



Tensor of the vastus intermedius muscle: anatomy, function, and clinical implications

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ABSTRACT

The quadriceps femoris is traditionally described as comprising four muscles. However, recent anatomical studies have identified a fifth muscle, the tensor of the vastus intermedius (TVI), located between the vastus lateralis and vastus intermedius. This structure remains underexplored, with limited understanding of its morphology, function, and clinical significance. This study aimed to analyze and describe the anatomical characteristics, morphological variations, and clinical implications of the TVI, contributing to its recognition in musculoskeletal anatomy. A systematic review was conducted following PRISMA guidelines. Scientific databases (PubMed, SciELO, LILACS) were searched for studies published between 2010 and 2025, focusing on the anatomy, biomechanics, and surgical relevance of the TVI. Articles describing cadaveric dissections, imaging studies, and clinical correlations were included. The TVI was identified in 65% of cadaveric dissections, showing variable morphology and fiber orientation. It contributes to patellar stabilization and interacts with neurovascular structures, raising concerns in orthopedic surgery and rehabilitation. Imaging techniques, particularly high-resolution MRI, improve its identification, preventing misdiagnosis such as tumors or muscle anomalies. The TVI plays a key role in knee biomechanics yet remains underrepresented in anatomical models. Its recognition may enhance surgical planning, rehabilitation protocols, and anatomical education. Further research is essential to clarify its functional impact and clinical applications.

Keywords: Quadriceps femoris, Tensor of the vastus intermedius, Anatomy, Knee biomechanics, Orthopedic surgery.

RESUMEN

El músculo cuádriceps femoral se describe tradicionalmente como compuesto por cuatro músculos. Sin embargo, estudios anatómicos recientes han identificado un quinto músculo, el tensor del vasto intermedio (TVI), ubicado entre el vasto lateral y el vasto intermedio. Esta estructura sigue siendo poco explorada, con escasa comprensión de su morfología, función y relevancia clínica. Este estudio tuvo como objetivo analizar y describir las características anatómicas, variaciones morfológicas e implicaciones clínicas del TVI, contribuyendo a su reconocimiento en la anatomía musculoesquelética. Se realizó una revisión sistemática siguiendo las directrices PRISMA. Se buscaron estudios publicados entre 2010 y 2025 en bases de datos científicas (PubMed, SciELO, LILACS), centrados en la anatomía, biomecánica y relevancia quirúrgica del TVI. Se incluyeron artículos que describen disecciones cadavéricas, estudios de imagen y correlaciones clínicas. El TVI fue identificado en el 65% de las disecciones cadavéricas, presentando morfología y orientación de fibras variables. Contribuye a la estabilización de la rótula e interactúa con estructuras neurovasculares, lo que plantea preocupaciones en cirugía ortopédica y rehabilitación. Las técnicas de imagen, especialmente la resonancia magnética de alta resolución, mejoran su identificación, evitando diagnósticos erróneos como tumores o anomalías musculares. El TVI desempeña un papel clave en la biomecánica de la rodilla, pero sigue estando poco representado en los modelos anatómicos. Su reconocimiento puede mejorar la planificación

quirúrgica, los protocolos de rehabilitación y la enseñanza anatómica. Se necesitan más investigaciones para esclarecer su impacto funcional y aplicaciones clínicas.

Palabras clave: Cuádriceps femoral, Tensor del vasto intermedio, Anatomía, Biomecánica de la rodilla, Cirugía ortopédica.

INTRODUCTION

The quadriceps femoris muscle is classically described as a muscle group composed of four portions: rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius (Grob *et al.*, 2016). However, recent studies using anatomical dissection and magnetic resonance imaging (MRI) have identified the presence of a fifth muscle head, referred to as the tensor of the vastus intermedius (TVI) muscle, located between the vastus lateralis and the vastus intermedius (Grob *et al.*, 2017). This new anatomical perspective challenges the traditional description of quadriceps muscle anatomy, directly influencing biomechanical understanding and surgical approaches to the knee (Schueda *et al.*, 2021).

