A Review of the Anatomy, Physiology and Function of The Popliteus Muscle

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Abstract

The literature on anatomy, physiology, function and pathology of the Popliteus muscle (PM) is reviewed. The descriptive anatomy of the PM in the literature is much more variable than described in classical anatomy books. The literature gives different options on the function of the PM. The retraction of the meniscus is debatable and may not have clinical value. No one argues the rotary effect of the PM muscle. The PM muscle's placement and close relationship to the capsule makes it easy to emphasize its function as a stability muscle, however the PM muscle may not stabilize the knee in all directions. The PM muscle has shown feedforward activity in some movements but not in all. This makes it questionable to consider it as a local stability muscle.

Introduction

Stability dysfunctions of the knee are a major problem for athletes as well as among less active people. Seeking the best way to restore the passive stability has been a big issue in the orthopaedic field and finding the best way to restore the dynamic stability of the knee has created much research and discussion amongst physiotherapists.

Dynamic stability is created by muscles working around the joint. It appears some muscles can do this better than others. A useful classification of muscle function categorises muscles into local stability muscles, global stability muscles and global mobility muscles (Mottram and Comerford, 1998; Comerford and Mottram, 2001). This article will review the literature on the anatomy, physiology and function of the PM with specific reference to a potential for the muscle to play a role in stability of the knee complex. A better understanding of the function of the PM may lead to better conservative strategies in rehabilitation.

Methods

For the review, and electronic search was conducted in: Chinal, Medline Pubmed, Cochrane and PEDro.

Anatomy

According to Gray`s Anatomy (28) the PM is a thin flat triangular muscle, which forms part of the floor of the popliteal space. It arises by a strong tendon, from a depression on the
outer side of the external condyle of the femur, and from the posterior ligament of the knee joint, and is inserted into the inner two thirds of the triangular surface. The tendon of the muscle is covered by the biceps and the lateral collateral ligament (LCL). The function of the muscle is to unlock the knee with lateral rotation of the femur (14, 28).

Many authors have described the position of the PM. Studies write about function based on description of the muscles placement, origin and insertion. This is then taken to a theoretical biomechanical model, so for this reason it is important to review the literature on descriptive anatomy of the muscle.

9 articles were reviewed and in these different studies 305 cadaveric knees were dissected.
In all studies the major origin of the PM is on the lateral aspect of the femoral condyle. The PM crosses the knee joint in a posterior inferior direction beneath the LCL and the tendon of biceps femoris (1,3,5). The popliteofibular fascicle has the shape of an inverted “y”. It originates on the fibula and tibia (3). Most authors describe a deep and superficial layer of the muscle (1,2,3,4,5,7). The superficial layer blends with the capsule (1,4,5). There seems to be more variation in the deep fibres – both in anatomic and in the dissection studies. Watanabe (4) reports seven major anatomic variants of the postero-lateral human knee. Most authors (1,2,3,4,6,7) have seen a strong, or other type of attachment to the lateral meniscus. Prado (2) found no attachment to the lateral meniscus in 40% of cadavers; Watanabe (4) found 60%. Tria (8) argues about this attachment. In his study, 45% of the species had no connection to the meniscus, 37.5% had a very thin, almost translucent connection and only 17.5% had a strong attachment as described by others.

Nerve supply

The PM is innervated of the tibial nerve, from L4-5 and S1 (14).

Anatomy

Postero-lateral supporting structures

The postero-lateral compartment of the knee is probably the least understood region of the knee. It was once considered the “dark side” of the knee (19). It is composed of capsular and extra-capsular structures. The structures form a functional unit, named in some literature as the arcuate complex (18). The anatomy of the lateral aspect has been described using a three – layer approach (15). Layer I corresponds to the superficial layer and includes the iliobial band anteriorly and the biceps tendon posteriorly. Layer II consists of the quadriceps retinaculum and the patellofemoral ligament, while layer III consists of the lateral part of the joint capsule, including the LCL, the fabellon ligament, and arcuate ligament. Studies with dissection and MRI comparisons (16, 17), showed a large variation of the small postero-lateral structures of the knee. The popliteus tendon is frequently found to be connected to the lateral capsule. This gives the muscle a possible role in postero-lateral stability of the knee.

