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ORIGINAL ARTICLE

Unveiling the Tensor Vastus Intermedius – A distinct anatomical phenomenon or a standard variation? A comparative analysis of comprehensive literature and original cadaveric studies

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Abstract

Objective. The aim of this study was to enhance the understanding of the tensor vastus intermedius (TVI), a recently recognized addition to the quadriceps femoris muscle group, by conducting a systematic literature review with empirical cadaveric research to provide comprehensive data on its anatomical features, including dimensions, topography, variations, and prevalence.

Materials and Method. An exhaustive literature review was conducted using medical databases such as PubMed, MEDLINE, and Scopus. This review was complemented by original cadaveric research involving 30 autopsied adult bodies, encompassing 60 lower limbs, to empirically investigate the TVI's anatomical characteristics.

Results. The TVI was consistently identified in the medial aspect between the vastus lateralis (VL) and vastus intermedius (VI) in all examined cases. Detailed documentation covered its anatomical specifics, e.g. location, origin, and fascial connections, categorized using the criteria of Grob et al. Measurements of the muscle belly – length, width, and thickness – showed no significant lateral differences, but revealed gender-based disparities in TVI's size.

Conclusions. The review not only confirms the consistent presence of the TVI, but also addresses the discrepancies in existing literature about its anatomical distribution and dimensional metrics. The observed methodological variations in previous studies underscore the need for standardized research methodologies in muscle anatomy. This in-depth review analysis significantly contributes to a deeper understanding of TVI, proving particularly beneficial for professionals in rehabilitation and related medical fields.

Key words

quadriceps femoris, tensor vastus intermedius, TVI, QF, fifth head

INTRODUCTION

Current state of knowledge. The quadriceps femoris muscle (QF), belongs to the anterior group of muscles of the thigh. It is classically described as a muscle consisting of 4 heads – the rectus femoris muscle (RF), vastus medialis muscle (VM), vastus intermedius muscle (VI) and the vastus lateralis muscle (VL). Within the vastus intermedius muscle, the articular muscle of the knee is distinguished as its deepest layer. However, this muscle is not considered a separate head of the quadriceps muscle [1].

The first reports about the possibility of an additional head of the quadriceps femoris muscle were published many years ago [2–5]. The official description of the fifth head of the quadriceps femoris muscle dates back to 2016. In his study, Grob describes the fifth head of the quadriceps femoris muscle as the tensor muscle of the vastus intermedius (TVI) [6]. In 26 examined lower limbs from 16 donors, he found the presence of TVI between fascia VL and VI in all limbs. The author presented a classification of TVI depending on the possibility of separating the belly and tendon of this muscle from the neighbouring muscles. The classification distinguishes 5 variants of TVI. Following Grob's discovery, there was a need for a more detailed research on the prevalence of TVI, its dimensions, variants, as well as its function and clinical significance. So far, only a few works have been published based on original research exploring the anatomy of TVI. In his review, Franchi points out the need for further research to better understand the anatomy of TVI [7]. A year later in their review of existing TVI studies, Sahinis and Kellis

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state that more than half of the TVI studies included in the review were at a 'high' risk of bias in relation to various methodological issues, and therefore further high-quality studies assessing TVI morphology are needed. They also indicate a high variability in the incidence of TVI, ranging from 35% – 100% in cadaveric studies and approximately 83% – 100% in imaging studies [8].

OBJECTIVE

The primary objective of this review is to meticulously compare and contrast existing research findings on the prevalence, dimensions, and distribution of the Tensor Vastus Intermedius (TVI) types, as per Grob's classification, with the data meticulously collected gathered in own study. This comparative analysis not only aims to provide a more comprehensive understanding of the TVI's anatomical variations, but also seeks to underscore the profound significance of these anatomical nuances in the realms of physical therapy and clinical medicine.

