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Sonographic Evaluation of the Peroneus Longus and Brevis Tendons:
Anatomical Relationship at Rest and under Stress

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Abstract

Ultrasound has been considered a highly valuable imaging modality to assess superficial tendons due to its high resolution, non-invasiveness, and cost effectiveness. The normal locations of the peroneus longus and brevis tendons at rest and under stress have not been well characterized in the literature. It is hypothesized that the degree of tendon position changes is correlated with the various provocative maneuvers and the stress applied to the tendons. At the resting position, 65% of the samples showed the peroneus brevis tendon off-center lateral to the peroneus longus tendon. No statistically significant difference was seen in tendon displacements among four passive motions. Under stress, eversion combined with dorsiflexion demonstrated an averaged displacement of 66° ± 12° compared with the resting position, and this result does not show statistically significant difference from pure eversion (56° ± 6.9°). Inversion against resistance showed the least position change (25° ± 3.5°) from the tendons at rest. In conclusion, the optimal provocative test maneuver for assessing the status of the peroneal tendons is eversion and dorsiflexion of the foot against resistance.
Introduction

Musculoskeletal Sonography

The use of ultrasound technology has been part of the diagnostic tools for decades, but not until recently has the technology shown significant improvement with newer clinical applications. The capability to observe soft tissues such as muscles and tendons in high image resolution allows clinicians to address specific concerns without having patients undergo many costly and time-consuming tests. It also reduces the possibilities of missed diagnoses or unnecessary surgeries, providing patients a more positive experience with medical care.

Recent studies explore the substitution of ultrasound for magnetic resonance imaging (MRI) of musculoskeletal disorders by describing the use and costs in the Medicare population. From 1996 to 2005, the diagnostic use of musculoskeletal imaging in Medicare population had increased 25.7%, but the use of magnetic resonance imaging had shown a substantial increase of 353.5%. Projected musculoskeletal magnetic resonance imaging costs are $2.0 billion in 2020, while the projected total costs of all imaging modality will sum up to $3.6 billion. A study of 3,621 musculoskeletal magnetic resonance imaging reports showed that 45.4% of primary diagnoses and 30.6% of all diagnoses could have been made with musculoskeletal ultrasound. It was concluded that when appropriate, the substitution of ultrasound for magnetic resonance imaging in musculoskeletal disorders, when appropriate, would lead to savings of more than $6.9 billion in the Medicare population from 2006 to 2020 [1].

In addition to being cost effective, ultrasound also provides many more advantages in imaging musculoskeletal disorders. The ultrasound modality is capable of resolving finer details than magnetic resonance imaging, allowing real-time dynamic examination of the patient, better differentiating fluid from solid materials, and facilitating bilateral comparisons [2,3,4]. Its non-
invasiveness and ease of use allows every patient to undergo ultrasound imaging, and it can effectively image patients with surgical hardware. Musculoskeletal sonography provides a unique opportunity to both diagnose and treat in one session. For examples, musculoskeletal ultrasound is now commonly used in clinics guiding therapeutic interventions such as guiding the needle during aspiration of joints, bursae, and cysts, and injections of corticosteroids or other medications [2]. Its ease of transport also provides a great advantage for medical care in the rural settings and area with lesser resources.

**Lateral Ankle Anatomy**

Figure 1 provides an illustration of the lateral ankle anatomy [4,5]. The lateral peroneal complex consists of the peroneus longus and brevis muscles, the peroneus longus and brevis tendons, a common synovial tendon sheath, an os perineum, and the superior and inferior retinaculum [4,5]. The peroneus longus and brevis tendons arise from the respective muscles located in the later compartment of the leg, superficial and lateral to the fibula. The tendon of peroneus brevis courses anteriorly to the tendon of peroneus longus at the level of the ankle joint [4,5,6,7]. Both tendons are retained against the calcaneum surface by a second retinaculum, the peroneal inferior retinaculum, which inserts into the bone surface and on the tip of the tubercle. Distal to the inferior peroneal retinaculum, the peroneus brevis tendon is separated by the bone plane by fat and has a straight course to insert into the base of the fifth metatarsal. The peroneus longus runs closer to the cortex to reach a sulcus on the anteroinferior aspect of the cuboid bone, where it reflects to join the plantar aspect of the foot and finally insert into the base of the first and second metatarsals [6,8].

