ORIGINAL ARTICLE

Anatomical investigation of tensor vastus intermedius: A cadaveric study

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ABSTRACT

The major muscle in the anterior compartment of the thigh known as quadriceps femoris is made up of four parts; rectus (straight) femoris and three vasti (vastus lateralis, medialis and intermedius). A recently discovered muscle, making the fifth part, called the Tensor vastus intermedius (TVI) has been found in-between vastus lateralis (VL) and vastus intermedius (VI). The aim of this investigation was to study the presence of the TVI muscle, identify neurovascular supply as well as variations in the nature of the muscle and to ultimately classify them. The cadaveric study was conducted in the Gross laboratories of Yusuf Maitama Sule University, Bayero University and Ahmadu Bello University, all in Nigeria. Thirty lower limbs were examined using standard dissection techniques and the TVI was demonstrated in all of them. We then classified the muscle into four types, I to IV based on their origin, course and insertion. The Type I were the independent type; constituting 12 cases (40%), the VI-type (Type II) 7 cases (23%), the VL-type (Type III) 5 cases (17%) and the common type (Type IV) 6 cases (20%). The TVI was supplied by muscular branches of the femoral nerve and receives vascular supply by branches of lateral circumflex femoral artery and vein.

Keywords: tensor vastus intermedius, quadriceps tendon, quadriceps, cadaver.

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INTRODUCTION

The quadriceps femoris, also known as the quadriceps, is a collection of muscles that make up the anterior compartment of the thigh. These muscles are one of the strongest in the body and serve as the primary movers in knee extension (1,2,3). The four muscles that traditionally make up the quadriceps are rectus (straight) femoris (RF), vastus medialis (VM), vastus intermedius (VI), and vastus lateralis (VL). More specifically, the RF and VM originate from the anterior inferior spine of the ilium (AIIS), the VL too its origin from the femoral trochanter (greater) and continued inferiorly to the linea aspera on the posterior aspect of the femur, while the VI originate from both the anterior and lateral parts of the femoral shaft (3,4,5). Despite having separate origins, these muscles all join to form the quadriceps tendon, which envelopes the patella and continued as the patellar ligament which finally attaches to the tibial tuberosity (2,6). A fifth part, the tensor of the vastus intermedius (TVI), situated between the VL and the VI, was, nonetheless, mentioned in the literature. The fifth quadriceps muscle group component, the TVI, was originally identified in 2016 (5,7). Despite being one of the five quadriceps muscles, the TVI has received comparatively less attention in research studies (8). Due to the way it was described in earlier studies, it was likely assumed that this part constituted a morphological variant of the tendon of quadriceps structure surrounding the knee (9). The TVI is currently recognized by scientists as a distinct muscle and studies are ongoing to determine its exact anatomy (7,9,10). In early cadaveric studies; Golland et al. (11) found TVI in 29% of the specimens arising from the anterior aspect of the upper shaft of femur, while in another study it was reported that the muscle in 36% of the specimens were situated in the distal region between the VL and the VI (12). However, the TVI's point of insertion varied in each case. As a result, the majority of people do not view this muscle as being an essential component of the quadriceps (5). The muscle belly of the TVI forms in the proximal aspect of the thigh and continues to a thin and broad aponeurosis and tendinous structure under the rectus femoris (RF), vastus lateralis (VL), and intermedius (VI) muscles distally (11,12). The greater trochanter's anteromedial surface is where the TVI begins, and the medial aspect of the patella serves as its point of insertion. Although the muscular belly of the TVI can be distinguished from those of the VI and VL, in some circumstances, when it moves distally, it merges with one or both of these two nearby muscles (9,13). According to the fusions of the VL and VI aponeurosis, Grob et al. (7) divided the morphologic variants of the TVI into four distinct subtypes: Type I (independent-type), type II (VL-type), type III (VI-type), and type IV (Common-type).