In-depth knowledge of the TVI's various forms is crucial for clinicians and physiotherapists. Understanding these differences aids in the accurate diagnosis of musculoskeletal conditions and the development of targeted treatment plans. For instance, the size and shape of the TVI can influence the mechanics of the knee joint, impacting both the rehabilitation process following injuries and the management of such chronic conditions as osteoarthritis.

Moreover, the prevalence and specific type of TVI in a patient can also have implications for surgical procedures. Surgeons, aware of these anatomical variations, can better strategize their approach during interventions such as total knee arthroplasty or reconstructive surgeries of the knee. This knowledge is particularly pivotal in minimizing iatrogenic injuries and optimizing post-operative recovery.

Additionally, for physiotherapists, recognizing the variability in the TVI can enhance the effectiveness of therapeutic exercises and manual therapy techniques. Tailoring rehabilitation protocols to accommodate these variations ensures a more personalized and effective treatment, potentially accelerating recovery and improving outcomes for patients with knee-related issues.

Thus, this review not only contributes to the academic understanding of the TVI but also has significant practical implications in clinical and therapeutic settings. By providing a detailed comparison of the TVI's characteristics across different populations and synthesizing it with the authors' own findings, the aim was to bridge the gap between anatomical research and its application in medical and physiotherapeutic practice.

MATERIALS AND METHOD

The methodology of this review is bifurcated into a comprehensive literature review and empirical anatomical research. In the literature review segment, the focus was on analyzing the most recent and relevant scholarly articles concerning the Tensor Vastus Intermedius (TVI). The databases utilized for this purpose included PubMed, Scopus, Web of Science, and Google Scholar. This process involved a meticulous search using specific key words to ensure the inclusion of all pertinent studies, especially considering the relatively scarce literature available on this topic.

For the empirical part of the review, data were collected from dissections performed on adult cadavers at the Anatomy Department of the Medical University in Lublin, eadstern Poland. All preparations were protected with a typically prepared saturated formaldehyde solution. Ethical compliance was paramount, with consents obtained from the Prosecutor's Office and the family members of the deceased. The study involved a detailed examination of 60 lower limbs – 46 male and 14 female specimens.

Each dissection commenced with a standardized protocol, starting with a longitudinal incision from the mid-inguinal point to the patella on the front of each thigh. Following careful reflection of the skin and removal of both superficial and deep fascia, the quadriceps and sartorius muscles were exposed. To enhance the visibility of the TVI, the rectus femoris and sartorius muscles were transected distally and retracted proximally. The TVI was then identified between the vastus lateralis (VL) and vastus intermedius (VI) in the proximal part of each thigh.

The anatomical features of the TVI, such as its location, origin, and aponeurosis fusion point, were meticulously studied and classified according to Grob et al.'s system [6]. Measurements of the belly length of the muscle, width, and thickness were taken twice by two investigators; and the average of these measurements was recorded. Specimens with any lower limb anomalies or pathologies were excluded from the study. Finally, the collected data were statistically analyzed, focusing on parameters such as mean values, standard deviations, and comparisons based on size and gender. This dual approach of the literature review and empirical research provides a robust and comprehensive understanding of the anatomical variations of the TVI.

RESULTS

Literature analysis. This section of the study presents an analytical summary of the Tensor Vastus Intermedius (TVI) muscle, drawing on previous research, and the categorization of TVI types, as defined in Grob's study. In 2016, Rajasekaran provided the first ultrasonographic depiction of TVI, highlighting the superiority of cadaveric studies for identifying its proximal elements, which are often elusive in imaging techniques [9]. Following this, Veeramani's autopsy-based research in 2017 on South Indian subjects, examined 36 lower limbs, meticulously measuring the TVI, but not addressing gender differences or unilateral versus bilateral occurrence. This study, however, noted the variance in tendon attachment morphology [10] (Tab. 1–3).