Cadaveric studies and imaging analyses have shown that TVI is present in a significant portion of the population, with morphological variations that allow its classification into four distinct patterns: independent, vastus lateralis type, vastus intermedius type, and common type (Grob *et al.*, 2016). Additionally, its origin and insertion may vary, with some fibers merging into the vastus lateralis, while others follow an independent path to the quadriceps tendon, indicating that its function may be more complex than previously assumed (Grob *et al.*, 2017).

The presence of the TVI has significant clinical and surgical implications, particularly in orthopedic procedures involving the knee extensor apparatus, such as arthroplasties, tendon repairs, and femur fracture fixation (Schueda *et al.*, 2021). In surgical approaches, its proximity to critical neurovascular structures, such as branches of the femoral nerve and adjacent vessels, reinforces the need for detailed anatomical knowledge to prevent intraoperative complications and reduce the risk of iatrogenic injuries (Grob *et al.*, 2016).

The identification of the TVI through imaging techniques, such as MRI and ultrasonography, has proven to be a useful tool for surgical planning, enabling precise localization of the structure and its relationship with adjacent muscles (Grob *et al.*, 2017). Furthermore, its biomechanics may play a crucial role in patellar stabilization and knee alignment, directly impacting postoperative rehabilitation and the success of orthopedic treatments (Schueda *et al.*, 2021).

Therefore, this study aims to analyze and describe the anatomical characteristics of the tensor of the vastus intermedius muscle, its morphological variations, and its importance in orthopedic surgical practice, contributing to the advancement of knowledge on the functional anatomy of the quadriceps femoris and its impact on knee biomechanics.

MATERIALS AND METHODS

This study was conducted through a systematic literature review, based on the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), ensuring transparency and reproducibility of the research. The databases used were PubMed, SciELO, and LILACS, searching for articles published between 2010 and 2025 that addressed the anatomy and clinical relevance of the TVI muscle, its presence, anatomical variations, and surgical implications. The selection of articles was

performed using the Health Sciences Descriptors (DeCS) and the Medical Subject Headings (MeSH), with the terms "Skeletal Muscle," "Anatomy," "Orthopedic Surgical Procedures," and "Knee", ensuring a refined search strategy and greater accuracy in study selection.

Only studies that described the anatomy of the TVI based on cadaveric dissections and imaging techniques, such as MRI and ultrasonography, were included, as well as articles that explored the relationship between this structure and orthopedic surgical approaches, particularly in procedures such as knee arthroplasties, tendon repair, and femur fracture fixation. Original research articles and systematic reviews were included, provided they met rigorous methodological criteria to ensure the quality of the analyzed evidence. On the other hand, studies without direct clinical relevance to orthopedic practice, such as those focusing exclusively on anatomical descriptions without surgical implications, as well as isolated case reports without anatomical confirmation through imaging or cadaveric dissection, were excluded. Studies published in languages other than English, Portuguese, or Spanish were also excluded due to accessibility and translation limitations.

Data extraction was performed in a structured manner, considering information about the sample size in each study, the anatomical variations of the TVI, and its relationships with adjacent structures. The classification proposed by Grob et al. (2016) was used to categorize the TVI into independent pattern, vastus lateralis type, vastus intermedius type, and common type, allowing assessment of its frequency in the population and potential biomechanical implications. Additionally, the relationship between the muscle and neurovascular structures, such as branches of the femoral nerve, was analyzed based on anatomical and surgical studies, aiming to understand the intraoperative risks associated with its presence (Grob *et al.*, 2017). The extracted data were synthesized and organized in a structured manner to facilitate the interpretation of anatomical frequency and functional implications.

From an ethical perspective, this study did not involve direct experimentation with humans or animals, as it is a literature review, thus exempting the need for approval by an ethics committee. However, all the articles included in the analysis followed good scientific practices, including, when applicable, prior ethical approval of the primary studies and participant consent.

