Peroneal Tendon Injury in the Elite Athlete

24

Robert B. Anderson, Eric Folmar, Michael Gans, and Mark Sobel

Introduction

Peroneal tendon problems can be divided into three categories, which often overlap: (1) peroneal tendonitis or tendinosis, (2) peroneal tendon tears (splits) or ruptures, and (3) peroneal tendon subluxation or dislocation [4]. Pain and swelling in the posterolateral aspect of the ankle or lateral hindfoot are the main presenting complaints. The presence of chronic lateral ankle instability, and/or a cavovarus deformity, may predispose the patient to peroneal tendon pathology [5–9].

Peroneal tendon disorders occur in one of three anatomic zones as described by Smith et al. [10]. The three zones are shown in Fig. 24.1.

The original version of this chapter was revised. The correction to this chapter can be found at https://doi.org/10.1007/978-3-030-46646-6_26

R. B. Anderson (✉)
Titletown Sports Medicine and Orthopedics, Green Bay, WI, USA

Associate Team Physician, Green Bay Packers, WI, USA

E. Folmar
Department of Physical Therapy, Movement & Rehabilitation Sciences, Northeastern University, Boston, MA, USA
e-mail: e.folmar@northeastern.edu

M. Gans
PTSMC Orthopedic Residency Program, West Hartford, CT, USA

Physical Therapy and Sports Medicine Centers, Guilford, CT, USA

M. Sobel
Lenox Hill Hospital - Northwell Health, Orthopaedic Surgery, New York, NY, USA
e-mail: msobelmd@comcast.net

M. Sobel (ed.), *The Peroneal Tendons*,
https://doi.org/10.1007/978-3-030-46646-6_24

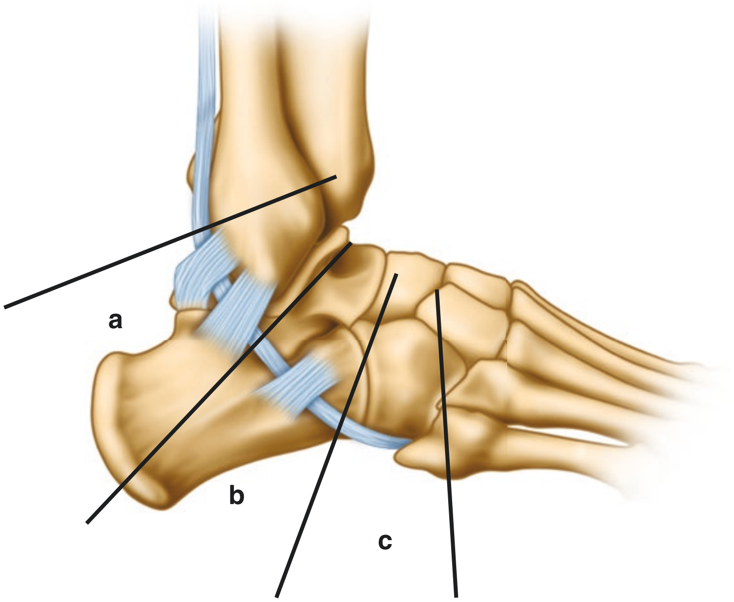

Fig. 24.1 Lateral view of the foot highlighting the three anatomic zones through which the peroneus longus tendon passes. Zone A is the region of the tip of the lateral malleolus and includes the area covered by the superior peroneal retinaculum. Zone B is the region of the lateral calcaneal trochlear process and covered by the inferior peroneal retinaculum. Zone C is the region of cuboid notch where the peroneus longus tendon turns to cross the plantar aspect of the foot [10]

In zone A, the region of the superior peroneal retinaculum (SPR), the peroneus brevis tendon can be torn or split longitudinally, as depicted in Fig. 24.2 [11, 12]. There is also the possibility of a low-lying peroneus brevis muscle belly or anomalous peroneus quartus causing encroachment within the fibular groove in this zone [13, 14]. These issues are often present in conjunction with tendon subluxation [15]. In zone B, along the lateral wall of the calcaneus, the presence of an enlarged peroneal tubercle can contribute to stenosing tenosynovitis of the peroneus longus tendon and one may see further splitting, tearing, or even frank rupture of the peroneus brevis tendon in this zone [16–18]. Zone C encompasses the cuboid tunnel, where the peroneus longus can rupture in an area of thinning and attenuation created by the os peroneum and its articulation with the cuboid. Injury to the os peroneum itself can include fracture of the os peroneum, shown in Fig. 24.3, or diastasis of an enlarged multipartite os peroneum, much like a hallux sesamoid [19, 20].

