J. Phys. Ther. Sci.
24: 475–479, 2012

Vastus Medialis: a Reappraisal of VMO and VML

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Abstract. [Purpose] The morphology and innervation pattern of the vastus medialis (VM) were investigated to determine if there was an anatomical distinction between the oblique (VMO) and longus (VML) parts. [Subjects and Methods] Forty lower limbs were dissected. The innervation pattern was observed in 39 specimens. Muscle length and fibre angles of 14 specimens were recorded. [Results] In 22 specimens there was a distinct separation between the VML and VMO (change in fibre angle, fibrofascial plane, vasculature or nerve branch). The mean fibre angle of VMO was 52°, and the mean VML fibre angle was 5° (relative to the shaft of the femur). Ten limbs (25.6%) had separate innervation to the VML. The separation between VMO and VML was found to be more proximal than expected, with the VMO on average accounting for 70% of the VM, in contrast to the much more distal point of separation reported elsewhere, leading us to raise the possibility that VML and vastus intermedius may have been misidentified in some previous studies. [Conclusions] In conclusion the VML/VMO division (when present) is much more proximal than has been previously reported, and there is no consistent pattern of innervation to the two parts of the muscle.

Key words: Fibre angle, Vastus medialis, VML, VMO

(This article was submitted Nov. 22, 2011, and was accepted Jan. 10, 2012)

INTRODUCTION

The vastus medialis (VM) is part of the quadriceps femoris complex which envelops the anterior surface of the femur. It originates on the lower part of the intertrochanteric line, and the upper third of the medial supracondylar line and has attachments to the medial lip of the *linea aspera* as it wraps around the femur[1)]. The most distal fibres are usually described as a separate part of the muscle, the *vastus medialis oblique* (VMO), due to the oblique orientation of the fibres, as distinct from the more longitudinal orientation of the proximal fibres, which are usually termed the *vastus medialis longus* (VML)[1–3)].

The idea that vastus medialis has properties that set it apart from the other vasti is by no means new, having first been suggested by Duchenne in 1867[4)]. Lieb and Perry[2)] reported that the VML was involved in knee extension, whereas the primary function of the VMO was medial stabilisation of the patella throughout extension. This view has been supported by several authors (e.g.[5–8)]). However, Peeler et al.[9)] found that less than 10% of the VMO inserted directly into the patella, with the rest inserting into the quadriceps tendon, and concluded from this that the primary function of the VMO is not stabilisation of the patella *per se*, but that it acts with the other quadriceps muscles to maintain patellar alignment throughout knee extension.

Three features of the VM have been used to identify the VML and VMO: fibre angle, the presence or absence of a fascial plane of separation, and the pattern of innervation. Lieb and Perry[2)] reported (in a sample of 6 specimens) that the upper fibres were angled 15–18° and the lower fibres 50–55° (with respect to the shaft of the femur), and concluded that the 2 portions should be regarded as separate entities. Numerous authors have since reported similar findings (e.g.[3, 9–14)]). However a spectrum of differing conclusions has been drawn, with some authors specifically stating that the difference in fibre angle does not mean that the two parts of the muscle are functionally different, and should not therefore be considered as individual muscles[12, 13)].

A fascial plane of separation between the VML and VMO has been found in several studies[2, 3, 11, 12)]. The quantity found ranged from 1 out of 48 specimens (2%)[3)] to 57 out of 115 specimens (50%)[11)]. This wide range of findings, and the fact that some authors did not consider this finding sufficient to give the two parts of the muscle independence of action[3, 12)] brings into question the definition of 'fascial plane.' In addition, some studies found no such separation[8, 9)].

