



Original Article

In vivo ultrasound imaging of the popliteus muscle: investigation of functional characteristics

NAOKI SODA, RPT, MS¹*, YUICHIRO FUJIHASHI, RPT, MS¹, TAKA AKI AOKI, MD, PhD²

¹) Department of Rehabilitation, Major in Physical Therapy, Heisei College of Health Sciences, 180 Kurono, Gifu City, Gifu 501-1131, Japan

²) Department of Orthopaedic Surgery, Gifu University School of Medicine, Japan

Abstract. [Purpose] The aim of this study was to use ultrasound imaging equipment for *in vivo* observation of the popliteus muscle thickness during rest and exercise to examine its functional characteristics and to establish a training method for this muscle. [Subjects and Methods] The subjects included 30 healthy adults (15 men and 15 women). The measurement tasks, consisting of isometric knee flexion and extension and internal rotation of the lower leg were performed in an arbitrary order. The popliteus muscle thickness was measured using an ultrasound. [Results] The popliteus muscle thickness significantly increased in the internal rotation in 27 subjects (90%), whereas, it remained unchanged in the remaining three subjects (10%). [Conclusion] This study differed from most of the previous studies because it involved *in vivo* observation of the popliteus muscle. We found that ultrasound was an effective method for the measurement of popliteus muscle thickness. The results suggest that internal rotation of the lower leg is the most effective exercise for working the popliteus muscle.

Key words: Popliteus muscle, Ultrasound imaging, *In vivo*

(This article was submitted Nov. 19, 2015, and was accepted Dec. 12, 2015)

INTRODUCTION

The popliteus muscle runs from the lateral condyle of the femur and inserts above the soleus muscle on the posterior surface of the tibia. As it is located under the popliteal artery and vein, the muscle is thought to be a cause of pain in the popliteal region and related to the stability of the posterior support mechanism. The muscle is also considered to be a cause of restricted knee joint extension. Therefore, many clinical approaches use the popliteus muscle.

Basic studies of the popliteus muscle have reported that the composition of the muscle fibers consists of a large amount of slow oxidative-type fibers and a high density of muscle spindles.

The main functional characteristics of the popliteus muscle that are widely recognized are the bending of the knee and internal rotation of the lower leg. However, although many previous reports have investigated the internal rotation of the lower leg, no consistent findings regarding the action of the popliteus muscle during bending of the knee have been reported. Studies by Laprade et al.¹⁾ using specimens suggested that, as the site of entheses of the femoral side of the popliteus muscle was located anterior to the flexion-extension axis, the muscle may be involved in knee extension. In a study using needle electromyography, Ann-Katrin et al. confirmed the activity of the popliteus muscle during knee extension²⁾. However, William et al. used specimens to measure the knee flexion-extension moment arm and reported that there was negligible flexion-extension action³⁾. These differences in entheses sites suggest that moment arm differences would be brought about by changes in the knee flexion angle, and there are still many elements of the popliteus muscle action that have not been clarified.

In addition to the action of the popliteus muscle in knee flexion and extension, there are several reports on the significant variation in the anatomical characteristics of the popliteus muscle. A study that used specimens to investigate the insertion of the popliteus muscle in the lateral meniscus determined that an insertion was observed in 95% of the cases⁴⁾. Another report

*Corresponding author. Naoki Soda (E-mail: n.soda@heisei-iryuu.ac.jp)

©2016 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License <<http://creativecommons.org/licenses/by-nc-nd/4.0/>>.

found that the popliteus muscle inserted into the lateral meniscus in 55% specimens without any attachment in the remaining 45% specimens⁵).

Thus, no clear findings have been obtained, and the functional and anatomical characteristics of the popliteus muscle remain unknown. However, most of the previous studies have been involved in anatomical discussions using specimens and few studies have conducted *in vivo* investigations. Gaining an understanding of the *in vivo* activity of the popliteus muscle is very important for establishing methods for training the popliteus muscle. One reason for the lack of previous studies despite such importance could be that the popliteus muscle is deeply located. Thus, methods of studying its function or contraction dynamics have not been established. However, ultrasound imaging equipment have recently been used for imaging some deep muscles, and we expect that they can also be applied for the observation of the popliteus muscle^{6, 7}).

Therefore, the aim of this study was to use ultrasound imaging equipment (hereinafter referred to as “ultrasound”) for *in vivo* observation of the popliteus muscle thickness during rest and exercise to examine its functional characteristics and to establish a training method for this muscle.

SUBJECTS AND METHODS

The subjects included 30 healthy adults (15 men and 15 women; age, 21.1 ± 3.2 years; height, 164.9 ± 9.5 cm; and weight, 60.0 ± 9.9 kg). The participants were given sufficient explanations of the purpose and methods of this study and were informed that they would not suffer any disadvantages regardless of whether or not they participated. Thereafter, we received their consent in writing. This study was conducted according to the principles of the Declaration of Helsinki. All test protocols were approved by Heisei College of Medical Technology Ethics Committee (H27-16).