RESULTS

A total of eight studies were included in this review, comprising four based on cadaveric dissections and four utilizing imaging techniques, such as MRI. The analyzed anatomical studies demonstrated that the TVI muscle is present in a significant portion of the population. Its morphology was classified into four distinct types: independent, vastus lateralis type, vastus intermedius type, and common type, as described by Grob et al. (2016). Data from cadaveric dissections indicate that the TVI was identified in 100% of the 26 specimens analyzed (Grob *et al.*, 2016), while imaging studies have shown identification in approximately 65% of individuals (Grob *et al.*, 2017). This discrepancy may reflect limitations in imaging resolution or anatomical variability.

High-resolution MRI has proven to be a reliable tool for identifying the TVI in vivo. This imaging technique allows detailed observation of the muscle's shape, dimensions, and spatial relationship with surrounding muscles, reducing the likelihood of misdiagnosis (Franchi, 2021).

Morphological variability was observed among individuals. In some dissections, the TVI was found to share fibers with the vastus lateralis; in others, it inserted directly into the quadriceps tendon. This anatomical

variability may reflect differences in muscle activation and function during knee extension (Schueda *et al.*, 2021).

Additionally, the proximity of the TVI to neurovascular structures, particularly branches of the femoral nerve and the lateral circumflex femoral artery, was consistently noted. This anatomical relationship carries clinical implications for surgical procedures in the anterior thigh region (Grob *et al.*, 2016).

DISCUSSION

The presence of the TVI modifies the traditional understanding of quadriceps biomechanics, especially in relation to patellar stabilization. Its functional contribution appears to influence the tension distribution within the knee extensor mechanism. Biomechanical studies suggest that the TVI helps modulate the force vectors acting on the patella, supporting proper alignment and minimizing overload on the femoropatellar joint (Grob *et al.*, 2017).

This functional role becomes particularly relevant in clinical contexts such as total knee arthroplasty, where the balance of quadriceps components affects postoperative recovery. Recognizing and preserving the TVI during surgery may favor better joint stability and improved rehabilitation outcomes (Franchi, 2021).

In rehabilitation, the existence of the TVI prompts the need for individualized muscle training strategies. In cases of patellofemoral pain syndrome or quadriceps tendinopathy, its selective activation could enhance treatment efficacy. Electromyographic analyses have shown that the TVI is more active during high-resistance or eccentric contraction exercises, suggesting a role in joint impact absorption and dynamic control of knee extension (Schueda *et al.*, 2021).

Surgically, the failure to recognize the TVI may lead to intraoperative complications. These include unintended damage to muscle fibers and excessive bleeding, particularly during procedures such as femoral fracture fixation or anterior thigh exposure (Franchi, 2021; Grob *et al.*, 2016).

Radiologically, unawareness of the TVI's existence may result in misinterpretation of MRI scans. There are case reports of the TVI being mistaken for abnormal soft tissue masses, such as neoplasms or pseudotumors, leading to unnecessary diagnostic procedures (Schueda *et al.*, 2021). Thus, radiologists and surgeons must be trained to differentiate this anatomical variant correctly.

In summary, the TVI is not merely an anatomical curiosity but a structurally and functionally significant component of the quadriceps complex. Its inclusion in anatomical education, surgical planning, and physical therapy protocols has the potential to improve diagnosis, patient safety, and treatment effectiveness in musculoskeletal care (Grob *et al.*, 2016; Grob *et al.*, 2017; Schueda *et al.*, 2021).

CONCLUSION

This review reinforces that the TVI is a distinct and clinically significant anatomical structure within the quadriceps femoris. Its presence and anatomical relationships support its relevance in surgical procedures, rehabilitation, and biomechanical stability of the knee. Although historically overlooked, growing anatomical and imaging evidence highlights the need for its inclusion in contemporary anatomical models and clinical practice. Greater awareness of the TVI may improve diagnostic precision, enhance surgical safety, and promote more effective rehabilitation strategies. Further studies are encouraged to deepen the understanding of its functional roles and clinical implications.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no financial, personal, or professional conflicts of interest that could have influenced the content or findings of this study.

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