Grob's 2017 MRI-based investigation of TVI prevalence [11] was soon complemented by a 2021 embryonic study revealing TVI's emergence at the CS 22 phase, marking it as the last developing component of the Quadriceps Femoris (QF) [12]. A Polish case report then revealed the existence of a double-bellied TVI, and an unprecedented sixth QF head originating from the vastus medialis [13] (Tab. 4). Further extending this understanding, a 2020 study identified a rare occurrence of seven QF heads [14].

A significant Korean study by Hyeng-Kyu Park examined 116 lower limbs, revealing disparities in TVI prevalence compared to prior research. Park's study was comprehensive,

Table 1. Comparison of the incidence of TVI and its types on the lower limb according to different authors

	TVI	ID	VL	VI	CM	2-B
Grobe (2016) [6]						
Total (n. 26)	26 (100%)	11 (42%)	5 (19%)	6 (23%)	4 (15%)	5 (19%)
Veeramani (2017) [10]						
Total (n. 36)	36 (100%)	12 (33.33%)	11 (30.56%)	3 (8.3%)	10 (27.78%)	3 (8%)
Hyeng-Kyu Park (2022) [15]						
Total (n. 116)	40 (34%)	21 (18.1%) – muscle part	12 (10.4%) – muscle part	7 (5.7%) – muscle part	0% – muscle part	0% – muscle part
		2 (1.7%) – tendinous part	27 (23.3%) – tendinous part	11 (9.5%) – tendinous part	0% – tendinous part	0% – tendinous part
M (n. 82)	29 (35%)	15 (18%) – muscle part	9 (11%) – muscle part	5 (6%) – muscle part	0% – muscle part	0% – muscle part
		2 (2%) – tendinous part	18 (22%) – tendinous part	9 (11%) – tendinous part	0% – tendinous part	0% – tendinous part
F (n. 34)	11 (32%)	6 (17%) – muscle part	3 (9%) – muscle part	2 (6%) – muscle part	0% – muscle part	0% – muscle part
		0 (0%) – tendinous part	9 (26%) – tendinous part	2 (6%) – tendinous part	0% – tendinous part	0% – tendinous part
Bonnechere (2019) [16]						
Total (n. 20)	7 (35%)	1 (5%) – muscle part	6 (30%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part
		4 (20%) – tendinous part	3 (15%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part
M (n. 8)	3 (37,5%)	1 (12,5%) – muscle part	2 (25%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part
		2 (25%) – tendinous part	1 (12,5%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part
F (n. 12)	4 (33%)	0 (0%) – muscle part	4 (33%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part	0 (0%) – muscle part
		2 (17%) – tendinous part	2 (17%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part	0 (0%) – tendinous part
Olewnik (2020) [17]						
Total (n. 106)	67 (63.2%)	44 (41.5%)	18 (17%)	3 (2.8%)	0 (0%)	16 (15.1%)
M (n. 68)	43 (63.2%)	34 (50%)	6 (8.8%)	1 (1.5%)	0 (0%)	14 (20.6%)
F (n. 38)	24 (63.2%)	10 (26.3%)	12 (31.6%)	2 (5.3%)	0 (0%)	2 (5.3%)
Results of own investigation – UMLub (2023)						
Total (n. 60)	60 (100%)	16 (27%) R – 6 (10%) L – 10 (17%)	20 (33%) R – 8 (13%) L – 12 (20%)	14 (23%) R – 11 (18%) L – 3 (5%)	7 (12%) R – 4 (7%) L – 3 (5%)	3 (5%) R – 1 (1.7%) L – 2 (3.3%)