Independent-type, which was the most prevalent in the aforementioned study and was identified by a TVI tendon that is easily separable from both the VL and VI, was seen in slightly less than half of the cases. It is known as VL-type when the TVI aponeurosis can be easily distinguished from the VI but not from the VL; it is known as VI-type when expressed in the opposite pattern.

The newly discovered fifth head has an independent neuronal and vascular supply. Furthermore, evidence of the presence of the TVI muscle has been demonstrated in clinical practice where Grob et al (15) diagnosed an isolated case of ruptured TVI. The images showed the TVI in each participant and in the transverse plane, the tendon and muscle bellies were visible. These findings led to the hypothesis that inability to recognize the TVI could lead to an incorrect interpretation of the images of the quadriceps femoris. Clinically, this extra muscle is unlikely to result in any significant impairments throughout the majority of therapies or rehabilitative therapy; nonetheless, some orthopedic or reconstructive procedures in the femoral area may call for `updated anatomical information (9,16).

There is a paucity of knowledge on this recently found muscle since the TVI has been generally disregarded. This study aims to investigate the presence of the TVI in the Gross Anatomy Laboratories of three universities in Northern Nigeria which are, Yusuf Maitama Sule University, Bayero University, and Ahmadu Bello University. The objectives were to establish neurovascular supplies and any anatomical variations within the muscle itself.

MATERIALS AND METHODS

The study was conducted in the Departments of Human Anatomy of Yusuf Maitama Sule University, Bayero

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University and Ahmadu Bello University. Ethical clearance was given by the Faculty Research Committee of Basic Medical Sciences, Yusuf Maitama Sule University, Kano. All the cadavers used were from Northern Nigeria through the Body Donation Program of Murtala Muhammad Specialist Hospital (Kano) and were obtained following ethical guidelines. The cadavers were fixed in formalin-based solution and include 10 males, 4 females and 1 child. Convenience sampling method was used until the sample size was attained. The sample size was determined by the number of available lower limb specimen in the three Departments. Normal and healthy lower limbs were included in the study while lower limbs showing signs of pathology (such as fracture, hematoma, tumors or lacerations) or are distorted were excluded from the study. A transverse incision was made at the inguinal region and another was made at the level of the apex of the patella. Then another incision was made longitudinally joining the mid-inguinal point and the patella on the anterior aspect of the thigh. The muscles in the anterior compartment were then revealed by reflecting the incised skin and superficial fascia followed by clearance of the fascia lata. The rectus femoris muscles was identified and then cut its area of insertion into the quadriceps tendon. Upon reflection of the RF, the other components of the quadriceps were identified. The TVI muscle was identified between the origins of the vastus lateralis and the intermedius and it was traced distally to its insertion. The iliotibial tract was cut at the level of the midthigh, to release the proximal attachments of the quadriceps. The neurovascular bundles were carefully dissected and identified. The TVI was classified based on origin, course, insertion, shape and size. Variations in the TVI were noted. All images were captured using DSLR camera (Nikon D3400) and the images labeled using Adobe Photoshop.

RESULTS

A total number of 30 lower limbs were dissected from 15 cadavers (10male, 4 female and 1 child) and in all the specimen (n=30), the TVI muscle was identified (as shown in Figure 1). The TVI was divided into four categories based on the shape and muscle fibers: fusiform (n=10) as shown in Figure 2 and 3, which made up 33%; flattened fibres (n=16), which were the most prevalent and accounted for 53%; quadrangular (n=2), which made up 7%; and huge fleshy fibers (n=2), which made up 7% (Figure 3).

On the basis of origin, we classified TVI into four types, based on other previous studies (7,14) as shown in Table 1. We found 40% of cases (n=12) were the independent type (Type I) in which the TVI had a separate origin from the VL and VI and the aponeuroses of the 3 muscles were distinctly separate. Type II is the VI-type and arises along with the VI with the aponeuroses of the two being inseparable; accounted for 23% (n=7). Type III or the VL-type takes its origin from the VL and accounted for 17% of cases (n=5). Type IV is the common type in which the TVI arises between the VL and VI but there are 3 distinct aponeuroses and it accounted for 20% (n=6). Specifically, the TVI originates from the superior part of the intertrochanteric line and anterior part of trochanter (greater) of femur.