At the level of the malleolar region, the peroneal tendons run along a bony groove located on the posterior aspect of the peroneal malleolus. The depth of the groove varies among
individuals, and it is suggested that hypoplasia can lead to tendon instability [8]. The peroneal superior retinaculum, consisting of a thick fibrous band, inserts into the lateral edge of the peroneal malleolus and increases tendon stability during movements of the foot. The retinaculum attaches to a fibrocartilaginous structure, which further increase the tendon stability by deepening the retromalleolar groove and providing a larger surface for tendon forces [9].

**Common Ankle Pathology**

Tenosynovitis and tendinous disruption are problems frequently associated with peroneus longus tendon, and longitudinal tears of peroneus brevis tendon are also common pathological conditions [10,11]. Repetitive ankle motions in sports can lead to wear and tear on the tendons inside the groove [12,13]. Inversion ankle sprain can result in tearing the ligaments or retinaculum, and the forceful stretch on the peroneal tendons from ankle sprains can also cause subluxation [10,14,16,17]. In addition, peroneal tendonosis can occur in elderly population as the tendons weaken or degenerate, which make the tendons more prone to tear, rupture, and other injuries [12,13].

The common complaints of the peroneal tendons disorders are laterally based ankle and foot pain. The pain usually exacerbates with activity. Peroneal tendon subluxation or dislocation may present acutely following a traumatic injury to the ankle. However, sometimes patients may not recall any specific trauma; presentation and diagnosis are then delayed [10,12,14,16]. On physical examination, tenderness to palpation along the course of the peroneal tendons is usually observed. Edema may also be present. Clinical diagnoses of peroneal tendon pathology include a provocative maneuver test. The patient’s foot is examined hanging in a relaxed position with either the knee flexed 90 degrees or with ankles hanging outside of the examination bed. Slight pressure is applied to the peroneal tendons posterior to the fibula. The
patient is then asked to forcibly dorsiflex and evert the foot. The patient may report pain, or the clinician may be able to feel the tendons sublux from this provocative test [15].

**Study Objectives**

This study involves evaluating the peroneal tendons using musculoskeletal ultrasound technology. The normal location of the peroneus brevis and longus tendons at rest and under stress has not been well described in the literature, and very few studies have characterized specific positioning of imaging techniques to assess the peroneal tendons. This study will characterize the location of the peroneus brevis and longus tendons using musculoskeletal ultrasound in a normal population. With the establishment of normative data, the location of peroneal tendons can be characterized. Differences between the anatomical relationships of peroneal tendons at rest and under stress will be determined in this study. Referring to the provocative test for peroneal tendon pathology mentioned above, it is hypothesized that the degree of tendon position changes is correlated with the various provocative maneuvers and the stress applied to the tendons. The goal of this study is to identify the particular provocative maneuver of an ankle that best demonstrates the greatest changes in tendon positions. Practitioners could then rely on this maneuver as their primary assessment method.

**Materials and Methods**

**Anatomy Dissection**

A dissection of the peritoneal complex was performed on an embalmed cadaveric lower extremity specimen. The skin at the lateral ankle was removed in order to observe the anatomical relationship between the peroneal longus and brevis tendons. The superior and inferior retinaculum and the fibrocartiligenous structures surrounding the peroneal complex were
observed. The skin on the lower half of the lateral compartment of the leg was later removed to observe the relationship between the peroneal longus and brevis muscles and their transitions into tendons.

Clinical Sonography

The sample population consisted of 17 asymptomatic subjects (34 ankles) with no history of ankle pathology (9 F: 20Y36/ 8M: 18Y29). Volunteers were selected based on randomized recruitment to achieve normative data without targeting a specific age, gender, ethnicity, and physical activity levels and types.

Inversion, eversion, plantarflexion, and dorsiflexion were performed, first passively without resistance to image the ankles at rest then actively against resistance to stimulate the ankles under stress. A combined motion of eversion and dorsiflexion was also performed actively against resistance, which is described in the above section (Common Ankle Pathology) as the current standard provocative test. Transverse dimensions were imaged.

The changes in the positions of the peroneal tendons at rest and under stress were determined by the degree of the displacement angle of the peroneus brevis tendon with respect to the peroneus longus tendon. The measurement schematics was shown in Figure 2. The centers of mass of the peroneus longus and brevis tendons were connected (Figure 2 top); the two lines represented the anatomical relationship of the two tendons before (at rest) and after movements (Figure 2 bottom). The angle formed from the two lines was defined as the displacement angle.