n. – sample size; M – male; F – female; R – right side; L – left side

Table 2. Comparison of TVI length measurements according to different authors

	Average length of the muscle belly. (F)	Average length of the muscle's tendon (F)	Average length of the muscle belly. (M)	Average length of a muscle tendon (M)	Average length of the muscle belly.	Average length of the muscle's tendon
Veeramani et al. (2017) [10]	162.59 ± 47.41 mm	200.87± 35.64 mm	139.70± 32.72 mm	191.11± 44.68 mm	145.40± 37.55 mm R – 142.91± 39.37 mm L – 148.23± 36.40 mm	193.55± 42.32 mm R – 196.41 ± 45.05 mm L – 190.35 ± 40.18
Ruzik et al. (2021) [13]	-	-	105.57 mm – superficial 84.52 mm – deep	8.55 mm – superficial turns into deep 212.02 mm – deep	L - 105.57 mm – superficial 84.52 mm – deep	L - 8.55 mm – superficial turns into deep 212.02 mm – deep
Ruzik et al. (2020) [14]	-	-	110.73 mm	242.33 mm	-	-
Results of own investigation – UMLub (2023)	158.8 mm	-	142.5 mm	-	146.3 mm R – 142.8 mm L – 149.9 mm	-

M – male; F – female; R – right side; L – left side.

Table 3. Morphology of the end insertion of the TVI tendon

	Common attachment with the VL or VI tendon	Common attachment with the tendon VL and VI or VL and RF or VI and RF	Common attachment with the VL, VI and RF tendons
Veeramani (n. 36) [10]	26%	66.67%	8.33%

n. – sample size;

detailing gender-specific incidence, unilateral and bilateral occurrences, and TVI type distribution [15]. Bonnechère's dissection of 10 cadavers paralleled Park's methodology, focusing on gender-specific and unilateral/bilateral prevalence of TVI, and also considering QF in triceps form [16]. A summary of these studies is presented in Tables 1, 5.

Olewnik's innovative research proposed a new classification for additional QF heads, examining 106 lower limbs and

Table 4. TVI double belly measurements

	Ruzik et al. [13]		
	Superficial belly of TVI	Deep belly of TVI	6 QF head
Belly length	105.57 mm	84.52 mm	129.38 mm
Width of the belly at the beginning	22.92 mm	13.42 mm	26.17 mm
Thickness of the belly at the beginning	3.04 mm	2.02 mm	1.27 mm
Width of the belly at the transition to the tendon	14.07 mm	12.20 mm	5.68 mm
Thickness of the belly at the transition to the tendon	1.75 mm	1.70 mm	1.78 mm
Tendon length	8.55 mm	212.02 mm	147.15 mm
	Results of own investigation – UMLub		
	Belly 1	Belly 2	-
Belly length	180.0 mm	221,0 mm	-
Width of the belly at the beginning	27.0 mm	65.0 mm	-
Thickness of the belly at the beginning	19.1 mm	30.0 mm	-

Table 5. Comparison of the incidence of TVI in humans (bilateral, unilateral) taking gender into account.

		Mutually	On the right	On the left	Lack of TVI	TVI present
			Hyeng-Kyu Park (n=58) [15]			
M	41 (70.7%)	10 (24.4%)	3 (7.3%)	6 (14.6%)	22 (53.7%)	19 (46.3)
F	17 (29.3%)	5 (29.4%)	0 (0%)	1 (5.9%)	11 (64.7%)	6 (35.3)
Total	58 (100%)	15 (25.9%)	3 (5.2%)	7 (12.1%)	33 (56.9%)	25 (43.1%)
			Bonnechere (n=15) [19]			
M	4 (40%)	1 (25%)	1 (25%)	0 (0%)	2 (50%)	2 (50%)
F	6 (60%)	1 (17%)	2 (33%)	0 (0%)	3 (50%)	3 (50%)
Total	10 (100%)	2 (20%)	3 (30%)	0 (0%)	5 (50%)	5 (50%)

n.= sample size; M – male; F – female

identifying three primary types of additional heads and their subtypes. This study brought to light new TVI variations, including multi-bellied forms [17]. These were aligned with Grob's classification for comparative purposes, except for a unique type originating from the gluteus minimus, which was excluded from the TVI type statistics but counted in the overall TVI numbers. Notably, one four-bellied TVI type, previously only singularly documented [18], was not included in the TVI type statistics. Olewnik's dimensional analysis, varying significantly by type, is consolidated in Table 1.