Thiranagama[15)] investigated VM innervation in a sample of 30 lower limbs. Two main branches of the femoral nerve supplying the muscle were identified: one branch to the proximal portion and a longer, larger branch to the middle and distal portions with most of the terminal branches supplying the distal portion. These findings, coupled with the change in fibre angle, led Thiranagama to suggest that the vastus medialis is in fact a tripartite structure, a view supported by Lefebvre et al.[8)] Lieb and Perry[2)] did not specifically study the pattern of innervation. However, they observed a separate femoral nerve branch entering the oblique section in the one specimen in which they observed a fascial plane of separation. Scharf et al.[11)] reported a separate femoral nerve branch to the distal portion of the muscle in their entire

Table 1. Structural features at the interface between the VMO and VML, expressed as a percentage of those specimens in which a separation is evident, and of the entire sample

Type of separation	no. of specimens	% of specimens with distinct VMO/VML	% of total specimens
fibrofascial plane	12	54.5	30.0
femoral nerve branch	11	50.0	27.5
vasculature	3	13.7	7.5

sample of 115 limbs. Ono et al.[14] reported similar findings in a sample of 2 lower limbs. Other studies, however, have contradicted these findings[9, 12, 13], reporting no specific pattern of innervation and concluding therefore that VM should be considered to be a single muscle.

MATERIALS AND METHODS

Dissections and measurements were carried out on 40 formalin-fixed lower limbs in the Dissecting Room of St. George's, University of London. There were 26 male and 14 female lower limbs, and the mean age of the donors was 84.9 years. Sartorius and rectus femoris were incised and reflected superiorly. The femoral nerve was located in the femoral triangle, and its branches followed to their point of entry into the body of the muscle. The fascia and adipose tissue were removed to reveal the attachments of VM. To clarify the distinction between the vastus medialis and vastus intermedius, deep dissections were performed with great care on four lower limbs from separate cadavers. All the muscles of the thigh were removed except for the vastus medialis and vastus intermedius so that the origins of these muscles could be analysed.

Using a flexible steel measuring tape, the following measurements were recorded on 14 lower limbs randomly selected from those in which there was a clear distinction between VMO and VML: VM length, VML length, VMO length, and length of VM inserted into the patella. The overall length of VM was taken from its most proximal attachment on the intertrochanteric line to its most distal point, medial to the patella, where the muscle forms an apex inserting into the medial retinaculum of the knee. Pins were inserted at these points to facilitate measurement. The VML length was measured from the most proximal attachment on the intertrochanteric line to the most distal point that its fibres reached. The VMO length was measured from its most proximal part to its most distal attachment onto the medial retinaculum. In many specimens there was an overlap between the VMO and the VML due to the division being oblique. When the VMO was present as a superficial layer covering the VML, the VMO was reflected in order to make length and fibre angle measurements on the VML. To measure the length of the VMO inserted into the patella, a steel rule was placed horizontally across the superior border of the patella. The distance from this to the most distal point of attachment of the VMO to the patella was measured.

With the knee in extension a 180° goniometer was used to measure fibre angles relative to the shaft of the femur. A pin was placed in the anterior superior iliac spine (ASIS) and another in the apex of the patella. A length of string between these points was used to indicate the direction of the shaft of the femur[12]. Each measurement was repeated 3 times, and the mean calculated. The following fibre angles were measured: the point of maximum obliquity of VMO (determined by measuring each fascicle of the VMO in turn); the VMO angle at the division between VMO and VML; just proximal to the division (i.e. the most distal fibres of VML); and the most proximal fibres of VML. A fibre angle of 0° indicates that the fibres ran parallel with the femoral shaft; mean fibre angle was recorded as negative (i.e. − x°) if the angle was lateral to the shaft of the femur. A division between the VML and VMO was regarded as a visible and distinct change in fibre angle between the 2 portions with or without other structural features such as a fibrofascial plane, femoral nerve branch, and/or vasculature.

RESULTS

Twenty-two of the 40 limbs analysed (55%) exhibited a distinct change in fibre angle between VML and VMO. Structural features observed at the division between VML and VMO were a fibrofascial plane (12 specimens), a branch of the femoral nerve (11 specimens), and vasculature (3 specimens) (Table 1). Some of the limbs exhibited more than one of the structural features. None of the features was seen without a change in fibre angle.

In 5 of the 22 specimens (22.7%), the VMO was present as a superficial layer covering the VML. The longitudinal fibres of the VML continued deep to the VMO until approximately 2 cm above the patella where the fibres of the VML and VMO fused.

The pattern of innervation was recorded in 39 specimens (one limb was excluded due to femoral nerve damage). The dominant branch to the vastus medialis will hereafter be described as the *muscular branch*. Any branch not originating from the muscular branch was considered to be a separate innervation. The branching patterns are shown in the diagram (Fig. 1) and are summarised in Table 2.