The insertion of the TVI is also highly variable. It inserts into the medial aspect of upper part of the base of the patella. In 13% (n=4), the muscle inserts by means of a flattened aponeurosis into the upper part (base) of the patella deep to the common tendon of the quadriceps. Another 17% (n=7) inserted by means of an aponeurosis into the medial part of the quadriceps tendon. In 33% (n=10) cases, the TVI inserted by means of a long tendon into the deep aspect of the quadriceps tendon. Another 23% (n=7) inserted by means of a flattened aponeurosis into the VI and then into the medial aspect of the upper part of the base of patella deep to the quadriceps tendon. In 7% (n=2) the muscles insert by means of fleshy fibres into the medial side of the base of the patella (Table 2).

On the basis of size, two specimens showed a large bulk of muscle that were even larger than the VL (Figure 4). In the fusiform type, the TVI was a small muscle with a long, thin tendon. Most of the TVI observed were in between the 2 sizes (medium-sized) with a wide flattened aponeurosis.

The TVI muscle showed variations in terms of shape, size, insertion, even with the same cadaver. In this study, 5 cadavers showed no variations on the right and left sides, but 10 cadavers had different types of the TVI on the different sides. In the female specimen (Figure 5), both left and right sides showed a similar flattened TVI muscle with a similar insertion on both sides.

Femoral nerve provides the nervous innervation to the TVI via its muscular branches, while vascular supply

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was by branches of ascending branch of the LCFA and transverse branches of lateral circumflex femoral artery (LCFA). Venous drainage is by corresponding veins (Figure 6 a,b).

DISCUSSION

The functional importance of the quadriceps, in movements such as walking upstairs, running, jumping, climbing, rising from sitting or squatting positions (2,17) has enabled several research to further our understanding of the functionality of the knee. Standring et al described the quadriceps muscle as a great extensor of the leg, which is divided into four parts (3). Several variations have been demonstrated in the morphology of the quadriceps muscles. Despite the various studies on the morphology of the quadriceps, the presence of an independent muscle between the VI and VL has not been previously explored as the TVI has been given little attention until Grob et al's discovery (7, 14, 15).

Grob et al (7, 14) dissected 26 lower limbs in cadavers and reported the presence of a 5th head of quadriceps, named the TVI, in all the specimen. This finding is in line with the finding of the current study which studied 30 cadaveric lower limbs and found the newly discovered TVI in all the specimens. A similar study conducted in the South Indian population, dissected 30 cadaveric lower limbs and reported the presence of the fifth head in all the specimens (20). The morphology of the TVI is highly variable even within the same cadaver. The findings of the current study were in line with Grob et al and Veeramani and Gnanasekaran (7, 14, 20) which classified the TVI into four types. Similar types were found in this study as shown in Table 3.

In our study study, all four types according reported earlier (7,14, 20) were found as shown in Figure 7. This is in line with the findings of Veeramani and Gnanasekaran (20) which showed type I 33.33%, type II 8.33%, type III 30.56% and type IV 27.78%. The study by Grob et al (7,14) also showed similar findings of type I 42%, type II 23%, type III 19% and type IV 15%.

In the Grob et al (7,14) study, 5 cases showed two or more smaller muscle lamellae of the TVI. In contrast to this, however, no additional muscle lamellae were found in association with the TVI muscle in this study.

On the basis of frequency, the study showed the type I (independent type) to have the highest frequency of 40%, which is in line with the studies by Grob et al (7,14) and Veeramani and Gnanasekaran (9, 20) which showed type I frequencies of 42% and 33.33% respectively.