Function/ Biomechanics
The function and biomechanics of the PM have been described in many different papers. Table 1 gives an overview of reviewed papers and the author’s conclusions on function and biomechanics.

The PM is likely to have more than one function. Its function in postero-lateral stability is significant. This is discussed in further detail below. Some anatomical papers describe a common idea of the PM as a retractor of the lateral meniscus (32, 34, 60-67). This is an area of debate. Tria et al (8) did not find any major attachment of the PM tendon in 82.5 % of 40 anatomical dissections. They concluded that on the basis of this finding they could not support the theory of a role for the PM in protecting the lateral meniscus. In a study using arthroscopic and electrical stimulation of the popliteus muscle (57) they found a retractive influence on the posterior aspect of the lateral meniscus, however this was variable.

Fitzgibbons et al (58) looked at 189 lateral meniscus tears that were left in situ at the time of anterior cruciate ligament reconstruction. The average finding on clinical follow up was that there were no clinical symptoms on patients who had vertical longitudinal tears posterior to the popliteus tendon. These patients did not suffer from unstable bucket handle lesions later as a result of the PM tear.

Many studies emphasize the role of the PM as an internal rotator of the tibia, or from reversed insertion, as a lateral rotator of the femur. The lateral rotation of the femur is often described as the PM ability to “open” the locked knee. Stäubli and Birrer (3) found that the popliteus muscle’s tendon gradually increases when the knee extends. They suggest that the PM and its intact fasciculii play an important role in restraining hyperextension. Davis et al (56), using electromyography (EMG), could see the same happening in some patients during gait. They also found an increase in EMG during downhill walking.

Only one study argues the case for the PM for being an extensor of the knee (6). Computer analysis measured the distance between insertion points in flexion and extension. Watanabe et al (4) lends some support to this idea. In their study they showed that the anterior fibres of the PM tendon increases in tension under flexion and posterior fibres increase tension under extension.

During locking of the knee the femur undergoes medial rotation (14). Stability in this position is mainly maintained by ligaments. Electrophysiological evidence supports that receptors in these ligaments do not provide a comprehensive feedback for monitoring joint position (10). On the other hand the PM will be passively stretched in this position.

Knee instability

To know whether we should emphasize the activity of the PM in the unstable knee we have to consider the biomechanics and traumatology. Medial instability infers the tibia is moving away from the femur on the medial side. Antero-medial rotatory instability infers the tibia is rotating anteriorly and moving away from the femur on the medial side. The classification of instabilities, listed below, was devised by the Research and Education Committee of the American Orthopaedic Society for Sports Medicine (56).
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<tr>
<th>Instabilities</th>
<th>Structure</th>
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<tr>
<td>Medial</td>
<td>MCL, Posterior oblique ligament ACL, PCL Medial middle one-third of joint capsule</td>
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<td>Lateral</td>
<td>LCL, middle one-third of lateral complex Arcuate-popliteus complex ACL, PCL ITB</td>
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<td>Anterior</td>
<td>ACL Middle and posterior one-third of medial capsule and lateral capsule, MCL, deep fibres ITB posterior oblique ligament, arcuate ligament</td>
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<td>PCL, Middle and posterior one-third of medial capsule and lateral capsule, MCL deep fibres ITB, arcuate ligament</td>
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<td>Posteromedial</td>
<td>PCL, posterior medial oblique ligament, MCL, posterolateral joint capsule, ACL</td>
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Irvin 1998 (56)

Anterolateral and posterolateral instability

Depending of which ligaments are ruptured or lax, uncontrolled medial rotation of the femur on the tibia will produce either an antero-medial instability (20) or postero-lateral instability (21,22). Krudwig et al (9) looked at the possible role of the PM’s ability to control the medial rotation of the femur in 10 cadaveric knees. The postero-lateral structures were cut one by one. The degree of tibial rotation was measured with or without loading of the PM. Loading the PM with 50N led to clear and significant internal tibial rotation 4-5° in near extension and up to 12° in 90° flexion of the knee. They consider the PM as an important structure resisting excessive external tibial rotation and maintaining the neutral tibial rotation, even if all other postero-lateral ligaments were cut.

