



A Cadaveric Analysis of the Vastus Medialis Longus and Obliquus and their Relationship to Patellofemoral Joint Function

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Abstract

This anatomical study examined: i. whether the VMO and VML are two distinct muscles, ii. muscle fiber angles of the VMO and VML, iii. VMO and VML muscle fiber lengths, iv. VMO nerve supply, v. VMO insertion onto the patella. The length of the VML, VMO superior, and VMO inferior sections were calculated as a percentage of total VM length. Fiber angle data for VML, VMO superior, and VMO inferior were determined according to the femoral axis. It was concluded that the distal portion of the VMO is not distinctly separated from the proximal portion of the VM and VML. There was not a distinct fascial plane between the two sections. Each head of the VM was innervated by different branches of the femoral nerve. Most of the VM inserts into the quadriceps tendon with only a small portion inserting directly into the patella.

Keywords: Quadriceps femoris, vastus medialis, femoral nerve, patellofemoral joint.

Introduction

Twenty-five percent of all sports-related tibiofemoral joint injuries can be attributed to patellofemoral pain which is described as pain on or around the patella¹. This pain, also known as anterior tibiofemoral joint pain, seems to be the result of dysfunction of the patellofemoral joint (PFJ). A PFJ problem is commonly used to refer to any condition that is related to the dysfunction of the patellofemoral joint. Some of these conditions include chondromalacia patellae, extensor mechanism malalignment, subluxating or dislocating patella, and vastus medialis oblique muscle (VMO) insufficiency². One of the major factors that cause PFJ problems is improper tracking of the patella within the trochlear groove of the distal femur².

Tracking of the patella within the trochlear groove during flexion and extension of the tibiofemoral joint is affected by the forces acting at the patella in either a medial or lateral direction. Generally, the two types of forces acting at the tibiofemoral joint are classified as either passive or active forces. The passive forces are the forces exerted by bony structures, connective tissue structures, and inactive muscles². The active forces are the muscles attached to the patella whose contractile elements are activated by the nervous system causing a muscle contraction. Thus, the imbalance of the medially and laterally directed forces at the patella is believed to be a cause of PFJ problems. In this imbalance of forces, the laterally directed force at the patella is typically greater than the medially directed force³. All of the quadriceps femoris muscles, with the exception of the vastus medialis oblique, provide a laterally directed force on the patella.

The quadriceps femoris consists of four muscles: rectus femoris (RF), vastus lateralis (VL), vastus intermedius (VI) and vastus medialis (VM). The quadriceps femoris provides an active force at the tibiofemoral joint which includes acting as the major extensor of the tibiofemoral joint and stabilizing the patella within the trochlear groove of the femur. The role that the individual quadriceps femoris muscles play during dynamic tibiofemoral joint function is not completely understood¹. The vastus medialis oblique's (VMO) role in tibiofemoral joint function is relatively unclear. The obliquely orientated, distal fibers of the VMO may act as separate muscle with a separate function apart from the rest of the quadriceps. This separate function may be acting as a medial stabilizer of the patella. Because the VMO may act as a separate muscle, VMO weakness or dysfunction may be a possible cause of PFJ problems. Degeneration of the patellofemoral region is most common laterally and individuals with anterior tibiofemoral joint pain often have lateral patellar tilting or lateral subluxation, which leads to increased patellofemoral contact forces¹. This may indicate that there is an imbalance between the VMO acting to stabilize the patella and the laterally directed forces produced by the remainder of the knee extensor mechanism.

Anatomically, the vastus medialis muscle arises from the medial border of the linea aspera, located on the posterior surface of the femur, and extends from approximately the lower end of the trochanteric line to the upper third of the medial supracondylar line. It wraps around the femur from back to front⁴. The VM is reported to be able to be divided into two sections or heads⁴. The superior head follows the shaft of the femur and forms the longitudinal portion of the muscle, the VM longus (VML). The inferior head is believed to originate from the adductor longus

and adductor magnus tendons and slant horizontally to form the oblique part of the muscle, the VMO⁴.

The four quadriceps femoris muscles are innervated by branches of the femoral nerve. In order for the vastus medialis muscle to be viewed as two separate muscles, the VMO and VML, the VMO and VML need to have separate nerve supplies. There is disagreement on the nerve supply to the VMO. Research has shown that both heads of the vastus medialis receive separate innervations from different branches⁵. Others have found no separate or distinct innervation to the VMO and VML⁴. Two supplies from the femoral nerve to the VMO with one of the nerves having 4 or 5 branches have also been discovered. An additional supply was from the saphenous nerve. The branch from the saphenous nerve arose from the adductor canal and followed the course of the articular branch of the descending genicular artery⁶.