The presented comprehensive examination of the literature and empirical data provides a nuanced understanding of TVI's anatomical diversity, contributing significantly to the field of muscle anatomy and its clinical implications.

RESULTS

In this study of 60 dissected lower limbs, the tensor vastus intermedius muscle was consistently identified. The TVI muscle belly is situated between the fasciae of the vastus lateralis (VL) and vastus intermedius (VI) muscles. The TVI morphology was categorized into five primary types based on the course of its aponeurosis. In 27% of cases (n=16), the TVI tendon was distinctly separable from both vi and vl (independent-type) (Fig. 1). The tvi's aponeurosis was fused with that of the vi in 23% (n=14) (vi-type), and separable from vi but not vl in 33% (n=20) (vl-type) (Fig. 2). in 12% of limbs (n=7), the TVIs aponeurosis could not be distinguished from either the vl or the vi (common type) (Fig. 3a). Additionally, a TVI variant with two bellies was observed in 5% (n=3) of cases, and a unique case, not previously described in Grob's classification, featured a TVI with two bellies and two independent tendons in a single male lower limb (Fig. 3b).

The mean length of the TVI was 14.63 ± 0.01 cm. The average lengths on the right and left sides were 14.28 ± 0.01 cm and 14.99 ± 0.01 cm, respectively. Notably, female lower limbs (only 14 in the sample) exhibited longer TVI muscles (15.88 ± 0.01 cm) compared to male muscles (14.25 ± 0.01 cm).

The TVI's average width was 5.07 ± 0.01 cm. The widths for right and left sides were 4.76 ± 0.01 cm and 5.39 ± 0.01 cm, respectively. Similar to length, TVI width was greater in female limbs (5.79 ± 0.01 cm) than in male ones (4.86 ± 0.01 cm).

The average thickness of the TVI was 3.48 ± 0.01 cm, with the right and left sides measuring 3.54 ± 0.01 cm and 3.43 ± 0.01 cm, respectively. All three dimensions – length, width, and thickness – were larger in females (4.31 ± 0.01 cm) compared to males (3.23 ± 0.01 cm).

The study included only three muscles with two bellies, but these showed greater dimensions in all aspects compared to other types.

In sixteen paired specimens (both sides dissected), the TVI was symmetrical. The independent (n=5) and VL-common (n=5) types were most common bilaterally. However, in the remaining fourteen pairs, different TVI types were observed on opposite sides.

No significant difference was found in the length, width, and thickness of the TVI between right and left sides, but notable distinctions were observed between the female and male TVI dimensions.

