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REVIEW Open Access

Reconsidering the nomenclature of the flexor digiti minimi muscles: a proposed solution to ambiguity in anatomical description

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Abstract

Background The nomenclature surrounding the 'flexor digiti minimi brevis' muscle prompts deliberation concerning its accuracy and potential variations. Addressing this uncertainty entails expunging the term 'brevis' from nomenclature references to the muscle, opting instead for the term 'flexor digiti minimi.' This nomenclatural adjustment currently being advocated raises inquiries about the necessity for descriptors denoting the muscle's specific placement along the upper or lower extremities. This study was conducted with a dual objective: to illuminate this topic and consolidate existing research on this issue.

Main body of the abstract Research encompassing the terms 'flexor digiti minimi' OR 'flexor digiti minimi brevis' was screened within this field. The inclusion criteria involved original articles, case reports, case series, relevant books, and book chapters. Excluded from this review were articles mentioning 'flexor digiti minimi' and 'digiti minimi' that were unrelated to the subject, as well as poster presentations, proceedings, conference materials, abstracts, and atlases.

Short conclusion In summary, changing the name of the muscle enhances anatomical understanding, promotes clarity and precision in communication, facilitates research efforts, and helps prevent confusion in medical education and clinical practice. These benefits highlight the importance of revising nomenclature to reflect anatomical accuracy and improve healthcare outcomes. It also promotes consistency in studies and allows for more meaningful comparisons across studies, ultimately advancing our understanding of anatomical variations and their clinical significance. Furthermore, it allows for more effective teaching and learning experiences, enabling medical practitioners to make accurate diagnoses, develop effective treatment strategies.

Keywords Flexor digiti minimi, Flexor digiti minimi brevis, Flexor digiti minimi longus, Foot, Muscle, Anatomy

1 Background

Medical education plays a pivotal role in comprehending the intricate nuances of anatomical variations and nomenclature revisions within musculoskeletal structures [1]. The deliberation over whether to retain the term 'flexor digiti minimi brevis' (FDMB) or opt for 'flexor digiti minimi' (FDM) and the potential presence of accessory muscles necessitates a profound understanding for medical practitioners. The flexor digiti minimi longus (FDML) muscle was found to be an accessory muscle, and it was suggested to be named as such due to its similar function and location with the FDMB muscle [2–4]. Therefore, the naming of the FDM muscle as '*flexor digiti minimi brevis*' should be reconsidered, depending on the possible presence of the accessory muscle. If the FDML muscle is an accessory muscle, why do we use the FDMB instead of FDM in both the hand and foot? It has been

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stated that the hand's fifth digit has a distinctly different flexor, which was named FDMB at first, and it has been mentioned that no indication of a FDML has so far been observed in the upper extremity [3]. It has been reported that this naming was made to mirror the *flexor pollicis brevis* (FPB) muscle in the thenar compartment with the corresponding digiti minimi muscle in the hypothenar compartment of the hand. This ensures a symmetrical alignment, including the reflection of the FPB [3].

The term 'flexor digiti minimi' is conventionally employed, encompassing a narrative review. The variations in nomenclature from specific sources led to the consideration and inclusion of the term 'flexor digiti minimi brevis' in the analysis. From an anatomical perspective, the presence of the brevis muscle implies the existence of its longus counterpart. Consequently, materials inclusive of the accessory 'flexor digiti minimi brevis,' sometimes denoted as 'longus' in certain studies [2, 3], were integrated into the study. This study was conducted with a dual objective: to illuminate this topic and consolidate existing research on this issue.

1.1 Anatomical variations of the flexor digiti minimi muscles in the hand

A substantial proportion of anatomical variations within muscular structures are typically asymptomatic and often encountered incidentally during surgery, imaging, or routine cadaver dissection [5]. Yet, once symptoms appear, they might encompass detectable swellings or, in specific instances, compression neuropathies, especially focusing on incidents occurring within Guyon's canal [6]. Such pathologies encompass a range of conditions, including traumatic injuries, benign, and malignant tumors located in this anatomical region [6]. An in-depth exploration of the anatomical intricacies discussed in this study can serve to enhance a surgeon's understanding and expertise, particularly in the context of diagnosing and treating various pathologies that can affect the hypothenar region. Various FDMB variations were documented, encompassing instances of its nonexistence, the occurrence of an additional palmar belly, its attachment to the metacarpal bone, and its fusion with the abductor digiti minimi (ADM) muscle [7–10]. These variations have been observed in terms of their origins from the antebrachial fascia [11, 12], convex surface of the hook of hamate bone [13], flexor retinaculum, opponens digiti minimi (ODM) muscle, the fibromuscular arch [10], medial epicondyle of the humerus [14], while in some instances, it was substituted by a tendinous sheath originating from the flexor carpi ulnaris muscle [8, 15, 16] or the tendon of the flexor carpi radialis muscle [9, 17]. It has been reported that the hand's FDMB or related accessory muscles commonly originated from the tendon of the palmaris longus muscle [18–22], the intracompartmental septum, or the ulnar tuberosity [2, 3, 23]. The palmaris longus and FDMB developed from the same embryological tissue, potentially elucidating the persistence and origin of the accessory FDMB. This phenomenon could be attributed to a failure of the tissues to fully migrate to the hand [24, 25]. The insertion of this muscle was identified at the fifth proximal phalanx resembling the scenario where an additional FDMB or FDML muscle was present [2–4, 6, 23, 26–28] (Fig. 1). The positioning of the hand's FDMB was lateral to the ADM muscle responsible for flexing the fifth digit at the metacarpophalangeal (MCP) joint. Its innervation was provided by the deep branch of the ulnar nerve [29, 30]. The FDMB of the hand does not cross the joint but provides strength and stability due to its relationship with the hamate bone in the wrist. The muscular fibers of the FDML might be fused with the FDMB or ADM muscle, or they may be attached to the distal end of the fifth metacarpal by a muscular slip [29]. The tendon of this muscle or muscle belly can pass through the carpal tunnel, Guyon's canal [4], or the superficial to the flexor retinaculum [2, 3]. The potential existence of this muscle might lead to compression within Guyon's canal, contribute to the development of a convoluted ulnar artery, and result in the compression of the ulnar nerve [4]. The length of muscle size could serve as a pivotal determinant in ascertaining the significance of an anomalous muscle in instances of ulnar nerve compression at Guyon's canal. It has been reported that the size of the muscle exhibits correlations with sex, hand dominance, and occupation [31].