Studies have demonstrated the trilaminar structure of the quadriceps made up of profunda and superficial medial aponeurosis of the VI, VL, TVI and RF lateral aponeurosis of the VI, (1,7). Like these studies, the tendon of the quadriceps in the current study also showed a trilaminar arrangement, with the rectus femoris being superficial and the VI being in the deepest layer. The VL, TVI and VM occupying the intermediate layer.

Of the 15 cadavers, five paired specimens showed identical type of TVI muscle on both sides while the remaining ten paired specimen showed variations between the both sides of the same cadaver. This follows the Grob et al (7,14) study in which four paired specimens showed identical TVI on both sides and six paired specimen showed different types on opposite sides.

The current study demonstrated 2 fleshy muscle bellies of the TVI in line with a study in Brazil (21) which reported a case of TVI with bulky muscle bellies (Figure 4). From an evolutionary standpoint, it may be possible to determine the most likely cause of these variations in the TVI. The TVI and the VI and VL share a same primordium embryologically. As a result, the TVI may have varied morphologies depending on how these muscles differentiate and separate. The result from the Utsunomiya et al (9) study which looked at embryologic development of the quadriceps, 7 out of 10 limbs in Carnegie Stage (CS) 22, showed clusters of the TVI's myocyte between the VL and VI, demonstrating that the TVI develops at this time. The TVI was evidently present in all but one of the specimens in CS 23. However, in these embryonic stages, neither the TVI's aponeurosis nor its tendonous structure were visible. The data indicate that the TVI is the final component to develop in the quadriceps femoris complex since formation of the traditional four quadriceps muscle components is finished by CS 21. The idea is that the TVI continues to develop after the embryonic stage while developing the tendinous structure toward the patella and receives circulatory supplies from particular

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blood vessels.

In all 30 dissected lower limbs, the TVI was innervated by branches femoral nerve and receives blood supply from the ascending and transverse branches of the LCFA (Figure 5 a,b). Venous drainage is by LGFV. Veeramani and Gnanasekaran also demonstrated a similar vascular and innervation pattern (20). Grob et al demonstrated the VL. TVI and lateral portions of the VI all received innervation from the femoral nerve via its lateral deep division; while vascular supply is by side branches of the ascending branch of the LCFA and transverse branches of the LCFA (7).

CONCLUSION

The TVI muscle is a distinct muscle of the knee extensors with a separate innervation and a separate vascular supply and has been identified in all the specimen. The muscle in itself shows a lot of inter- and intra-individual variations. Four distinct types have been described, types I-IV; with type I having the highest frequency. This study is, however, not exhaustive as the exact role of the TVI in knee extension needs to be explored. Also, the significance of this newly discovered muscle needs to be studied further in terms of exercise or pathological conditions. The results of this study will provide more insight into the architecture of the TVI, as well as open up avenues for further research. This study provided insight into the variations of TVI and highlighted the most prevalent morphological type using strong anatomical landmarks such as shape, origin, and insertion. It is pertinent that TVI be recognized as parts of the muscle in the anterior compartment of the thigh in anatomy education and clinical practice.

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Table 1. Classification of TVI based on origin

Origin of TVI	n (%)
Type I	12 (40%)
Type II	7 (23%)
Type III	5 (17%)
Type IV	6 (20%)
	N=30

n=frequency, %=percentage, N=Total number of specimen

Table 2. Distribution of insertion of the TVI

Insertion	n (%)
Base of patella	4 (13%)
Medial part of quadriceps tendon	7 (17%)
Deep to quadriceps tendon	10 (33%)
Medial side of base of patella	2 (7%)
	N=30

n=frequency, %=percentage, N=Total number of specimen

Table 3. Types of TVI based on attachments and course

	Type I Independent	Type II VI-type	Type III VL-type	Type IV Common type
Origin	Upper part of the trochanteric line and anterior part of greater trochanter of femur	Together with VI from the anterior and lateral surfaces of upper two-thirds of shaft of femur	Together with VL from the upper part of intertrochanteric line and anterior part of greater trochanter	Common origin with VI and VL
Course	Aponeurosis is separate from both VI and VL	Aponeurosis not separate from VI	Aponeurosis not separate from VL	Aponeuroses of the 3 muscles are separate
Insertion	medial aspect of upper part of the base of the patella in various combinations with the quadriceps tendon or the insertions of VI or VL			