Wang et al (51) looked at the posterior cruciate ligament (PCL) and coupled postero-lateral instability. They found that cutting the PM tendon had the largest effect on postero-lateral displacement of the tibia (198% compared with a healthy knee). When cutting both the LCL and the PM tendon it was 299%, and when cutting the PCL and the PM tendon it was 241%. They conclude that the PM tendon is the primary stabilizing structure of the posterior corner of the knee. LaPrade (25) et al measured the force of the ACL grafts in cadaver knees where the postero-lateral structures were selectively cut. The tension in the graft increased with varus loading and further with varus and external rotation at 0° and 30° of flexion after the LCL, the popliteofibular ligament, and the popliteus tendon were cut. This could indicate a risk for the ACL or ACL graft in the postero-lateral rotary knee instability.

According to Peterson et al (26), the PM plays a major role in the active performance of the pivot shift manoeuvre in the ACL deficit patients. In a case study including 4 ACL deficit patients, they were able to voluntary and actively perform the pivot shift manoeuvre. It was later reproduced by electrical stimulation of the PM alone. From these findings retraining Popliteus may not be appropriate in cases with anterolateral instability.

The ability to sublux the lateral tibial plateau was used in a diverted sense reducing the postero-laterally subluxed tibial plateau (27). Postero-lateral instability of the knee allows abnormal posterior and posterior lateral subluxation of the tibial plateau. This condition is caused by injuries of the arcuate ligament complex and the PCL. In this study, 10 patients could produce the instability voluntarily by active muscle pull. Electromyographic studies
clearly demonstrated that the biceps femoris muscle acted as a major subluxer and the PM as a reducer.

**Feedforward**

To determine the stability role of the PM we need to have information about muscle recruitment. In an unpublished study, Danielsen, Frederiksen and Jensen (31) looked at the preactivation of popliteus using fine wire electrodes inserted in the PM. The activity and timing was measured using electromyography (EMG). The electrode was placed in the muscle under real time ultrasound. Eight subjects with no history of any knee injury (4 male, 4 female) were included in the study. The subjects performed 8 different movements. Anticipatory timing was found in 2 of the 8 movements. Anticipatory timing was seen ranging from 2/8 – 8/8 movements in each subject. Activity throughout movement was seen in 3/7 movements. The authors concluded that the PM can not be classified as a local stabiliser, as it is described by Comerford and Mottram (29), but its role it stability was demonstrated because it was active in several tasks that challenged stability.

**Pain and pathology**

Although the popliteus musculotendinous unit may be sufficiently mobile to avoid injuries in many instances, rupture of the PM probably occurs with a greater frequency than generally recognized. PM injuries were found in approximately 1% of 2412 consecutive MRI examinations (43). The PM was found to be either partially or completely ruptured in more than 75% of lateral ligament knee injuries surgically treated by Mueller (33). An even higher percentage of PM ruptures were seen by Backer et al (34) in knees operated for acute postero-lateral rotary instability. Several case studies on isolated lesion of the tendon have been reported (35-42), but far more often it is part of a more complex injury. An MRI study by Brown et al (43) found PM lesions in combination with ACL, PCL ruptures, medial and lateral meniscal tears, and arcuate-fibula collateral complex tears. In 95.8% (23/24) of the patients, the tear of the PM involved the muscular portion. The injuries were either partial or complete. Injuries in combination with the PM, or to other structures at the postero-lateral corner, such as the lateral head of gastrocnemius and biceps femoris complex have also been reported (44). Failure to diagnose a postero-lateral injury has been reported to lead to chronic instability, which is difficult to diagnose. According to Hughston and Jacobsen (45) the initial injury may cause slight discomfort and no immediate disability, over time the injury can become severe and result in chronic instability.