Moreover, these variants could mimic soft tissue tumors, potentially leading to misdiagnoses such as ganglioma or lipoma [32, 33]. The presence of an accessory belly or anomalous muscle within the hypothenar compartment was observed to alter kinematics concerning flexion, adduction, or even abduction at the fifth MCP joint [32].

Studies have suggested various names for this accessory muscle [2–4, 23, 27, 28, 34, 35] (Table 1). Beser et al. suggested that when this unusual hypothenar muscle of the hand is present, it should be named *FDML* or *accessory FDMB* because it has the same insertion and a similar function to the FDMB of the hand [2, 21, 36]. In another study, this accessory muscle was named *FDM profundus* based on its origin, location, and function [23]. However, Saadeh et al. named this muscle as an *accessory flexor (opponens) digiti minimi* [11]. Georgiev et al. classified the muscle in question as an unreported variant muscle, identified as a *deep abductor/flexor of the little finger*. Their study disclosed the existence of two proximal tendons within the FDMB muscle [26]. The medial tendon was attached to the hamulus, while the unusual

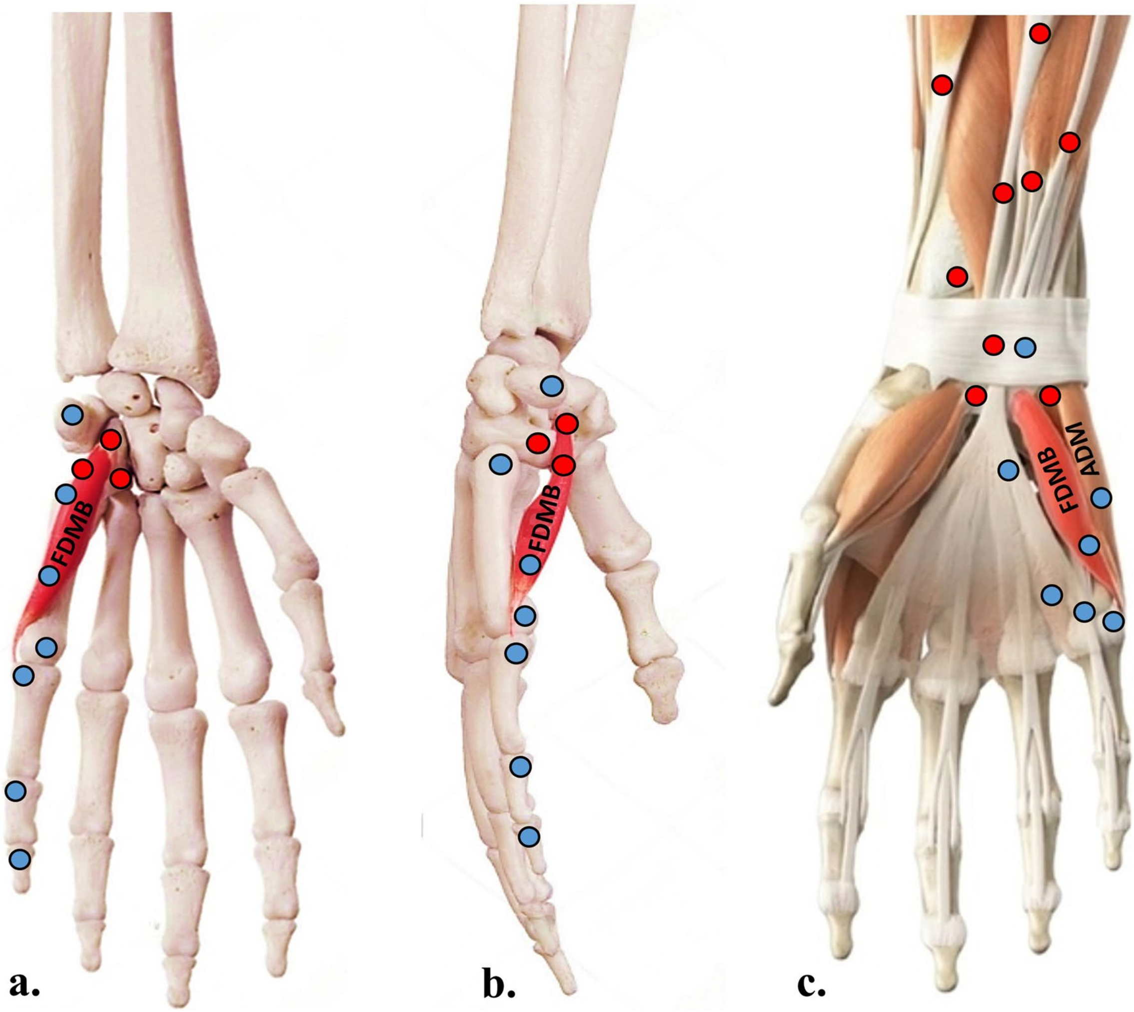

Fig. 1 **a** Anatomical position (left hand). After removing the palmar muscles and aponeurosis of the hand, the representation of the FDMB and the potential location of FDML or accessory FDMB were identified. **b** supine position (left hand). The red dots depict potential origins (hook of hamate bone, FDMB), while the blue dots illustrate potential insertions (fifth proximal, middle, distal phalanges, fifth metacarpal bone, FDMB, pisiform bone) for FDML or accessory FDMB in accordance with the literature. **c** Anatomical position (right hand). The red dots, representing potential origins (including the tendon of flexor carpi radialis, antebrachial fascia, tendon of palmaris longus, flexor retinaculum, tendon of flexor digitorum superficialis, tendon of flexor carpi ulnaris, intercompartmental septum, ODM), are indicative, whereas the blue dots illustrate potential insertion points (comprising ADM, FDMB, proximal phalanx of the fifth digit, palmar aponeurosis, tendon of flexor digitorum profundus, flexor retinaculum, ODM) for FDML or accessory FDMB, in accordance with the literature. *ADM* Abductor Digiti Minimi, *ODM* Opponens Digiti Minimi