In the professional or elite athlete, an accurate and timely diagnosis is crucial, and accordingly, one must have a high index of suspicion for these injuries in those who present with pain along the posterolateral ankle and lateral hindfoot region. A thorough history and physical examination can be diagnostic. In addition, one should have a low threshold for rapid use of ancillary tests, such as MRI and high-resolution ultrasound. MRI can identify the pathology and help in planning an appropriate surgical treatment should nonoperative management be unsuccessful.

Fig. 24.2 Zone 1 Injuries. Associated with peroneal tendon dislocation, subluxation with split tears, and vice versa, tendon rupture, and lateral ankle ligament instability

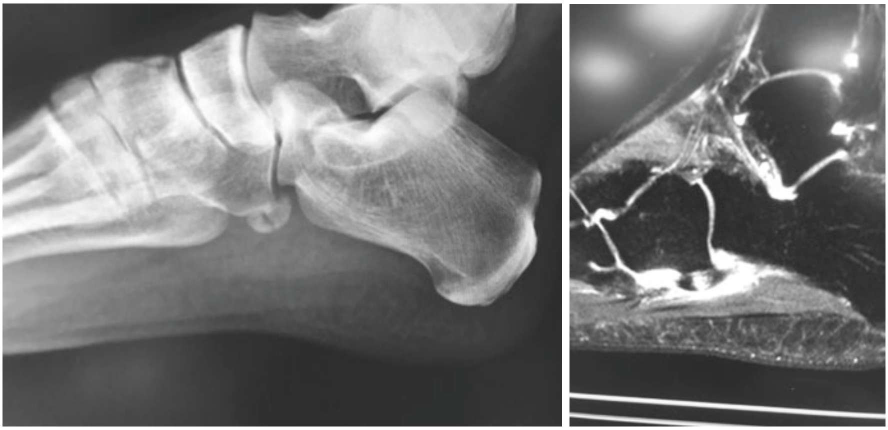

Fig. 24.3 Fractured os peroneum in zone C

However, unlike ultrasound, it is a static study and not helpful for tendon hypermobility, where dynamic ultrasound would be [21].

Various surgical procedures have been described and recommended depending on the specific pathology found at the time of surgery. These include tendon debridement or tubularization, removal of low-lying peroneus brevis muscle belly or anomalous peroneus quartus tendon, tenodesis, tendon transfer or graft, superior peroneal retinaculum repair +/− fibular groove deepening, and lateralizing calcaneal osteotomy or dorsiflexion osteotomy of the first metatarsal [1, 2, 4, 22–44].

Peroneal tenosynovitis often improves with conservative measures, such as rest with immobilization and injection with PRP, with surgery reserved for refractory cases. In contrast, surgical treatment is frequently required for peroneal tendon subluxation and includes anatomic repair or reconstruction of the superior peroneal retinaculum, typically with fibular groove deepening [34, 35, 45, 46]. Surgical treatment for peroneal tendon tears (splits) is based on the remaining viable tendon. Primary repair and tubularization is recommended for tears involving <50–60% of the tendon, and tenodesis is indicated for tears of the peroneus longus that are not repairable [4, 47]. It is now our preference to perform an interposition allograft reconstruction for complex tears and ruptures of the peroneus brevis [25]. Calcaneus and metatarsal osteotomies are considered in those with significant cavovarus [31, 48].

The mechanism of injury for these peroneal tendon disorders is quite variable, some do to acute forces while others present from chronic overuse [49, 50]. Given the forces generated, athletes are at more risk for both. In addition, hockey and baseball players are exposed to direct trauma along the lateral side of the ankle from errant pucks and baseballs. The surgical techniques employed for these peroneal tendon disorders are similar regardless of the individual's athletic involvement. Nonoperative modalities are initially attempted in both the athlete and non-athlete. This will include relative rest, immobilization, injection techniques (biologics), physical therapy, and orthoses. What does differ between the two groups is the duration of conservative treatment and postoperative care/rehabilitation. Given the player's schedule, a smaller window for conservative modalities is often the case. When performance limiting and refractory to nonoperative modalities, surgery may be recommended after 3–4 months so as not to interfere with consecutive seasons of sport participation.

This chapter wishes to illustrate the different injuries to the peroneal tendons in elite and "career" athletes, and the surgical procedures indicated with the rehab protocols recommended. In that light, the mechanism of injury may be the same for "elite" athletes and recreational ones, but given the high energy imparted with the elite athlete, the injuries are more common and dramatic. There may also be a relationship to the field surface and the cleat–turf interaction, as excessive torque may occur when a shoe fails to release.