There are probably multiple mechanisms of a PM lesion. Backer (34) suggests that PM injuries occur with blows to the anterior-medial aspect of the proximal tibia with the knee hyper-extended or by a non-contact, hyperextension with external-rotation. Nakhostine et al (39) reported 4 case studies on patients with isolated avulsion of the PM tendon in which the mechanism of injury was external rotation of tibia in slight flexion. Brown et al (43) could not find any clear mechanism of injury in their study on 24 patients.

There is no consensus on treatment of a PM lesion. Some authors report good short term results with conservative treatment (45-47). Nakhostine et al (39) advise anatomical reduction and fixation of the avulsed fragment. They argue that it prevents the possibility of long-term postero-lateral instability.
Atrophy

No studies were found that described an assessment of atrophy of the PM.

Rehabilitation

No studies were found that described exercise or rehabilitation programs for the PM.

Patella femoral pain syndrome.

The postero-lateral complex may also have an impact on the patellofemoral joint. In a study done on 10 cadaver knee, Skyhar et al. (24) showed that combined sectioning of the postero-lateral complex and the PCL resulted in significantly more patellofemoral joint pressure than if they did isolated sectioning of the PCL.

Popliteus Tendinitis and Tenosynovitis

Tendinitis is closely related with overuse. Mayfield (48) reported in a study of 30 patients that overuse was often produced with walking or running downhill. The characteristic symptom was pain in the lateral aspect of the knee on weight bearing with the knee flexed 15-30°. Sometimes pain was experienced in the early part of the swing phase of gait, and on attempting to rise from the crossed legged position.

Conclusion

A review of the literature shows variation in descriptive anatomy, function and pathology of the PM. The descriptive anatomy of the PM is much more variable than the description in classical anatomy texts. The PM’s placement and close relationship to the capsule makes it easy to emphasize its function as a stability muscle. The literature gives different options on the function of the PM. The retraction of the meniscus is debatable and may not have a clinical value. No one argues the rotary effect of the PM and it can be described as lateral rotation of the femur or an internal rotation of the tibia. The PM has shown feedforward activity in some movements, but not in all. This makes it questionable to consider it as a local stabiliser muscle.

Before we start the rehabilitation of the unstable knee we need to know the exact direction of the instability. The PM may not stabilize the knee in all directions as it is shown with antero-lateral instability. On the other hand postero-lateral instability is very well controlled by the PM.

Further research

To have a better understanding of the PM we need more information about how the muscle reacts in the presence of pain and pathology. The feedforward activity in the PM should be investigated further. The test positions should challenge the postero-lateral corner of the knee in healthy subjects and in subjects with postero-lateral instability. A randomized controlled trial could investigate a potential benefit of specific exercises for the PM in the rehabilitation of postero-lateral unstable patients. Although it appears that the PM does not have the potential to control the antero-lateral instability, the role of eccentric control should be considered. Further, other mechanisms of stability may exist and should be explored.
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### Table 1 Popliteus function and biomechanics.

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<th>Author</th>
<th>Medial rotation of the tibia</th>
<th>Lateral rotation of the femur, when tibia is fixed</th>
<th>Protection of the lateral meniscus when the knee is flexing by drawing meniscus back</th>
<th>Important for controlling posterolateral stability/Resists posterior tibial load</th>
<th>Activity in weight bearing functions</th>
<th>Resists a anterior glide of femur on tibia during flexion of the knee</th>
<th>Active during swing phase just prior to the heel strike and during 2/3 stance phase</th>
<th>Adjusts equilibrium in standing posture</th>
<th>Assists LCL under high flexion</th>
<th>Restraining hyper-extension</th>
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