lateral one had its origin in the lateral section of the flexor retinaculum [26]. Notably, both the aberrant lateral tendon of the FDMB and the lateral side of the deep abductor/flexor traversed over the palmar branch of the ulnar nerve, indicating their probable clinical significance concerning ulnar nerve compression [8]. This accessory head could potentially worsen damage to the superficial palmar branch of the ulnar artery due to its compressive effects, potentially leading to luminal thrombosis and thickening of the intima. Along its trajectory, this muscle intersected with both the median nerve and ulnar artery [37]. Due to its robust structure and its pathway intersecting both the ulnar and median nerves, this specific variation of FDMB might have caused effort-related pain for a patient during activities involving grip or prehension [38]. Such variations may have been implicated in the development of peripheral neuropathy, which would otherwise pose challenges in explanation [38].

1.2 Anatomical variations of the flexor digiti minimi muscles in the foot

Accessory anatomical structures in the foot typically manifest as inadvertent imaging observations. They can potentially evolve into sources of pathology, giving rise to

Table 1 Previous studies on anatomical variations and nomenclature of the accessory flexor digiti minimi muscles of the hand

Author	Year	Place	Study design	Names	Origin	Insertion	Function	Innervation	Significance
Morrison	1916	France	Cadaver (left side)	Accessory flexor muscle of the little finger	The tendon of the palmaris longus	Pisiform and base of the 5th metacarpal bone	Flexion of the little finger with a noticeable inclination toward opposition	The branch of the ulnar nerve and the trunk of the median nerve	The variable palmaris longus muscle is reported to occasionally have a digastric nature, with insertions into the muscles of the thumb or little finger
Carr	1977	UK	Cadaver (right side)	An unusual digastric flexor muscle of the 5th finger	The medial epicondyle of the right humerus	The proximal phalanx of the 5th finger	Flexion of the little finger	N/A	Simultaneously, the absence of the FDM and the unusual diminutiveness of the tendon of the flexor digitorum superficialis were observed
Sälgeback	1977	Sweden	Case	FDMB accessorius	N/A	N/A	Flexion	Deep branch of ulnar nerve	Ulnar tunnel syndrome
Saadeh	1988	Lebanon	Case	An accessory flexor (opponens) digiti minimi muscle	Antebrachial fascia	An additional slip extending to the 5th metacarpal bone	N/A	N/A	Multiple muscle variations can be observed in the same individual and on the same side
Zeiss	1992	USA	MRI (36 normal wrists,16–38 years)	FDMB and anomalous muscles	The fibromuscular arch	ADM	Flexion	Deep branch of ulnar nerve	MRI played a role in diagnosing ulnar nerve abnormalities, ulnar tunnel anatomy and anomalous muscles
Pribyl	1994	USA	Case	Anomalous hand muscle found in the Guyon's canal	Flexor carpi ulnaris	FDMB	N/A	Ulnar nerve	The consideration of ulnar artery thrombosis as a diagnosis arises when a patient reported symptoms such as ulnar neuropathy, hand ischemia, or the presence of a mass in the hypothenar region

Table 1 (continued)