Statistical Method and Human Subject Protocol
Statistical analysis was undertaken with analyses of variance (ANOVA) test, with the level of significance set at $p < 0.05$. The study was completed with appropriate institutional review board approval obtained through the University of Washington. All subjects in the study provided written consent for the sonography.

**Results**

**Anatomy Dissection**

It was demonstrated on Figures 1 and 3 that the peroneus longus tendon courses superficially and laterally to the peroneus brevis tendon. Our dissection showed that the peroneus brevis tendon inserts onto the base of the fifth metatarsal. The medial side of the foot was not dissected, but it was indicated that the peroneus longus tendon courses through the base of the foot toward the medial side for insertion. In addition, Figures 1 and 4 showed that the superior and inferior retinaculum and fibrous structures surrounding the peroneal tendons.

**Neutral Positions**

At rest, 64.7% of the samples showed the peroneus brevis tendon off-center lateral to the peroneus longus tendon. There were 17.7% of the study samples showed the peroneus brevis tendon lies directly underneath the peroneus longus tendon, and 17.6% demonstrated the brevis tendon off-center medial to the peroneus longus tendon, including brevis tendon more medial and more posterior to the longus tendon in 2.9% of the study samples (see Figure 5).

**Passive Movements**

As shown in Table 1 and Figure 6, the displacement angles among the four maneuvers without resistance averaged from 32.3 degrees (eversion) to 41.5 degrees (plantarflexion).
Analyses of variance (ANOVA) test among four groups and generated p-values ranging from 0.40 to 0.86. No statistically significant difference was seen in the tendon displacements among four passive motions.

** Movements with Resistance  

Under stress (see Table 2 and Figure 7), eversion combined with dorsiflexion demonstrated an averaged displacement of $66^\circ \pm 12^\circ$ compared with the resting position, and this result does not show statistically significant difference from pure eversion ($56^\circ \pm 6.9^\circ$). The p-value comparing the two sets of results was 0.65 according to the ANOVA test. Inversion against resistance showed the least position change ($25^\circ \pm 3.5^\circ$) from the tendons at rest. The p-value comparing inversion and eversion results was 0.0023. Figure 8 shows the sonography images of the peroneal tendons’ relationships under different maneuvers.

** Discussions  

From the anatomy lab dissection, landmarks of clinical sonography to determine the neutral position of the peroneal tendons were determined to be approximately an inch above and posterolateral to the lateral malleolus. The exact length above the malleolus varies among individuals. Through sonography images, the neutral position was defined to be at the starting point of the superior retinaculum. The neutral position of the peroneal tendons infers that the ankle is in a relaxed position with no movement and resistance [6,7].

As reported above, 64.7% of the samples at their neutral positions showed the peroneus brevis tendon off-center lateral to the peroneus longus tendon (Figure 5A). This is determined the most common resting position of the peroneal tendons. Under different maneuver tests, the peroneus longus tendons usually demonstrate smaller displacements, while the peroneus brevis
tendons travel from its resting position towards the fibula. This is described as the peroneus brevis tendon moving from off-center lateral to off-center medial in relation to the peroneus longus tendon on a transverse ultrasound image.

The peroneal tendons under passive movements compared with their resting positions were studied. The four movements are inversion, eversion, plantarflexion, and dorsiflexion. As shown in Table 1 and Figure 6, no statistically significant difference was seen in the tendons’ displacements among four passive motions. However, as the resistance is applied, the ankle movements lead to greater changes in the tendons’ displacements. Out of the four maneuvers, eversion results in the greatest degree of displacement, which means the peroneus brevis tendon travels the most amount from lateral to medial side with respect to the peroneus longus tendon (see Figure 8B). It is sometimes observed that the peroneus brevis tendons are compressed into a flatter shape as moving within the bony groove (see Figure 8B). This might be one of the causes of the longitudinal tear of the peroneus brevis tendon under high ankle pressure, but more studies on the clinical cases are required to support this hypothesis.