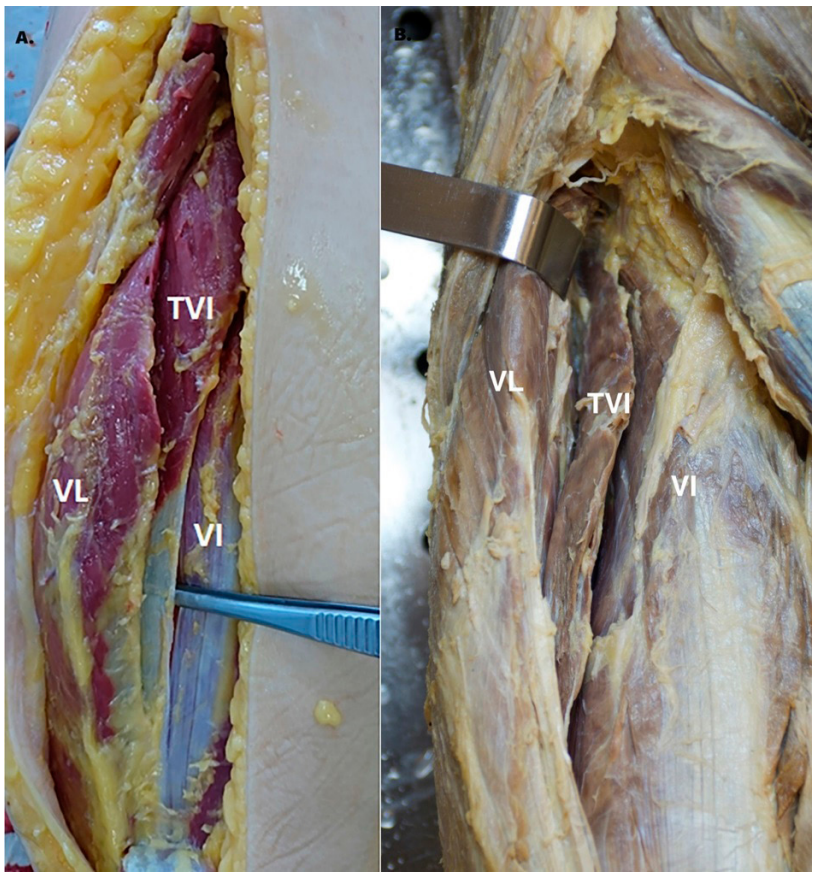

Figure 1. Independent type of TVI (1A, 1B).

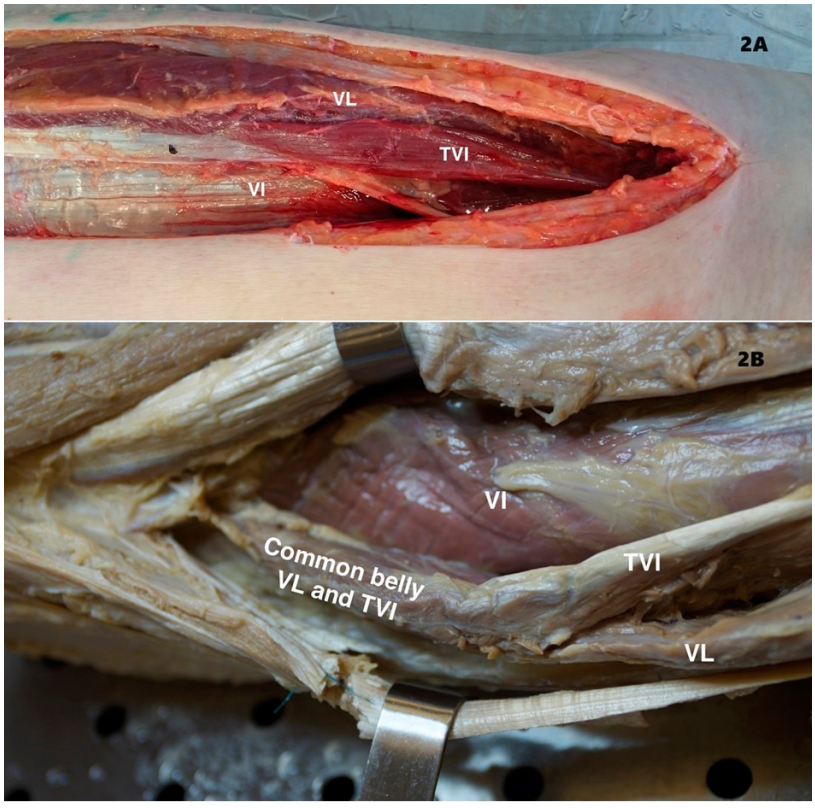

Figure 2. VL-type of TVI (2A; 2B).