The measurement tasks, consisting of isometric knee flexion and extension and internal rotation of the lower leg were performed in an arbitrary order. It was performed in loading which could be stopped by hand. The popliteus muscle thickness was measured using an ultrasound (Famio 8; Toshiba Medical Systems, Tochigi, Japan). A linear electronic scanning probe (12.0 MHz) was used, and imaging was performed in B mode. The probe was operated by a tester who had practiced sufficiently.

The measurements were made with the participant in the prone position on a bed with their knee bent at approximately 60° . It was performed in loading which could be stopped by hand. The tester placed the probe parallel to the popliteal region (the line joining the medial and lateral condyles), and the popliteal vein and fibula head were identified during imaging. Next, the probe was moved along the path of the popliteus muscle from the fibula head in the inward and downward directions to determine the popliteus muscle thickness. The popliteus muscle was distinguished from the soleus muscle and gastrocnemius by confirming that there was no contraction during plantar flexion (self-motion) of the ankle. The absence of bending of the soft tissue due to the contact pressure between the probe and skin was constantly confirmed on the images during measurement (Fig 1).

After identifying the popliteus muscle, the muscle thickness during rest was recorded. Each task (knee flexion, extension, and lower leg internal rotation) was then performed in an arbitrary order, and the muscle thickness was recorded during each task. The recorded images were analyzed using the imaging analysis software ImageJ. Measurement on each image was conducted three times, and the mean values of these measurements were used for analysis. The muscle thickness was determined by measuring the space between the surface and deep aponeurosis. The measurements during movement were made when the maximum muscle thickness was parallel to the aponeurosis.

For statistical analysis, ten individuals were randomly selected from the participants and the popliteus muscle thickness was measured again on the same day, and the intraclass correlation coefficient (ICC) for popliteus muscle measurement was calculated. In addition, the muscle thickness during rest was compared with the former measurement during each task. A comparison of increase, not change with each task we went at χ^2 test. A p-value less than 0.05 was considered to be significant. The proportion of increases in the mean thickness values observed during rest was calculated and used to report

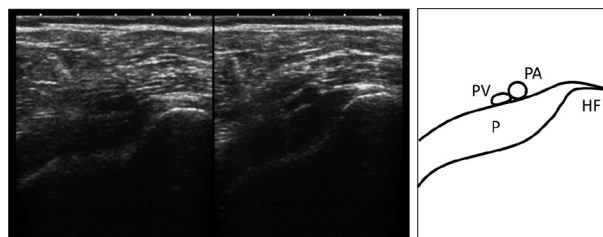


Fig. 1. The ultrasound imaging of the popliteus muscle

This figure shows the ultrasound image of the popliteus muscle for a subject. The figure on the left shows the popliteus muscle during rest. The figure in the center shows the popliteus muscle during the task.

PV: popliteus vein, PA: popliteus artery, P: popliteus muscle, HF: head of the fibula

the functional characteristics of the popliteus muscle. We used the statistical software “Statistical Package for the Social Sciences ver. 13” to calculate the ICC (intraclass correlation coefficient) and χ^2 test.

RESULTS

The ICC was 0.899 (1, 1) for the popliteus muscle thickness measurements. The mean popliteus muscle thickness during rest was 9.4 ± 1.6 mm. It significantly increased during internal rotation and significantly decreased during extension. There was no significant difference in flexion (Table 1). The results for each task indicated that the muscle thickness increased during lower leg internal rotation in 27 subjects (90%), whereas, it remained unchanged in the remaining three subjects (10%). The muscle thickness increased in 21 subjects (70%) during knee flexion and in nine subjects (30%) during knee extension, but it remained the same in six subjects (20%) for each of these tasks.

DISCUSSION

In this study, the ICC for popliteus muscle thickness measurement was 0.899, which appears to be favorable because it is higher than the ICC criterion of 0.8 proposed by Landis et al. As these results indicate equivalent reliability for ultrasound measurement as that established for other sites of the body, ultrasound appears to be useful for *in vivo* observation of the popliteus muscle.

With regard to the functional characteristics, we were able to confirm a significant difference in the lower leg internal rotation by an increased muscle thickness during lower leg internal rotation, which was noted in 90% of the subjects. This suggested that, as observed in a previous study⁸, internal rotation of the lower leg is the main function of the popliteus muscle.

Our results for knee flexion and extension showed that muscle thickness increased in 21 subjects (70%) during knee flexion and in nine subjects (30%) during knee extension, whereas, it remained unchanged in six subjects (20%) for each of these tasks. The action of the popliteus muscle did not appear to be concentrated on either flexion or extension in this *in vivo* experiment. These findings may be related to the muscle path.