VI=vastus intermedius; VL=vastus lateralis

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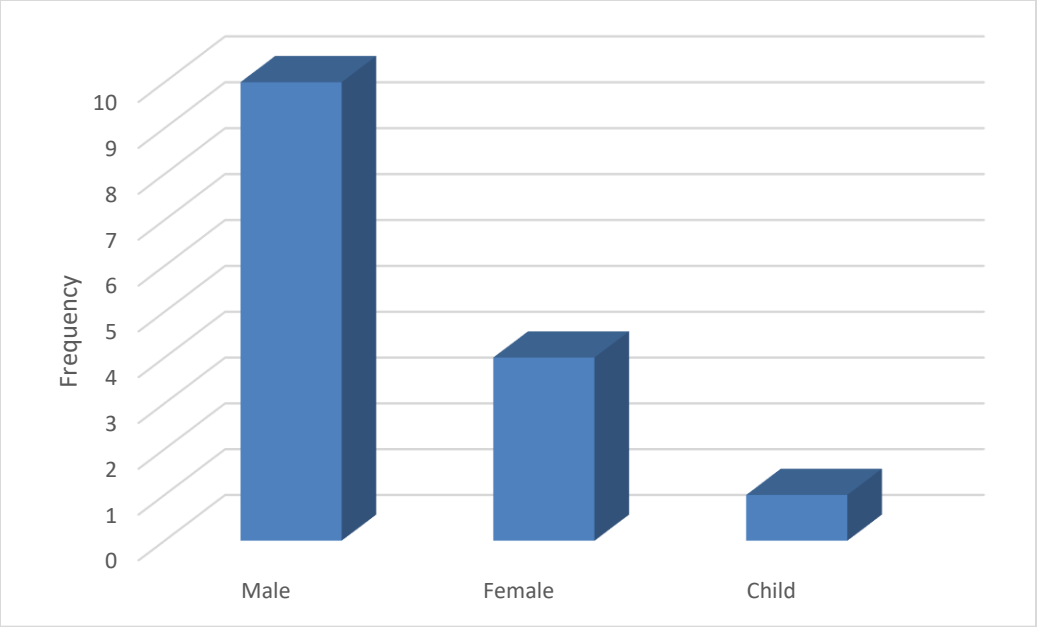