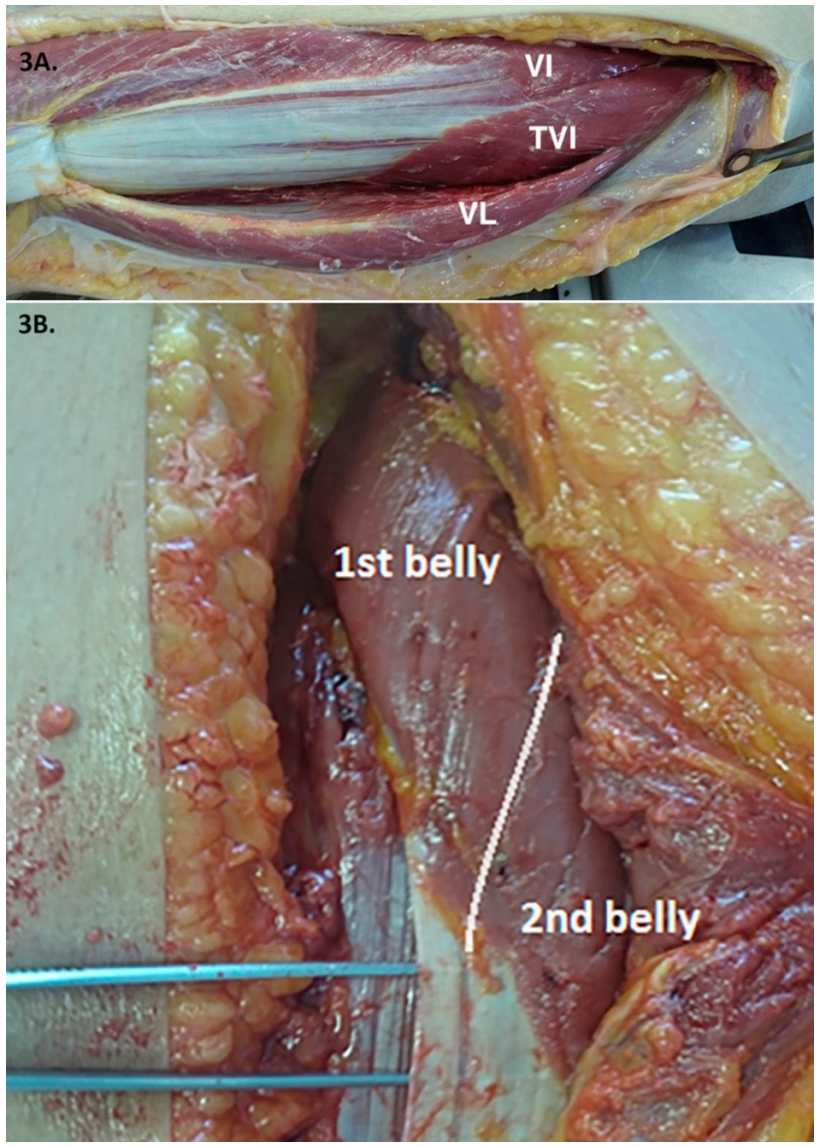

Figure 3. Common type of TVI; 3B. Two bellies with two independent tendons TVI.

DISCUSSION

The body of research on the tensor vastus intermedius (TVI), a relatively under-explored fifth head of the quadriceps femoris muscle, presents significant information yet remains fragmented and inconsistently categorized. Studies encompassing large sample sizes (exceeding 50 cadavers) exhibit a broad range in the reported prevalence of the TVI, with findings varying dramatically from 34% [15] to a full 100% [6, 10]. This wide discrepancy highlights the need for more rigorous and standardized methodological approaches in future research.

Two primary challenges confront researchers in this field. Firstly, the classification of TVI types is not uniform across studies. While the newly developed Olewnik classification aims to categorize emerging TVI types, even those appearing in rare instances [17], it is important to acknowledge that this classification may not encompass all possible variations. The second challenge lies in discrepancies in anatomical descriptions. While some researchers focus exclusively on the muscle portion of TVI, other authors [15, 16] emphasize the need to consider both muscle and tendon parts for a more comprehensive understanding.