Lengths of VM, VML, VMO, and the length of the VM inserted into the patella are summarised in Table 3.

The lengths of the VML, VMO and $VMO_{patella}$ (i.e. the length of the VMO inserted directly into the patella), were calculated as percentages of the total VM length. On average the VML section was 46.2% ± 13.8 of the total muscle length. The VMO made up 69.7% ± 14.3 of the entire muscle (there was some overlap). The section of the VMO inserting into the medial aspect of the patella made up 7.2% ± 1.8.

Fibre angle measurements are summarised in Table 4.

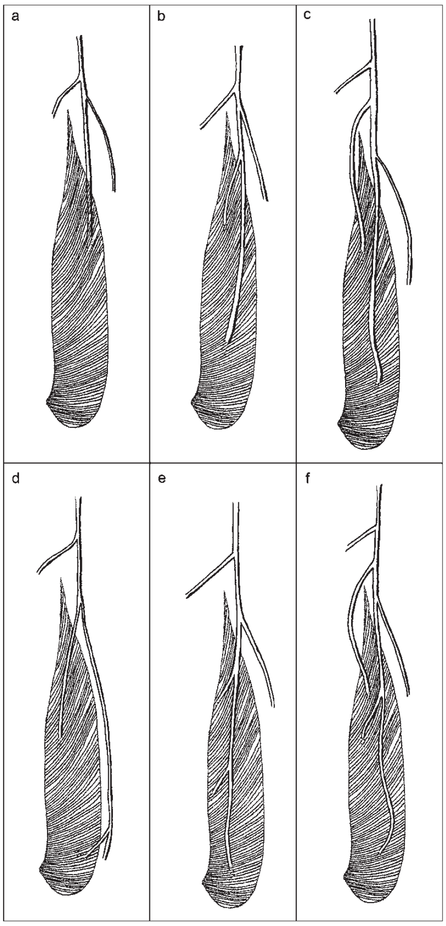

Fig. 1. Innervation patterns of vastus medialis: a) single muscular branch of the femoral nerve; b) two branches from muscular branch; c) muscular branch plus a separate branch; d) muscular branch plus branch from nerve running with the saphenous nerve; e) triple innervation from muscular branch; f) two branches from muscular branch plus separate innervations.

All 4 of the deep dissections clearly revealed the vastus intermedius (VI) originating from the anterior and lateral aspect of the shaft of the femur, and the VM arising separately from the intertrochanteric line, thus confirming our identification of these muscles. Distal to these distinct origins there was some fusion of VI and VM fibres (Fig. 2).

DISCUSSION

In this study, the morphology of the vastus medialis was analysed in a sample of 40 lower limbs. The innervation of the VM was investigated in 39 specimens, and measurements of length and fibre angle were carried out on 14 specimens. In 22 lower limbs (55% of the sample), there was a distinct change in fibre angle visibly dividing the VM into two portions.

There appears to be some controversy regarding the definition of and presence of a fascial plane between the VML and VMO[2, 3, 8, 9, 11–13]. We found a plane of separation composed of connective tissue, adipose tissue or a neurovascular bundle in 54.5% of the limbs in which the VMO/VML separation was evident (30% of the entire sample). Hubbard et al.[12] reported a similar finding in 22% of their sample. Scharf et al.[11], in a sample of 115 lower limbs, reported a plane of separation identified by a branch of the femoral nerve in 100% of their specimens, although we found this in only 11 specimens (27.5% of the entire sample, 50% of limbs with separate VML and VMO).

An interesting phenomenon observed in 5 of our specimens was the presence of the VMO as a superficial layer with the VML continuing beneath it. This apparently rare morphology was described in one out of a sample of 200 Nigerian cadavers[16], and in three out of “more than a hundred” lower limbs[17].