Figure 1. Distribution of Cadavers

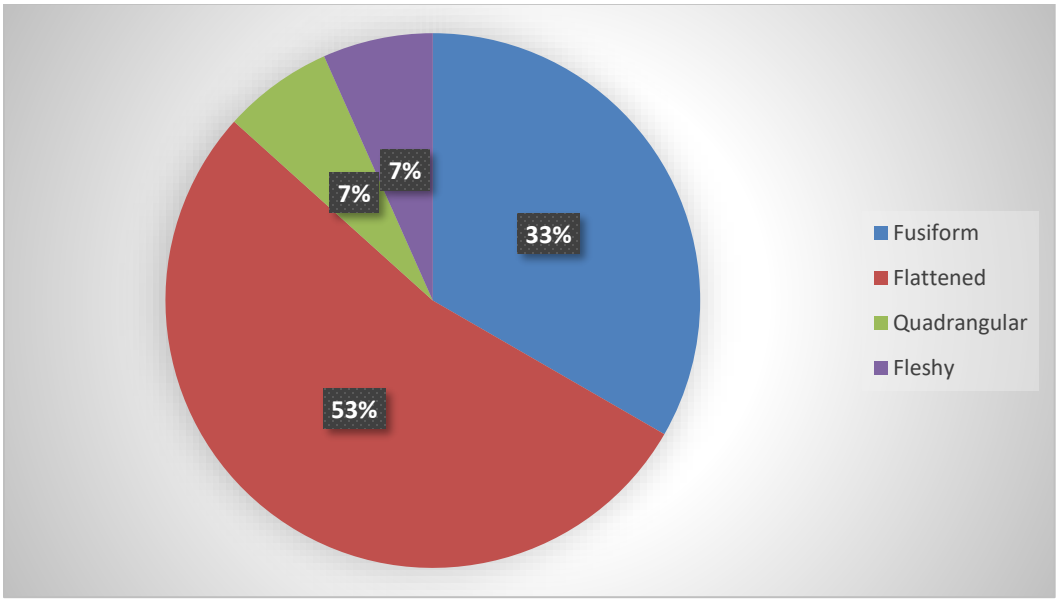

Figure 2. Classification of the TVI muscle based on shape of muscle fibres

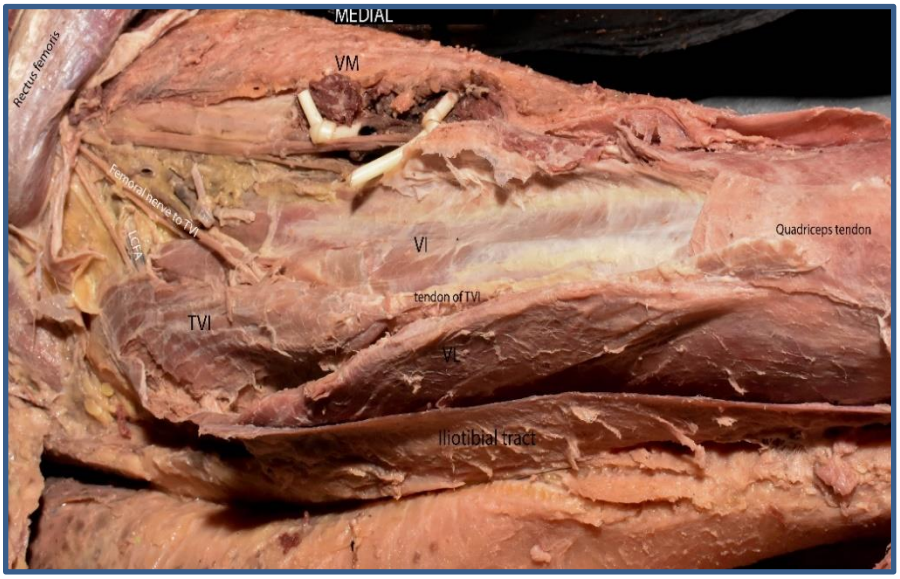

Figure 3. TVI on right thigh assumes a fusiform shape which accounts for 33% of cases. It's origin is in intimate contact with that of VL and VI, thus presenting 3 layers of muscle with a common origin; the VI is deepest and the VL most superficial, while the TVI was in between the two. It inserts by means of a long tendon into medial side of the base of the patella, deep to the quadriceps tendon.It was innervated by branches of the femoral nerve and receives vascular supply from the lateral circumflex femoral artery.
Key: TVI = Tensor Vastus Intermedius; VM = Vastus medialis; VL = Vastus lateralis; VI = Vastus intermedius; LCFA = Lateral circumflex femoral artery

Figure 4. Right thigh showing the Independent type of TVI muscle. In contrast to previous studies, the TVI here consisted of a large muscle belly, even larger than the VL. This large muscle inserted by means of a short tendon into the base of the patella, deep to the quadriceps tendon.

Figure 5. Right thigh of female cadaver showing the VL-type of TVI made up of small muscle belly inserting by means of a wide flattened aponeurosis into the base of the patella, deep to the quadriceps tendon.

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Figure 6 a,b. Neurovascular supply of the TVI showing the branch of the Femoral nerve to the TVI and the lateral circumflex femoral artery (LCFA).

Figure 7. The VI-type TVI muscle was inseparable proximally from the VI, but distally the aponeurosis of the TVI was separate from the VI.

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