Author	Year	Place	Study design	Names	Origin	Insertion	Function	Innervation	Significance
Spinner	1996	USA	Plain radiography, MRI (Case, 20, Female)	Anomalous origin of FDMB	Hook of hamate	ADM, neural loop	Flexion	Ulnar nerve	The compression of the medial deep branch of the ulnar nerve by an anomalous tendon, which penetrated through, led to an atypical presentation of ulnar neuropathy
Wahba	1998	Canada	Cadaver	Accessory FDM profundus	Medial intercompartmental septum	The proximal phalanx of the fifth digit	Flexion of the MCP joint of the fifth digit	Ulnar nerve	It possibly affects ulnar nerve function and circulation in the hand
Uz	2002	Turkey	Cadaver (bilateral, 60 male)	Accessory FDMB	Flexor retinaculum	FDMB	Flexion	N/A (close to median nerve)	The existence of accessory muscles holds significance in the context of hand surgery
Madhavi	2003	India	Cadaver (adult male)	Anomalous FDMB	Superficial transverse septum	Guyon's canal superficial to the ulnar nerve and vessels, hypothenar eminence	Flexion	Ulnar nerve	The ulnar tunnel syndrome
Kobayashi	2003	Japan	Cadaver (right hand, female)	Anomalous flexor of the little finger	The midpoint of the volar surface of the flexor retinaculum	The palmar base of the middle phalanx of the 5th finger	Flexion	A branch of the median nerve	The lack of migration of the palmar anlage resulted in the development of an additional muscle belly
Wingerter	2003	USA	Cadaver (right hand)	An unusual origin of the FDMB	The anterior aspect of the transverse fibers of the distal antebrachial fascia	The base of the fifth proximal phalanx	Flexion of fifth MCP joint	The deep branch of the ulnar nerve	Knowledge of anomalous muscles in the hand has important clinical significance in surgery and in determining associated pathology
Bakinde	2005	Switzerland	Cadaver (both hands, 77 male)	Accessory muscle in the hypothenar region	The tendon of the flexor carpi radialis	The ADM muscle into the ulnar aspect of the base of the fifth proximal phalanx	1. Palmar flexion 2. Rotation of the fifth finger toward the radial side, flexion of the fifth proximal phalanx, and weak abduction of the fifth finger	A branch arising from the main trunk of the ulnar nerve	This muscle variations can cause various clinical symptoms, compression of the ulnar nerve in the Guyon's canal, Dupuytren contracture, and trauma

Table 1 (continued)

Author	Year	Place	Study design	Names	Origin	Insertion	Function	Innervation	Significance
Hill	2006	Iran	Cadaver	An unusual muscle of the wrist	The tendon of the flexor carpi ulnaris	The muscle belly of FDM	Flexion	Ulnar nerve	The possibility of compression of the ulnar nerve by such muscles
Georgiev	2007	Bulgaria	Cadaver (left hand, 64-year-old female)	The deep abductor/flexor of the little finger	The lateral belly: lateral part of the flexor retinaculum The medial belly: hamulus of the hamate bone	The anterolateral base of the fifth proximal phalanx	Abduction and flexion	The palmar branch of the ulnar nerve	It causes ulnar nerve compression
Greiner	2008	Wisconsin (USA)	Cadaver (left, 68 year ol male)	An additional flexor of the fifth digit: FDML	The distal medial of the ulnar tuberosity, distal to the insertion of brachialis muscle	The fourth lumbrical, fifth digital ray of flexor digitorum profundus, base of the distal phalanx	Flexion	The ulnar nerve and dual innervation	The flexor digitorum profundus that arise off the coronoid process, but make no mention of muscular insertions. This muscle is the first identified and described example of FDML
Cope	2013	USA	Cadaver (left hand, female)	A robust FDMB muscle	The proximal attachments were found on the hamate bone and the flexor retinaculum	Its distal attachment was located on the anteromedial surface of the proximal phalanx of the fifth digit	FDMB might have caused effort-related pain for a patient during activities involving grip or prehension	The median and ulnar nerves	These variations could have led to peripheral neuropathy that would otherwise be difficult to explain
Claassen	2013	Germany	Review	Accessory heads of FDM	Flexor retinaculum, antebrachial fascia, long flexor muscles of the forearm	Head of the 5th metacarpal bone, 5th proximal phalanx	Flexion of the proximal interphalangeal joint	Ulnar nerve	It causes ulnar nerve compression or median nerve compression, paresthesia, decreased sensation, and ulnar side of the 4th and 5th finger pain caused by cervical radiculopathy, thoracic outlet syndrome

Table 1 (continued)

Author	Year	Place	Study design	Names	Origin	Insertion	Function	Innervation	Significance
Saran	2014	India	100 cadaver upper limbs (80 male and 20 female)	Absence of FDMB and accessory slips	Antebrachial fascia	ADM	Flexion of the little finger at MTP joint and lateral rotation	Deep branch of the ulnar nerve	The existence of an accessory slip was found to potentially induce compression, resulting in ulnar nerve entrapment. Its absence could contribute to hypothenar hammer syndrome through direct compression of the ulnar artery
Vanguri	2015	India	Cadaver (right hand, male)	Accessory head of FDM	The medial side of the palmaris longus tendon	The palmar aspect of base of the fifth proximal phalanx	Flexion of fifth MCP joint	Ulnar nerve	It causes ulnar nerve compression and enhance injury to superficial palmar branch of the ulnar artery
Beser	2015	Turkey	Cadaver (right, 61 year ol male)	An accessory FDMB or FDML	The tendon of palmaris longus	Medial base of fifth proximal phalanx	Flexion	Ulnar nerve	Ulnar nerve compression, hypovascularity symptoms due to the compression of ulnar artery
Sailabala	2015	India	Cadaver (right hand, male)	Accessory head of FDM	The medial aspect of the palmaris longus tendon, positioned just proximal to the wrist joint	The palmar aspect of the base of the proximal phalanx of the 5th digit	Flexion	The median and ulnar nerves	It modified the kinematics of fifth MTP joint. It had the potential to induce compression, resulting in ulnar nerve entrapment, and its compressive actions might exacerbate injury to the superficial palmar branch of the ulnar artery, potentially causing luminal thrombosis and intimal thickening

Table 1 (continued)