Many variations of the innervation of VM have been reported. The nerve supply of the VM is described as consisting of a short branch entering proximally, with a longer nerve travelling in the adductor canal before entering the mid portion of the muscle body[1]. A similar dual innervation pattern was observed here, both in the specimens in which the VML and VMO were identified, and those with no evident separation. The muscular branch was found to supply a proximal branch to the VM and also another branch or set of branches at some point along the muscle body in 17 specimens (43.6%) (Figs. 1 b, e, f). This pattern has also been reported in other studies[2, 12, 14]. Other authors, however, found no specific pattern of innervation[9, 13]. In 3 of our specimens the muscular branch entered the VM at only one site (Fig. 1 a), an unusual finding in this study, though Peeler et al.[9] report this for their entire sample of 32 limbs.

Table 2. Pattern of innervation of VM. Nerve branches found in specimens with and without a division between VMO and VML, also expressed as a percentage of the whole sample

Nerve branches	Specimens with distinct VMO/VML	Specimens with no VMO/VML division	% of entire sample
1 (muscular branch)	0	3	7.7
2 (muscular branch)	8	9	43.6
2 (muscular branch plus saphenous nerve)	0	1	2.6
3 (muscular branch)	6	2	20.5
3 (2 x muscular branch 1 x separate branch)	7	3	25.6

Table 3. The mean ± SD and range of lengths of the VM, VMO, VML and length of VMO inserted into the patella (cm)

	Total VM length cm	VML length cm	VMO length cm	VMO (patella) length cm
Mean ± SD	34.5 ± 2.2	15.8 ± 4.4	24.2 ± 5.2	2.5 ± 0.7
Range	30–37.1	10.9–24.2	15.5–31.2	1.0–3.5

Table 4. The mean ± SD and range of fibre angles for: a) most oblique fibres of the VMO, b) VMO angle at the division of the VML and VMO, c) VML fibres just above the division, and d) the most proximal fibres of the VML

	$VMO_{max}{}^{a}$	$VMO_{division}{}^{b}$	$VML_{division}{}^{c}$	$VML_{prox}{}^{d}$
Angle° Mean ± SD	52 ± 8	16 ± 4	8 ± 3	5 ± 6
Range°	28–61	6–26	3–14	–10–12

Separate innervation (i.e. a branch that was given off from the posterior division of the femoral nerve before the muscular branch) was observed in 11 specimens (Fig. 1 c, f). It is difficult to ascertain whether this was observed in other studies as most do not specify exactly where the branches originated, although a similar phenomenon was reported by Thiranagama[15]. Lefebvre et al.[8] reported that the VM is innervated by 2 distinct pedicles arising from the terminal branch of the femoral nerve, one each to the proximal and distal portions, although whether these are completely separate branches or both from the muscular branch was not specified.

In 18 specimens a tri-innervation pattern was seen (Figs. 1 e, f), suggesting that the VM should perhaps be considered as a tripartite structure, as suggested by Thiranagama[15] and Lefebvre et al.[8] A single specimen in this study (Fig. 1 d) also showed distal innervation from a branch that accompanied the saphenous nerve. Gunal et al.[18] report secondary innervation from the saphenous nerve in their entire sample of 60 specimens.

The finding in this investigation that differs significantly from previous reports is where the actual level of the anatomical division between the VML and VMO is to be found, when such a division is present. We found the VMO to occupy some 70% of the total VM muscle length. Lieb and Perry[2] did not specify where the division was, however in their diagrams it appears to be in the lower third of the vastus medialis, if not more distal. Hubbard et al.[12] also showed photographs of the division in approximately the distal third of the muscle. Other authors have given no indication whereabouts along the muscle body they observed the separation[3, 13]. However, some have been quite specific in describing the location of the division. Ono et al.[14] found it to be at the level of the adductor hiatus, Peeler et al.[9] described the VMO as that part of the vastus medialis below the uppermost point of muscle fibre insertion into the quadriceps tendon, while Bose et al.[19] described the VMO as originating from the tendon of the adductor magnus. All of these levels are significantly more distal than the level of separation found in this study, which we found to be on average in the proximal third of the VM (Fig. 3).

We found the mean length of the VMO to be 25.0 cm while the mean length of the VML was 15.7 cm, indicating that the VMO is in fact longer than the VML, and the level of division therefore is nearer the proximal third of the muscle. Peeler et al.[9] found the percentages of VMO/VML to be 38/62% of total muscle length, almost the opposite of the results reported here (VMO/VML = 69.7/46.2%). Our results also indicate an overlap between the two parts of the muscle.