The current standard provocative maneuver test to determine the peroneal tendons pathology, the combined motions of eversion and dorsiflexion, was included in our evaluation. This maneuver demonstrated the greatest displacement angle of the peroneal tendons, representing the greatest movement of the peroneus brevis tendon towards medial and even posterior side in relation to the peroneus longus tendon in some individual (see Figure 8D). The analyses of variance (ANOVA) test showed no statistically significant difference between the combined motions (eversion and dorsiflexion) and the pure eversion itself. Nevertheless, the results suggest the standard provocative maneuver test is able to generate the optimal
displacement and changes within the anatomical relation of the two peroneal tendons in normal ankles. This is hence a valid test to assess abnormality or injury of the peroneal tendons.

Raikin et al. published a study of intrasheath subluxation of the peroneal tendons in 2008. The article discussed that patients with retrofibular pain and clicking of the peroneal tendons may not have demonstrable subluxation on physical examination and may have an intact superior peroneal retinaculum. These patients may have intrasheath subluxation and require surgical repair. Two types of intrasheath subluxation are discussed in the paper [16]. Patients with type A intrasheath subluxation were found to have the peroneus brevis and longus tendon snapping over one another and switching their relative positions within the peroneal groove without a tear in the tendons or disruption of the superior peroneal retinaculum. This usually happens as the peroneus longus tendon subluxates around an intact brevis tendon. Type B refers to the peroneus longus tendon subluxating through a longitudinal split tear within the peroneus brevis tendon with a portion of the longus tendon coming to lie deep to the brevis tendon at the level.

Our study on subjects without history of ankle trauma or surgery explored the relative positions of the peroneal tendons under various maneuvers both passively and actively. It was observed that the peroneus brevis tendon moves around the peroneus longus tendon during movements and frequently lies deep and medial to the longus tendon during provocative maneuvers. The reversal of tendon positions and subluxation of the peroneus longus tendon around the brevis tendon were not observed in any of our subjects. This further confirms that the relative position change of the peroneal tendons described in Raikin et al. was pathological, and it cannot be commonly observed in subjects without ankle injury or pathology [16,18].

The volunteers were asked about their physical activity levels and sport involvements prior to the sonography sessions. This is to ensure the randomization of the study, which we
hope to include a wide range of variety of sport involvements and activity levels. Interestingly, it is found in some of the subjects in this study that soccer players and dancers demonstrated greater tendon displacements during passive maneuvers. This finding is not explored further in the study. However, it is suggested that since these volunteers are involved with sports and activities which require more ankle movements, their retinaculums are likely to be looser subsequently, leading to greater instability of the peroneal tendons [19]. More investigation is required for further understanding of this observation.

**Conclusion**

Without resistance, the tendons do not show significant differences in positions among various maneuvers. The greatest displacements of the relative tendon positions were noted during eversion combined with dorsiflexion against resistance. These findings suggest that the optimal provocative test maneuver for assessing the status of the peroneal tendons is eversion and dorsiflexion of the foot against resistance.

**Acknowledgement**

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References

Tables and Figures

Figure 1. The peroneus brevis tendon courses anteriorly to the peroneus longus tendon at the level of the ankle joint, and the two tendons run along the lateral side of the ankle [R-3].

Figure 2. Schematics of measuring the displacement of the tendons (in degrees).
Figure 3. Dissection of the lateral ankle: peroneal tendons.

Figure 4. Dissection: retinaculum and fibrous structures surrounding the peroneal tendons.
Figure 5. Neutral positions (resting positions of the peroneal tendons.) Centers of mass of the peroneal tendons: A. the peroneus brevis tendon is off-center lateral to the peroneus longus tendon (64.7%); B. the peroneus brevis tendon lies directly underneath the peroneus longus tendon (17.7%); C and D. the brevis tendon is off-center medial to the peroneus longus tendon (17.6%); D. the brevis tendon is more posterior to the longus tendon (2.9%).

Figure 6. Passive motions compared with the resting position.

Table 1. Passive motions (unit: degree)

<table>
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<td>5.256</td>
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Figure 7. Ankle motions against resistance compared with the resting position.

Table 2. Movements with resistance (unit: degree)

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<th>Eversion</th>
<th>Plantarflex</th>
<th>Dorsiflex</th>
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<td>49.41</td>
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Figure 8. A. Inversion against resistance; B. Eversion against resistance; C. Dorsiflexion against resistance; D. Combined eversion and dorsiflexion against resistance.