It is widely known that when the muscle path passes through the front of the knee axis, it acts on the extension, and when the path passes behind the knee axis, it acts on flexion.

In previous studies of the popliteus muscle path, Zeng et al. investigated the femoral enthesis site of the popliteus muscle and reported that there were three types of enthesis: a Fibular collateral ligament of knee joint enthesis downward type (49.4%), forward downward type (24.7%), and backward type (25.9%)⁹. However, no consensus has been reached regarding the enthesis site. Laprade et al.¹ reported that all cases were an anterior type, whereas Brinman et al. reported that 94% were a backward type and 6% were forward type¹⁰. This may have affected the results of the present study. In either case, the muscle path appears to be close to the knee flexion–extension axis, which suggests that the popliteus muscle function only has an auxiliary role in knee flexion and extension.

Furthermore, as the knee generally has a very large range of movement ranging from 0° to 140°, the moment arm changes, and the accompanying angle changes are also expected to be large, which suggests that flexion angle in the measurement position may have affected our results.

An issue to be investigated in the future is whether accurate popliteus muscle action can be promoted by examining changes in the action brought about by the different knee flexion angles. In addition, the popliteus muscle is a deep muscle, thus, we also want to investigate the change in muscle thickness due to the load amount and the relationship of the popliteus muscle and the lateral meniscus.

Nevertheless, our results clearly demonstrated that the popliteus muscle’s main function was the internal rotation of the lower leg, which suggests that the training of the popliteus muscle should focus on the lower leg internal rotation. This study differed from most previous studies because it involved *in vivo* observation of the popliteus muscle. We found that ultrasound was an effective method for measurement of the popliteus muscle thickness. The results suggest that internal rotation of the lower leg is the most effective exercise for working the popliteus muscle. These results may also contribute in establishing a training method for the popliteus muscle.

Table 1. Results of the χ^2 test

	Popliteus muscle thickness		
	Increases		No change
	Number of subjects	Percentage	Number of subjects
Internal rotation	27/30**	90%	3/30**
Flexion	21/30	70%	9 (6) /30
Extension	9/30	30%	21 (6) /30**

(): No change for each task. **p<0.01

REFERENCES

- 1) LaPrade RF, Ly TV, Wentorf FA, et al.: The posterolateral attachments of the knee: a qualitative and quantitative morphologic analysis of the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon. *Am J Sports Med*, 2003, 31: 854–860. [[Medline](#)]
- 2) Stensdotter AK, Dalén T, Holmgren C, et al.: Knee angle and force vector-dependent variations in open and closed kinetic chain for M. popliteus activation. *J Orthop Res*, 2008, 26: 217–224. [[Medline](#)] [[CrossRef](#)]
- 3) Buford WL Jr, Ivey FM Jr, Malone JD, et al.: Muscle balance at the knee—moment arms for the normal knee and the ACL-minus knee. *IEEE Trans Rehabil Eng*, 1997, 5: 367–379. [[Medline](#)] [[CrossRef](#)]
- 4) Feipel V, Simonnet ML, Rooze M: The proximal attachments of the popliteus muscle: a quantitative study and clinical significance. *Surg Radiol Anat*, 2003, 25: 58–63. [[Medline](#)] [[CrossRef](#)]
- 5) Tria AJ Jr, Johnson CD, Zawadsky JP: The popliteus tendon. *J Bone Joint Surg Am*, 1989, 71: 714–716. [[Medline](#)]
- 6) Yu JY, Jeong JG, Lee BH: Evaluation of muscle damage using ultrasound imaging. *J Phys Ther Sci*, 2015, 27: 531–534. [[Medline](#)] [[CrossRef](#)]
- 7) Otani Y, Itotani K, Maeda N, et al.: Reliability of the deep abdominal muscle thickness measurements using ultrasonography in normal subjects. *J Phys Ther Sci*, 2011, 23: 357–359. [[CrossRef](#)]
- 8) Basmajian JV, Lovejoy JF Jr: Functions of the popliteus muscle in man. A multifactorial electromyographic study. *J Bone Joint Surg Am*, 1971, 53: 557–562. [[Medline](#)]
- 9) Zeng SX, Wu GS, Dang RS, et al.: Anatomic study of popliteus complex of the knee in a Chinese population. *Anat Sci Int*, 2011, 86: 213–218. [[Medline](#)] [[CrossRef](#)]
- 10) Brinkman JM, Schwering PJ, Blankevoort L, et al.: The insertion geometry of the posterolateral corner of the knee. *J Bone Joint Surg Br*, 2005, 87: 1364–1368. [[Medline](#)] [[CrossRef](#)]