The different fiber orientation between the VML and VMO has been noted by several researchers. The VML muscle fibers were more vertically aligned with the angles ranging from 14-34°⁴. The VMO's fibers were more horizontally orientated with the range from 28-50° for the VMO superior and 39-69° for VMO inferior. Anatomically, the VM can be viewed as two separate muscles because of the difference in fiber orientation. In order for the VMO and VML to be viewed as two distinct muscles rather than one muscle with two heads, there needs to be a distinct fascial plane between the VMO and VML. Research disagrees as to the presence of a distinct fascial plane^{4,7}.

Where the VMO inserts is important in determining what its function can be. The only way that the VMO could act as a medial stabilizer of the patella is if it inserts directly onto the patella. To act as a medial stabilizer of the patella, the VMO's muscle fibers have to be attached to the patella and have an orientation that, when contracted, would pull on the patella in a medial direction. The majority of the VMO fibers insert along the length of the quadriceps tendon before reaching the patella⁴. Only a small portion of the VMO, the VMO inferior, inserts onto the patella. This finding seems to contradict that the VMO's function is to act as a medial stabilizer of the patella. The VMO has been shown to be attached to the quadriceps tendon as well as the medial border of the patella¹. It was also found that the VMO can be directly continuous with the patellar tendon¹. Based on previous research, it is still inconclusive as to whether or not the VMO can act as a medial stabilizer against the patella to prevent patellofemoral joint problems.

The purpose of this study was to determine, anatomically, if the VMO can act as a medial stabilizer against the patella. The study will specifically examine the following: i. whether or not the VMO and VML are two distinct muscles, ii. measure the differences in muscle fiber angles of the VMO and VML, iii. measure VMO and VML muscle fiber lengths, iv. determine if VMO has a distinct nerve supply, v. determine if VMO and

VML are separated by a distinct fascial plane, vi. evaluate how much of the VMO inserts on the patella.

Material and Methods

Both lower limbs from one whole, intact cadaver were examined in this study. The cadaver had no visible evidence of surgery or trauma to the hip, thigh, tibiofemoral joint, or lower leg region. The cadaver did not appear to have any abnormalities in relation to the patella.

The dissection protocol was adopted from a previous investigation⁴. Each dissection began with a vertical incision along the femoral axis and progressed in a proximal-to-distal manner from the anterior superior iliac spine (ASIS) to the tibial tubercle. Three horizontal incisions were made to intersect the vertical incision at the levels of the ASIS, the inferior aspect of the quadriceps tendon, and approximately 2 inches below the head of the fibula. This procedure divided the anterior thigh region into two sections. Blunt dissection was used to reflect this fascia away from the underlying quadriceps and tendon and to separate the different portions of the quadriceps muscle. The sartorius muscle was cut and medially retracted to fully expose the distal portion of the VM.

The VM was visually divided into two sections. The VML section was defined as the VM below the intersection point with the sartorius muscle and above the uppermost point of muscle fiber insertion into the quadriceps tendon. The VMO section was defined as the VM below the uppermost point of muscle fiber insertion into the quadriceps tendon. The VMO was further divided into two sections, superior and inferior. The superior section of the VMO is the VMO below the uppermost point of muscle fiber insertion into the quadriceps tendon and above the superior aspect of the patella and the inferior section was defined as the VMO below the superior aspect of the patella and that directly inserts on the medial aspect of the patella. The boundaries of these sections were marked with pins inserted into the muscle and the lengths of the three sections were measured (cm) with a flexible ruler.

The cadaver was placed in a position with the tibiofemoral joints fully extended and the hips in a neutral position. The femoral axis was determined and labeled by placing pins at the point of the ASIS and the mid-point of the tibial tubercle. A taut string connected the two pins. Muscle fiber angles were marked and measured at the mid-point of each of the three sections using pins. A goniometer was used to measure the angle that each line intersected with the femoral axis.

Blunt dissection was used to assess each section for the presence of a fascial plane and separate innervation. The femoral nerve and its branches were traced from a superior point, in the femoral triangle, to an inferior point below the VMO fibers.

The length of VML, VMO superior, and VMO inferior sections was calculated as a percentage of total VM length. Fiber angle data for VML, VMO superior, and VMO inferior were

determined according to the femoral axis. The nerve innervation and fascial plane for the VML and VMO were recorded. Descriptive statistics were calculated for all of the above measurements and analyzed for statistical differences using a one-way ANOVA (SPSS v16). A Tukey post hoc test was used to analyze a significant ANOVA. The level of significance was set at $P < 0.05$.

Results and Discussion

The origin of the VM arose from medial border of the linea aspera⁴. The VM wraps around the femur from back to front. On both legs the VMO originated from the adductor magnus and adductor longus tendons. There was a tendinous connection between the VMO and the adductor magnus and longus tendons. The VMO and VML were innervated by the femoral nerve on both legs. They were innervated by different branches of the femoral nerve. The saphenous nerve did not enter the VM at any point.