History and Physical Examination

A detailed review of when and how the pain and swelling began is helpful. In acute situations, the athlete may recall a specific maneuver, perhaps ankle inversion or forced dorsiflexion against active plantar flexion. Chronic situations will require a discussion of what treatment methods have already been initiated. It is important to determine what maneuvers reproduce the pain, its location, and whether or not there is a feeling of subluxation.

The exam begins with a careful assessment of the entire lower extremity, evaluating the overall alignment with comparison to the contralateral. Genu varum and cavovarus are associated with lateral overload issues. Heel and toe walking is observed, along with one-legged maneuvers. Is pain or tendon subluxation reproduced with a single limb heel rise? The sitting exam determines areas of fullness, localized tenderness, skin or soft tissue changes, as well as continuity and function of the peroneal tendons. Resistance testing helps to assess for strength as well as for the presence of tendon hypermobility, intra-sheath snapping, tendon subluxation, and gross dislocation [49–51]. Ankle and hindfoot joints are tested for pain and instability, with careful comparison to the contralateral.

Imaging

Ankle and foot radiographs are performed routinely for all patients presenting with a potential peroneal tendon problem. As shown in Fig. 24.4, three views of the ankle are recommended as the oblique view better identifies abnormalities to the posterolateral rim of the distal fibula (fleck sign).

Foot X-rays help to highlight avulsions as well as the overall posture of the foot. The oblique view best demonstrates the presence of an os peroneum. Hindfoot alignment views assist with evaluation of the associated cavovarus posture.

Fig. 24.4 Example of a peroneal tendon dislocation in a professional football player. SPR avulsion with a "fleck sign" (Type 3) was noted. ORIF was performed as the fragment was of adequate size

MRI is routinely ordered for those patients failing to improve with conservative care. Soft tissues are assessed, as well as any associated intra-articular pathology. The peroneal tendons are examined for tenosynovitis, tears, ruptures, and dislocation. However, it should be noted that longitudinal split tears can be difficult to identify on even the best MRI units. In addition, there is a phenomenon of the “magic angle.” When a tendon changes direction, as the peroneals do, thinning and partial ruptures can be overdiagnosed. In addition, T2 weighted signals can overread ruptures, and the physician needs to consider this when embarking on surgical intervention. Ultrasound is another imaging modality useful in suspected peroneal tendon issues. Although technologist and reader dependent, this dynamic study helps to define the size of the tendon, its location, and whether it subluxes through various maneuvers.

Conservative Treatment Management

Nearly all peroneal tendon problems encountered are initially managed with nonoperative modalities: immobilization, relative rest, ice, compression, antiinflammatory medications, and eventually, strengthening. Cast immobilization, even for 1–2 weeks, is very beneficial for acute tenosynovitis/tendonitis. A cast ensures compliance over a boot, despite the inconveniences. Formal physical therapy is initiated once acute pain and swelling have subsided, with emphasis on peroneal tendon strengthening. Those with cavovarus will eventually be transitioned to a custom orthoses with a lateral heel wedge and forefoot posting. Associated lateral ankle instability is best treated with a brace that limits inversion. The entities not treated with initial nonoperative management are those with acute dislocation of the peroneals, dislocatable peroneals, and rupture of the peroneus brevis. Failing stage 1 management, other modalities to consider include injection of a biologic material. Cortisone can further weaken a diseased tendon and therefore is avoided for fear of rupture. However, amniotic tissue derivatives and PRP/stem cells can be considered.

Surgically Managed Disorders

As mentioned above, there are several peroneal tendon disorders that will require surgical intervention. Many of these may also need to address associated ankle ligament pathology and an overlying cavovarus [6–8, 48]. It is recommended that an MRI be performed prior to surgery to determine the need for arthroscopic evaluation of the ankle at the same setting. The surgeon needs to be prepared for all reconstruction options, i.e., allograft, hardware, and biologics. The postoperative course and rehabilitation are dependent on the pathology addressed.

Acute Peroneal Tendon Dislocation

It is very difficult to manage an unstable peroneal tendon (Fig. 24.5) nonoperatively. Both acute and chronic types typically require a fibular groove deepening and SPR repair. Multiple techniques for deepening are reported below.

Fig. 24.5 Peroneal tendon dislocation

While a J-pad may be utilized to try to "buy" time, it will not suffice long term and could even place the patient at risk for split tears and frank ruptures of the peroneus brevis tendon. When embarked upon, surgical repair will nearly always necessitate deepening of the fibular groove [1, 45].

