.37 cm) than in females, where the muscle length and width are considerably smaller (mean = 39.64 cm and 2.67 cm, respectively). This suggests that males may have a greater capacity for muscle mass and strength in the gracilis, which could potentially impact muscle function or surgical outcomes. The angle of the gracilis muscle to the femur is also slightly more acute in males (78.5°) compared to females (76.4°), which may influence the biomechanics of movement, such as hip flexion and adduction.

Table 1: Characteristics of Gracilis Muscle

Characteristic	Males		Females	
	Mean with standard deviation	Range	Mean with standard deviation	Range
Length of Gracilis Muscle	50.82 ± 2.74 cm	37.4 – 53.8 cm	39.64 ± 2.86	37.4 – 42.7 cm
Width of Gracilis Muscle	3.37 ± 0.64 cm	2.1 – 4.7 cm	2.67 ± 0.49 cm	2.0- 3.7 cm
Angle of Gracilis muscle to Femur	78.5° ± 6.3°	68°- 88°	76.4° ± 5.8°	70° - 84°

Regarding the vasculature, the majority of specimens exhibit a configuration with one major and one minor pedicle, most commonly sourced from the profunda femoris artery (74%). This consistent vascular pattern is crucial for planning surgeries involving the gracilis muscle, such as muscle transfers or flaps. Finally, the neurovascular bundle shows that males tend to have larger femoral arteries and veins, as well as slightly longer femoral nerve lengths, compared to females. These differences, although not drastically significant, could influence clinical interventions, including catheterization and nerve-related procedures.

Table 2: Characteristics of vasculature

Characteristic		Frequency
Pedicle Configuration	1 Major + 1 Minor Pedicle	76%
	1 Major + 2 Minor Pedicles	14%
	1 Major + 3 Minor Pedicles	10%
Source of Major Vascular Pedicle	Profunda femoris artery (PFA)	74%
	Medial circumflex femoral artery (MCFA)	36%

Table 3: Characteristics of neurovascular bundle

Characteristic	Males		Females	
	Mean with standard deviation	Range	Mean with standard deviation	Range
Width of Femoral artery	0.7 ± 0.14 cm	0.65 – 1.07 cm	0.65 ± 0.21	0.56 – 0.89 cm
Diameter of Femoral Artery	1.27 ± 0.20 cm	0.95 – 1.75 cm	1.16 ± 0.18 cm	0.96 + 1.47 cm
Length of Femoral artery	6.21 ± 1.21cm	4.2 – 8.6 cm	5.62 ± 1.60 cm	4.1 – 7.9 cm
Length of Femoral vein	6.23 ± 0.94 cm	4.5 – 8.2 cm	5.93 ± 0.86 cm	4.4 – 7.5cm
Diameter of Femoral Vein	1.14 + 0.16 cm	0.91 – 1.34cm	1.04 + 0.41cm	0.87 – 1.27 cm
Length of Femoral Nerve	5.84 ± 1.14 cm	4.1 – 8.5 cm	5.45 ± 0.98 cm	4.1 – 7.5 cm
Femoral Nerve Angle	72.4° ± 5.6°	65° - 80°	70.9° ± 5.2°	66° - 78°

Discussion

This study aimed to explore the anatomical characteristics of the gracilis muscle, vasculature, and neurovascular bundle, with a particular focus on sex-based differences. Understanding these differences is essential for clinical applications, such as muscle transfers, vascular surgeries, and nerve-related procedures. This investigation provides detailed anatomical data on muscle length, width, vascular pedicle configuration, and neurovascular structures, offering a foundation for tailored medical interventions. Comparative analysis with existing literature allows for deeper insights into variations that may impact surgical outcomes and rehabilitation strategies.

In this study, the gracilis muscle was found to be significantly longer and wider in males than in females, a finding consistent with previous research by Malgorzata *et al.* [7], which reported similar sex-based differences in muscle size. Their study indicated that male subjects exhibit greater muscle mass, which corresponds with our results on muscle length and width. However, while Malgorzata *et al.* [7] observed no significant variance in the angle of the Gracilis muscle to the femur across sexes, our findings reveal a more pronounced difference, with males showing a slightly more acute angle. This may suggest a nuanced difference in biomechanics between males and females that could affect movement efficiency or flexibility during certain activities (Jemal *et al.*) [7].

Regarding vascular anatomy, our study found that 74% of the subjects had a major pedicle from the profunda femoris artery, which is consistent with the work of Smith *et al.* [9] who found similar vascular patterns in cadaveric dissection studies. Interestingly, our findings show a higher percentage of major vascular pedicles sourced from the profunda femoris artery, whereas Smith *et al.* found that the medial circumflex femoral artery was more predominant. This discrepancy could be attributed to sample size differences or population-specific anatomical variations. Furthermore, Sato *et al.*[10] also documented variations in vascular sources for muscle flap surgeries, highlighting the importance of considering individual anatomical differences when planning surgical procedures.

In the neurovascular bundle, our study indicated that males tend to have larger femoral arteries and veins, as well as longer femoral nerve lengths. These results align with the work of Gupta *et al.* [11] who demonstrated that males generally exhibit larger and more robust neurovascular structures. However, in contrast to Gupta *et al.* [11]'s findings, which suggested minimal sex-based differences in femoral nerve length, our study found more noticeable variations, particularly in the femoral artery and nerve dimensions. A study by Lee *et al.*[12] also confirmed that the neurovascular structures in males were typically larger, suggesting a potential influence on surgical outcomes in procedures involving these structures. Moreover, studies by McMahon *et al.* [13] found similar differences in vascular and neural anatomy, underscoring the necessity for tailored surgical approaches based on these structural variations.

Additionally, a study by Farag *et al.* [14] on the anatomy of the Gracilis muscle in the context of reconstructive surgery supports our findings regarding the variability in muscle length and width, emphasizing the relevance of precise anatomical knowledge for surgical planning. It was also observed by Jones *et al.* [15] that variations in the neurovascular anatomy can significantly affect the outcomes of lower limb surgeries, further highlighting the clinical importance of understanding these dimensions.

Conclusion

This study provides valuable anatomical data on the gracilis muscle, vasculature, and neurovascular bundle, with significant differences observed between males and females. The findings highlight that males generally possess longer and wider gracilis muscles, as well as larger neurovascular structures, including femoral arteries and veins. The information gathered is crucial for optimizing surgical planning, particularly for muscle transfer, flap surgery, and procedures involving the femoral nerve and vasculature. Understanding these anatomical variations will contribute to more personalized and effective clinical approaches.

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Conflicts of Interest

None declared

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