Author	Year	Place	Study design	Names	Origin	Insertion	Function	Innervation	Significance
Roman	2016	Chile	2 Cases	The prominent accessory muscles at the distal forearm	Anteromedial side of palmaris longus tendon and antebrachial fascia, flexor carpi ulnaris tendon	ADM, palmar aponeurosis, flexor retinaculum	Flexion of the wrist and fifth finger along with ulnar deviation and abduction against resistance	Ulnar nerve	Accessory muscles have the potential to compress underlying structures in the carpal or ulnar tunnel, resulting in pain and paresthesia
Moraes	2018	Brazil	Cadaver (left hand, adult)	An anomalous FDMB	Hamulus of hamatum and the flexor retinaculum	The base of the proximal phalanx of the fifth finger and the tendon of ADM	Flexion	The deep branch of the ulnar nerve	Ulnar nerve compression, repetitive minor traumas, and muscular hypertrophy
Moore	2018	Canada	Cadaver (left hand, 83 male)	Accessory FDMB	Distal tendon of the palmaris longus	Base of the proximal phalanx of the fifth digit	Flexion	A branch of the ulnar nerve	Accessory muscles and their aberrant innervation patterns have the potential to complicate surgical procedures, leading to the compression of arteries and nerves, ultimately causing upper limb pain and paresthesia
Nation	2019	USA	Cadaver (right hand, 94-year-old female)	The additional flexor muscle (FDML)	The distal two thirds of antebrachial fascia	It passed through Guyon's canal	It is not clear if muscle function was affected	Ulnar nerve	The compression of Guyon's canal, median, and ulnar nerves
Patil	2021	USA	Cadaver hands (30)	FDM	The fibrous arch-like connection between FDM and the ADM The FDM muscle origin was situated radial to the origin of the ADM muscle by an average of 14 mm (range, 8–24 mm) the convex surface of the hook of hamate and flexor retinaculum	The distal part was fused to the ADM (55%) inserts onto the ulnar side of the base of the proximal phalanx of the little finger	Its radially located origin was a positional advantage while being used for opposition	The deep branch of the ulnar nerve	FDM muscle was absent in 33% of hands It had positional advantage over the ADM for opponensplasty FDM can be transferred if it is found to be suitable in surgery

painful syndromes, degenerative alterations, susceptibility to excessive use and injury, or appearing as growths causing entrapments [39–41]. The main FDMB muscle of the foot, positioned medially to the ADM muscle, originates at the medial plantar aspect of the fifth metatarsal bone and the peroneus longus tendon sheath [29, 42]. It is inserted to the lateral aspect of the base of the proximal phalanx of the fifth toe [43]. In the literature, accessory FDM muscles of the foot have been reported that provide flexion of the fifth toe [44, 45]. These accessory muscles originate from various sites, such as the tendon of the tibialis posterior, the fifth metatarsal bone, or the fourth metatarsal bone, tendon of peroneus longus [42] and insert into the fifth toe, anterior frenular ligament, and ODM [44, 45] (Fig. 2). Its distal tendon usually extends laterally to the ADM muscle, and its deeper fibers extend laterally to the distal half of the fifth metatarsal to form the ODM muscle [29]. In a study, the ADM and FDMB muscles were found to deviate from their normal positions, exhibiting a variable arrangement where the ADM muscle was situated beneath the FDMB. The underlying cause of this variation could be attributed to genetic factors or patterns of use [46]. The possible presence of this muscle provides structural support to protect the lateral