The VMO and VML's fiber orientation differed. The VML had more vertically aligned fibers. Progressing distally, the fiber orientation gradually changed to more obliquely aligned fibers with the VMO inferior having the most horizontally aligned fibers. The mean VML, VMO superior, and VMO inferior fiber angles, respectively, are $21^\circ \pm 4$, $30^\circ \pm 3$, and $57^\circ \pm 4$. There were significant differences among all groups ($P < 0.05$). There was not an abrupt change in fiber orientation that would indicate that there are two separate muscles. An abrupt fiber orientation change would also indicate that there may be a distinct fascial plane between the VML and VMO. There was not a distinct fascial plane in the VM. The fascia was the same throughout the muscle.

The percentage of the lengths of the VML, VMO superior, and VMO inferior were calculated relative to the total VM length for each limb. The percentages of VML, VMO superior and VMO inferior compared to total VM length are $71\% \pm 2$, $23\% \pm <1$, and $6\% \pm <1$. Most of the VMO inserts directly into the quadriceps tendon before ever reaching the patella. Only $22\% \pm 1$ of the total VMO length inserts into the patella which is the VMO inferior. Only a small percentage of the entire VM, VMO inferior ($6\% \pm <1$), inserts directly onto the patella.

Table-1

Vastus medialis fiber angles and section percentages of total VM length

	VML	VMO superior	VMO inferior
Fiber angles (degrees)	$21 \pm 4^*$	$30 \pm 3^*$	$57 \pm 4^*$
Section length / Total length (%)	$71 \pm 2^\#$	$23 \pm 1^\#$	$6 \pm 1^\#$

* Indicates significant difference of fiber angles ($P < 0.05$).

Indicates significant difference of section percentage length ($P < 0.05$).

Conclusion

The VMO and the VML are not two distinct muscles with their own distinct function. Instead, they should be classified as one muscle with one main function of tibiofemoral joint extension with a secondary function of medial stabilization of the patella.

The origin of the VM was found to be consistent with others in that the muscle originated from the linea aspera of the femur and wrapped around from back to front⁴. The inferior head of the VM had a tendinous connection to the tendons of the adductor magnus and adductor longus. The findings on the innervation of the VM are conflicting. It was found that the saphenous nerve never entered the muscle belly of the VMO⁷. The VM was only innervated by the femoral nerve. The VML and the VMO were innervated by different branches of the femoral nerve. A branch of the femoral nerve entered the superior portion of the VM and another branch entered the inferior portion of the VM. This finding supports previous research⁵. This indicates that the VML and the VMO have distinct innervation from one another.

Visually, one can observe the change in fiber orientation from superior to inferior. There is a gradual change in fiber orientation from vertically aligned to more horizontally aligned. There never is an abrupt change in fiber orientation which would indicate separate muscles. If there was an abrupt change in fiber orientation, one would think that there would be a distinct fascial plane where the fibers changed abruptly indicating separate muscles. This study did not observe a distinct fascial plane anywhere in the VM. Again, visually the VML and VMO can be thought of as two muscles because of the difference in fiber orientation from superior to inferior, but they should not be specifically classified as two distinct muscles.

In order for the VMO to functionally act as a medial stabilizer of the patella, its fibers need to insert directly onto the patella. Most of the VMO's fibers actually insert into the quadriceps tendon before ever reaching the patella. Only $22\% \pm 1$ of the VMO's fibers insert onto the patella. This indicates that much of the VMO's function is the same as the other quadriceps femoris muscles with a secondary function of providing a medial pull on the patella.

The distal portion of the VM, commonly referred to as the VMO, is not distinctly separated from the proximal portion of the VM, VML. There was not a distinct fascial plane between the two sections. Each head of the VM was innervated by different branches of the femoral nerve which may be of importance. Most of the VM inserts into the quadriceps tendon with only a small portion of the total muscle actually inserting into the patella. The VMO and VML should be thought of as one muscle with distinction given to the VMO in that it may provide some medial stabilization of the patella based on some of its fibers inserting into the patella.

This study was limited in that only two lower limbs were examined from the same cadaver. More cadavers need to be examined using the same methods. One problem that was found in the literature is that the same dissection and measurement techniques were not employed in repeated studies. Further studies need to be performed using the same dissection methods.

In summary, the VM should be viewed as one muscle. It can be divided into two sections based on anatomical landmarks, but there is not a separation between the two heads. In order to prevent PFJ problems and an imbalance of forces acting on the patella, one should focus on strengthening the quadriceps femoris muscle as a whole. Each muscle of the quadriceps femoris needs to have adequate strength in order to prevent imbalances at the patella.

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