The discovery of additional heads of the quadriceps femoris muscle in select instances opens new avenues for research. These findings, albeit sporadic, underscore the complexity and variability of muscular anatomy in the thigh region. Separate and focused studies on these muscles, independent of TVI research, are imperative for a detailed and systematic understanding of thigh muscle anatomy.

Standardization remains a critical gap in current TVI research. Most studies fail to use uniform parameters, often focusing solely on the incidence rate of TVI. Future studies should aim for a more holistic approach, considering factors such as unilateral versus bilateral occurrence, gender differences in TVI presence and morphology, and distribution of TVI types. Such a standardized approach will provide insights that are directly applicable to clinical and physiological contexts, especially for living subjects, rather than just anatomical specimens.

Dimensional measurements of TVI, including muscle and tendon sizes, have been largely overlooked. These

measurements are crucial for understanding the functional implications of TVI variations, as indicated by Hyeng-Kyu Park [15]. Detailed and standardized measurements across various types of TVI will contribute to a better understanding of its biomechanical role and potential clinical significance.

Lastly, the influence of body weight and height on TVI morphology remains an unexplored area. This aspect could be crucial in understanding the adaptive nature of muscle morphology in response to biomechanical demands placed on the lower limbs. Such insights could have significant implications for fields like orthopaedics, sports medicine, and rehabilitation, offering a more tailored approach to patient care, based on individual anatomical variations.

In conclusion, while the existing literature on TVI provides a foundation, there is a clear need for more comprehensive, standardized, and detailed research to fully understand the anatomical variations, functional significance, and clinical implications of this muscle.

Limitations of the study. The review has certasin limitations, including potential publication bias due to reliance on specific databases like PubMed, MEDLINE, and Scopus, while possibly overlooking unpublished or non-indexed studies. The small sample size and selection criteria in the cadaver study may limit the generalization of the findings. Additionally, the inherent nature of cadaveric research might not accurately reflect the anatomical variances in a living population. Methodological variability and the lack of standardized measurements across the reviewed studies further complicate the integration and comparison of literature and cadaveric data. These factors should be considered in the interpretation of the obtained results and highlight the need for more standardized approaches in future research.

CONCLUSIONS

The presented study on the tensor vastus intermedius (TVI), or the fifth head of the quadriceps muscle, offers significant insights for clinicians, suggesting a reconsideration of TVI as a normal anatomical variant rather than an anomaly due to its high incidence, which ranges between 34% – 100% in lower limbs, and 43.1% – 50% in cadavers. The occurrence of TVI is slightly higher in males, emphasizing the need for gender-specific approaches in diagnosis and treatment.

The Independent (ID) and Vastus Lateralis (VL) types were identified as the most common TVI variations, which are crucial for accurate diagnosis and effective treatment, particularly as they influence knee joint mechanics and rehabilitation outcomes. Gender-based anatomical differences were also observed, with female muscle bellies typically being thicker, wider, and slightly longer than those in males. These findings underscore the necessity for tailored therapeutic approaches.

The consistent results obtained underline the need for further research with a large number of dissected lower limbs. Future studies should focus on:

- the incidence of TVI in relation to both lower limbs and cadavers, considering unilateral and bilateral occurrences and gender differences;
- distribution of TVI types as per Grob's Classification, especially in muscle and tendon parts, and observing changes in type from muscle to tendon;
- measurements of TVI belly and tendon length, belly thickness at initial and final parts, and the morphology of the end attachment of the TVI.

Such research should also incorporate body weight and height as variables. This study aimed to systematize knowledge about TVI, acknowledging the diversity in literature reports. A unified scheme for assessing and examining the muscle should be considered in order to standardize findings and enhance clinical applicability. These conclusions contribute significantly to the field, paving the way for more personalized and effective patient care in rehabilitation and orthopaedic medicine.

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