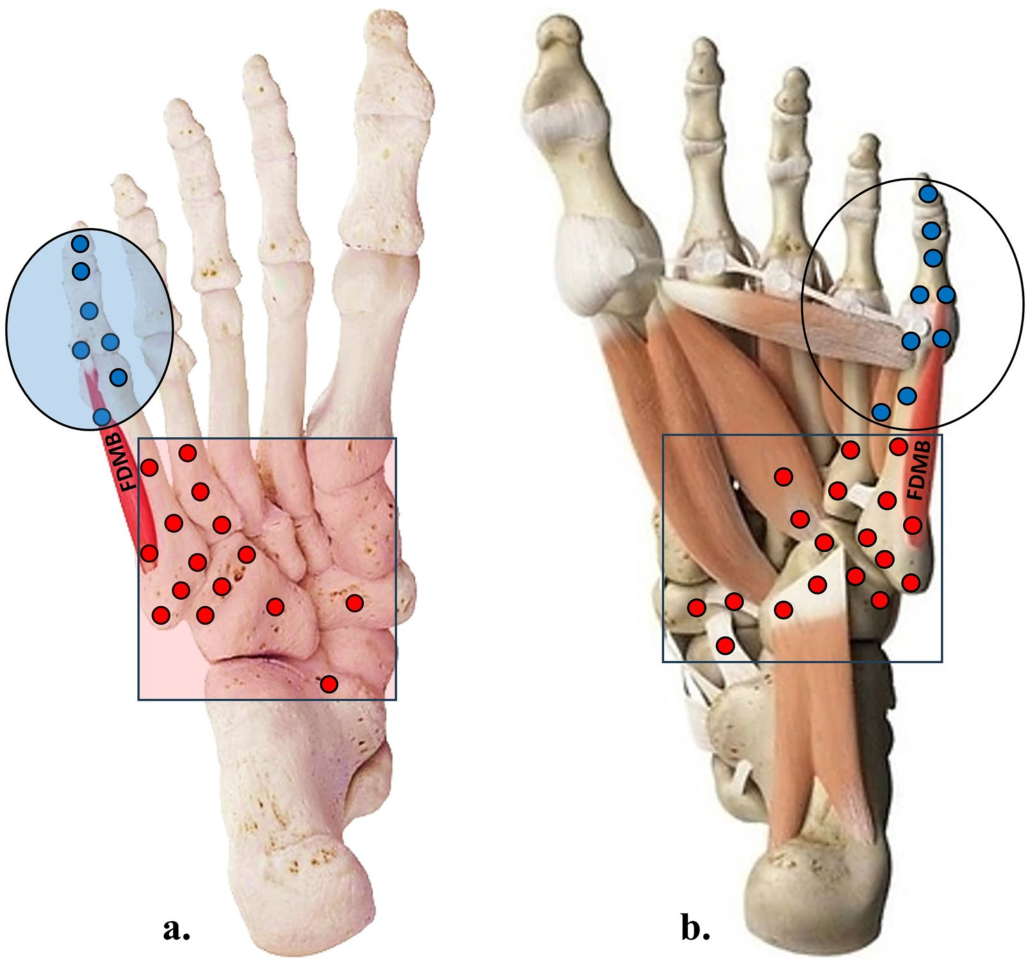

Fig. 2 **a** Following the removal of the plantar muscles of the foot, the representation of the FDMB and the potential location of FDML or accessory FDMB were indicated. The FDMB originates from the base of the fifth metatarsal bone and inserts at the base of the proximal phalanx of the fifth digit. The red dots within the rectangle depict potential origins (The 4th and 5th metatarsal bones, attachment sites of tendon of tibialis posterior, peroneus longus muscles, FDMB) for FDML or accessory FDMB in accordance with the literature. The blue dots within the circle illustrate potential insertions (proximal, middle and distal fifth phalanges, head of fifth metatarsal bone, FDMB) for FDML or accessory FDMB according to the literature. **b** The plantar view following the removal of the first and second layers of plantar muscles of the foot. The square, marked with red dots, indicates potential origins (The 4th and 5th metatarsal bones, tendon of tibialis posterior and peroneus longus muscles, adductor hallucis) while the circle, marked with blue dots, represents potential insertions (proximal, middle and dital phalanges of the fifth toe, fifth metarsal bone, anterior frenular ligament, ODM). Despite its nomenclature, it is more anatomically precise to refer to it as the 'Flexor Digiti Minimi' due to the absence of a longus muscle or tendon in the foot. For greater accuracy, the term 'Flexor Digiti Minimi Pedis' in the foot is recommended

longitudinal arch of the foot. Currently, there is no evidence suggesting the existence of the FDML muscle in humans. Several instances of additional digital flexors delineated as adaptations originating from the flexor digitorum profundus muscle [34]. Similarly, few studies have documented diverse variations or configurations regarding the attachment of variant muscles [44, 45, 47] (Table 2). In an earlier investigation, an assessment of bilateral differences was documented, highlighted a correlation between increasing age and a reduction in both amplitude and area [48]. In the event of their presence, accessory FDM muscles might have acted as compensatory elements for the absent segment of the related muscle [49]. It is essential to note that this observation is based on available anatomical evidence and may be subject to change if new evidence emerges.

2 Main text

2.1 Methodology

For this narrative review, articles were acquired independently from various databases, including Scopus, Web of Science, Science Direct, JSTOR, PubMed, and iCITE. The methodology involved a two-stage analysis. Initially, a preliminary search and screening were conducted on results to establish the framework for subsequent analysis. This preliminary search revealed a limited number of publications meeting the criteria of interest. Consequently, the decision was made to include case reports and case series in this review. Additionally, this initial search brought attention to significant data heterogeneity. The second search encompassed publications in any language, using search terms combining 'Flexor Digiti Minimi Brevis' [MeSH Terms] with variations including 'Accessory Flexor Digiti Minimi Brevis [Title/Abstract]' OR 'Accessory Flexor Digiti Minimi Muscle' OR 'Accessory Flexor Digiti Minimi Brevis Muscle' OR 'Flexor Digiti Minimi Brevis of the foot' OR ' Flexor Digiti Minimi Brevis of the hand' OR 'Accessory Flexor Digiti Minimi' OR 'Flexor Digiti Minimi Longus.'

2.1.1 Studies selection and eligibility criteria

All studies meeting the inclusion criteria were assessed, including original articles, meta-analyses, retrospective studies, cross-sectional analyses, systematic or comprehensive reviews, cohort studies, case reports, case series, books, and book chapters. A single author conducted relevance screening by evaluating titles and abstracts, followed by a thorough examination of complete texts.

2.1.2 Inclusion criteria

Incorporated into the study were all relevant studies, original articles, case reports, case series, retrospective studies, relevant books, and book chapters detailing FDMB muscle and accessory FDMB or FDML.

2.1.3 Exclusion criteria

Publications lacking original data were excluded, along with those featuring overlapping study populations. Excluded from this review were articles mentioning 'flexor digiti minimi' and 'digiti minimi' that were unrelated to the subject, as well as poster presentations, conference materials, abstracts, proceedings, and atlases.

2.1.4 Evaluation

This narrative review was categorized based on a specific classification system if the provided information allowed for extraction. In instances where details were insufficient, complications were individually addressed and documented separately.