What could account for this disparity? When we first observed the very proximal division between VMO and VML, we were concerned that we might have mis-identified the vastus intermedius as the VML. In order to rule out this possibility, we undertook deep dissections on four lower limbs to reveal the origins of VI and VM. We found that the VI, although very closely related to the VM, had a distinct origin from the anterior and lateral aspect of the femoral shaft, whereas VM originated from the intertrochanteric line[1]. We speculate that what some previous authors might have regarded as the separation between the VM and VI is in fact the division of the VML and VMO, and none of the reports cited here describe deep dissections to clarify this point, and close examination of the fibre angles recorded tends to support this.

The mean angle of the distal fibres of VMO was 52°, very similar to other studies[9, 12, 13] (Table 4). However, we found the mean VML fibre angle to be 5°, with a range between −10° to 12°, whereas numerous other authors have reported this angle to be 15–18° (e.g.[2, 9, 12, 14]). We found this to be almost exactly the angle of the VMO at the division between VMO and VML It is striking that what we found to be the fibre angle of the most proximal fibres of the VMO so closely resembles the mean VML fibre angle reported by some previous authors, and that the VMO/VML separation reported here is so much more proximal than expected. One possible explanation for this is that previous investigators have presumed the very proximal division between VMO and VML, which we report here, to be instead the division between the vastus medialis and vastus intermedius, and have consequently looked more distally for the VMO/VML divide. Indeed, Thiranagama[15] even concluded that the VM should be divided into 3 functional compartments because of the changes in fibre angle: the upper third consisting of

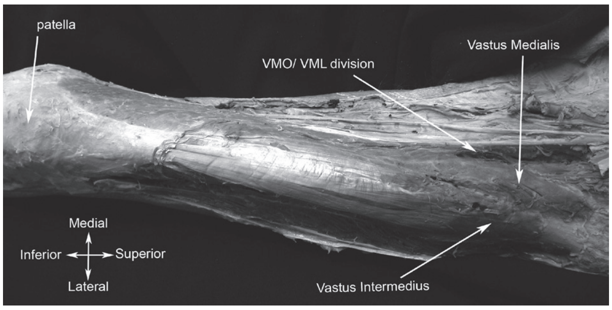

Fig. 2. Deep dissection showing the origins of the vastus medialis and vastus intermedius. The vastus lateralis and rectus femoris have been removed. Note the extremely proximal location of the division between the VMO and VML in this specimen.

fibres with angles of 10°, the middle third 15° − 35° and the lower third 40° − 50°. The fibre angles reported here tend to support this tripartite hypothesis.

We report here that the VMO comprises nearly 70% of the VM, with only 7.2% inserted directly into the patella (Table 3). These findings, coupled with an apparent lack of separate innervation to VMO, suggest that a reappraisal of the vastus medialis may be overdue, and to this end a larger study is already under way, in which we are using ultrasound to investigate VM architecture in healthy volunteers.

ACKNOWLEDGEMENT

This study was funded by St George's, University of London.

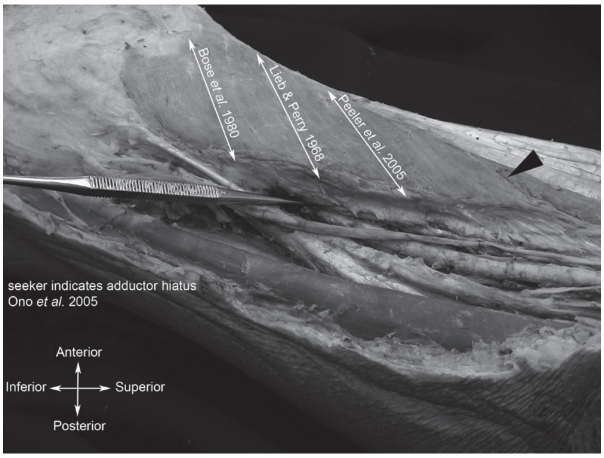

Fig. 3. The actual VMO/VML separation in relation to positions described in previous studies. Black arrowhead indicates separation identified in this specimen.

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