3 Discussion

3.1 Muscle development: an overview

Numerous distinctions existed in the muscular composition between the hand and foot, which became readily apparent through superficial gross anatomical comparisons in adults [50]. Cihak's research from 1972 had indicated that the blastema of the ODM and FDMB, both derived from the flexor brevis profundus, became apparent at crown rump length (CR) 20 mm. Complete differentiation of these two muscles occurred CR 40 mm. Conversely, Bardeen had suggested that the blastema emerged at CR12 mm, with the onset of differentiation commencing at CR18 mm [51]. At the point CR30.5 mm, these two muscles exhibited incomplete differentiation. However, by CR36 mm, a substantial level of differentiation was observed in them (even though both remained present at CR51 mm, with the opponens having reduced in size significantly by that stage). The latter muscle had been initially present in early stages but progressively diminished during fetal development [50]. This timing of differentiation corresponded more closely to Cihak's proposed schedule. Moreover, the time of blastema appearance, which gave rise to both muscles, appeared to align more closely with Cihak's findings [51]. Significantly, at CR12 mm, discernible primordia of hand muscles had not yet emerged. However, in humans, the development of the hand had already progressed ahead of the foot at this stage [50]. In the course of limb development, myogenic cells, originating from somatic sources, give rise to primary dorsal and ventral premuscular masses. Subsequently, these masses undergo differentiation, leading to the formation of distinct muscles. Excessive division of these cells within the hypotenar eminence can result in the development of accessory muscle slips or extra variants [52]. The origin of these anomalies and fibrous

Table 2 Previous studies on anatomical variations and nomenclature of the accessory flexor digiti minimi muscles of the foot

Author	Year	Place	Study design	Name	Origin	Insertion	Function	Innervation	Clinical relevance and significance
Asomugha	2005	Nigeria	Cadaver (left foot)	Accessory FDM	Tendon of tibialis posterior	The middle phalanx of the fifth toe	Flexion of the fifth toe	Medial plantar nerve	It helps the FDM muscle and causes abnormal swelling in MRI and ultrasound
Rana	2006	India	Case	FDM muscle	Plantar surface of base of the fifth metatarsal bone and the sheath of the peroneus longus tendon	ADM muscle, distal phalanx, plantar deep transverse metatarsal ligaments	It may take part in the biomechanics of the FDM muscle	Lateral plantar nerve	Surgeons should be aware of the inadvertent injury and compression of adjacent nerve
Mehta	2011	India	Cadaver	FDMB	The tendon of the tibialis posterior, the fifth metatarsal bone, or the fourth metatarsal bone	It inserts into the fifth toe	Flexion of the fifth toe	N/A	These anatomical variances mitigate the occurrence of post-operative risks and complications, prompting surgeons to meticulously strategize their surgical approaches
Lucaciu	2007	Canada	Cadaver (76,Female,Case)	Accessory FDMB muscles	The tendons of the two accessory FDM muscles had merged into a single tendon before the 5th MTP joint	The middle phalanx of the 5th toe	Two accessory FDM muscles seemed to have compensated for the absent section of the FDB muscle	N/A	Biomechanical compensation likely played a role in guiding myotomal cell migration during embryogenesis and could have helped explain the occurrence of muscular variants
Buschbacher	1999	USA	205 volunteers	FDMB	The normal variance between the medial and lateral branches was a 3.5 ms elevation of the lateral latency over the medial latency or a medial latency within 0.3 ms of the lateral latency	The maximum threshold for interlimb latency divergence was either 1.8 or 1.5 ms	Side-to-side variability	The conduction of tibial nerve	A correlation was observed between advancing age and a decline in both amplitude and area
Edema	2020	Japan	Cadavers (52)	FDMB	The peroneus longus tendon	Additional band: anterior frenular ligament, ODM	N/A	N/A	These variations and functions seem to be linked to a challenging diagnosis during the initial clinical assessment

Table 2 (continued)

Author	Year	Place	Study design	Name	Origin	Insertion	Function	Innervation	Clinical relevance and significance
Knellwolf	2019	Australia	12 healthy subjects (18–40 years)	FDMB	N/A	N/A	FDMB displayed a response to passive flexion and abduction of the fifth MTP	Tibial nerve	Spindle endings in the intrinsic muscles of the foot contribute valuable proprioceptive information during free standing
Karip	2021	Turkey	Cadaver	FDMB	Base of the fifth metatarsal bone	Base of the fifth proximal phalanx	The normal function of the lateral plantar aspect	N/A	The ADM and FDMB muscles were favored choices in the treatment of certain diseases as flaps

structures within the hand can be attributed to an undifferentiated set of mesenchymal cells. These cells are linked to the superficial layer of muscular anlagen found within the hand, positioned amid the muscle blastema of the flexor digitorum superficialis (which possesses migratory capabilities) and that of the ADM or FDMB variations [53]. These muscles also present themselves as anomalies in congenital malformations and anomalies might be linked to delayed or halted developmental processes [50]. Biomechanical compensation probably influenced the migration of myotomal cells during embryonic development and might contribute to elucidating the occurrence of muscular variations [49, 54].

3.2 Clarifying nomenclature and enhancing anatomical understanding in flexor digiti minimi muscles

When discussing these muscular structures, two inquiries arise. First, if there is no FDML muscle, why do we use the expression FDMB in both the hand and foot? The question to be asked here is whether the FDML is considered an anatomical variant or whether the FDMB is misnamed. If it is misnamed and there is no FDML muscle, the word *'brevis'* should be removed from all anatomy texts and atlases for the FDMB muscle, and only FDM should be used. However, suppose its occurrence in some individuals as a variant muscle is considered. In that case, a new nomenclature should be made, considering the presence of all accessory muscles. In addition, the knowledge of variant muscles provides a better explanation of clinical conditions such as associated pathology, nerve entrapments, dysfunction, or pain and a better imaging interpretation.

The second question that comes to mind is, when we say FDMB muscle, whether there is a need for a word, indicating that it belongs to the upper or lower extremities. For example, the expression *'pollex'* denotes the thumb, and the term *'hallux'* denotes the big toe. Such an expression can also denote the fifth fingers of the hand and toes because when we only say FDM muscle, it is not clear whether it is in the hand or the foot. Perhaps using the muscle names 'FDM *pedis*' for the foot and 'FDM *manus*' for the hand in the atlas to replace 'FDMB' for both hand and foot and removing '*brevis*' from both will clear up the confusion. Additionally, a new nomenclature should be considered that takes into account the presence of accessory muscles, to provide greater clarity and accuracy in anatomical descriptions. This could involve revising the naming convention of the FDM muscles, as well as determining whether modifiers are necessary to indicate their location in the upper or lower extremities. Moreover, the complexities surrounding the naming of these muscles highlight the need for meticulous anatomical education. The potential ramifications of variant muscles, such as entrapments, pathologies, and dysfunctions, underscore the importance of comprehensive medical education to facilitate accurate clinical assessments and informed decision making [1, 40, 41].

Furthermore, the query regarding upper or lower extremity context in muscle nomenclature brings forth the necessity for precise terminology to communicate anatomical concepts effectively. Medical education serves as the foundation for understanding such distinctions, ensuring clear and unambiguous communication among healthcare professionals. Proposing a revised nomenclature that integrates the presence of accessory muscles and specifies extremity location highlight the role of medical education in fostering accurate anatomical comprehension. In essence, medical education is indispensable in deciphering the intricate relationships, variations, and terminologies within anatomical structures. It equips medical practitioners with the knowledge needed for accurate diagnoses, effective treatment strategies, and optimal patient care, ultimately contributing to advancements in clinical practice and research.

3.3 Suggestions

Changing the name of the muscle in anatomical education and research settings has far-reaching implications for enhancing anatomical comprehension, facilitating accurate clinical assessments, and advancing medical knowledge in the field of musculoskeletal anatomy. Clear and precise nomenclature is fundamental in medical education to ensure accurate comprehension of anatomical structures. Revising the nomenclature of the FDM muscle could clarify whether the term 'brevis' accurately reflects its anatomical characteristics or if it should be revised to reflect potential variations, such as the FDML. Incorporating a revised nomenclature that accounts for accessory muscles and specifies the location in the upper or lower extremities could enhance students' understanding of anatomical concepts and promote clarity in medical education materials such as textbooks and atlases.

It also allows researchers to accurately describe and categorize anatomical variations, including the presence of accessory muscles. Addressing the naming ambiguity surrounding the FDM muscle facilitates more precise anatomical descriptions and classifications, contributing to a deeper understanding of anatomical variations and their clinical implications.

Clear and consistent muscle nomenclature aids in clinical assessments, diagnoses, and treatment planning. Improved anatomical understanding resulting from revised nomenclature supports more accurate clinical evaluations of patients with musculoskeletal disorders, nerve entrapments, and other related conditions. Enhanced anatomical comprehension through medical education facilitates informed decision making among healthcare professionals, leading to better patient outcomes and advancements in clinical practice.

A revised terminology that integrates anatomical specifics not only aids in anatomical comprehension but also provides valuable insights into related clinical conditions. These considerations highlight the crucial role of medical education in advancing anatomical knowledge and fostering accurate clinical assessments. Clear indications of muscle location in the upper or lower extremities help avoid confusion among healthcare professionals and students. It ensures that anatomical terms are interpreted accurately, reducing the risk of miscommunication and errors in clinical practice and research.

3.4 Limitations

The variations in musculoskeletal structures are often individual-specific, making it challenging to establish a standardized nomenclature that accommodates all possible configurations. Additionally, anatomical studies may not capture the full spectrum of variations, leading to potential gaps in our understanding. Moreover, the naming conventions used in medical literature and education have historical and traditional roots, and changing them requires a consensus among the medical community, which can be a lengthy process. The limitations in this paper emphasize the complexity of anatomical variations and the need for continued research and consensus building in the field of medical education and anatomical terminology.

4 Conclusions

A revised nomenclature eliminates ambiguity and ensures clear communication among healthcare professionals, educators, and researchers. By accurately naming muscles based on their anatomical location and characteristics, we enhance the precision of anatomical descriptions and facilitate better understanding in medical education. Clear and precise terminology aids in the comprehension of anatomical structures and their relationships. It promotes consistency in studies and allows for more meaningful comparisons across studies, ultimately advancing our understanding of anatomical variations and their clinical significance. It allows for more effective teaching and learning experiences, enabling medical practitioners to make accurate diagnoses, develop effective treatment strategies. This knowledge is crucial for identifying potential clinical implications, such as nerve entrapments, pathologies, and dysfunctions, leading to better patient management and outcomes.

Abbreviations

ADM Abductor digiti minimi
CR Crown rump length
FDM Flexor digiti minimi
FDMB Flexor digiti minimi brevis
FDML Flexor digiti minimi longus
FPB Flexor pollicis brevis
MCP Metacarpophalangeal
MRI Magnetic resonance imaging
MTP Metatarsophalangeal
ODM Opponens digiti minimi

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Author contributions

EO was involved in research idea, design of the study, acquisition of data for the study, analysis of data for the study, interpretation of data for the study, drafted and wrote the manuscript, revised it critically for important intellectual content, and helped in final approval of the version to be published.

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