An isolated repair of the (SPR) should only be considered in the professional athlete, if it is an acute peroneal tendon dislocation and the patient is found to have a concave sulcus on imaging [49].

The most predictable manner in which to stabilize the tendons is to deepen the groove, as shown in Fig. 24.6, particularly in late presentations [45]. There are a number of different techniques described for fibular groove deepening [1, 35, 45]. Our preference has been to avoid an osteotomy or to create a bed of denuded bleeding bone that could lead to tenodesis and adhesions, thus the "indirect" method was employed [45]. Figures 24.7, 24.8, and 24.9 show the "indirect" groove deepening technique. First, we start with a small diameter drill at the origin of the CFL and

Fig. 24.6 “Indirect” groove deepening technique. Senior author’s preferred technique since 1993 as benefits of a “minimally invasive” technique in the elite athlete. Advantages = an “eggshell” procedure. Impaction technique. Maintains soft tissue on peroneal floor. No osteotomy to heal. Good results reported at 2 years [45]

Fig. 24.7 Indirect deepening. Start with small diameter drill at the origin of the CFL and gradually increase diameters, thinning the cortical bone along the posterior aspect of the distal fibula [45]

Fig. 24.8 Once the groove deepening is adequate, as assessed by coverage of both peroneal tendons in a neutral position, the SPR is repaired via drill holes in the posterolateral fibula

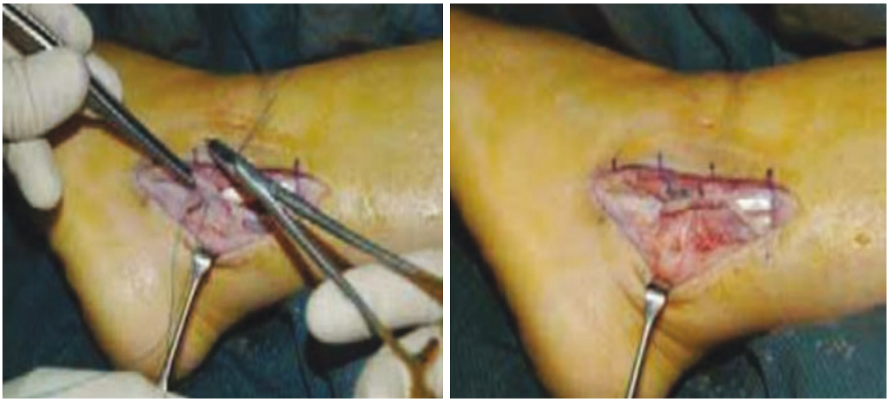

Fig. 24.9 Regardless of type, always add SPR repair. Preference is to do with drill holes in the posterolateral fibula

gradually increase diameters, thinning the cortical bone along the posterior aspect of the distal fibula [45]. Once the groove deepening is adequate, as assessed by coverage of both peroneal tendons in a neutral position, the SPR is repaired via drill holes in the posterolateral fibula.

This technique creates an eggshell of the distal fibula that allows the groove to be impacted inwardly, therefore accentuating the posterior rim. It is inherently stable, requires no bone healing, and maintains the natural floor of the groove [45]. In addition, the procedure includes removal of any excessive soft tissue in the sulcus, such as low-lying brevis muscle, or anomalous peroneal tendons (peroneus quartus). By doing so, there is more space to maintain the peroneus brevis and longus tendons posteriorly. Any split tears are identified and repaired. The SPR is excised of any redundancy and then secured back to drill holes in the posterolateral fibula, further stabilizing the tendons but avoiding a stenosis as well. This repair provides

Fig. 24.10 Case example – peroneal subluxation

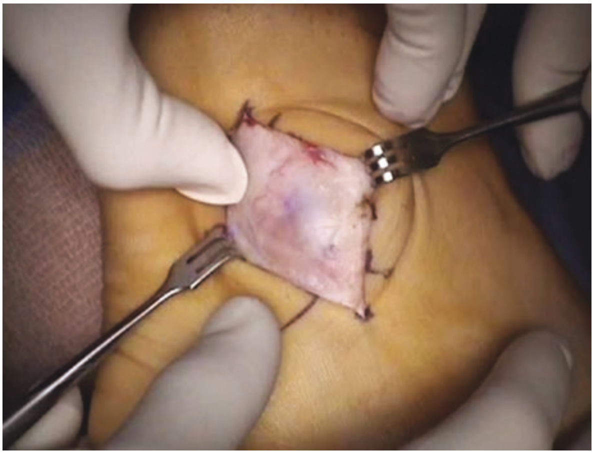

Fig. 24.11 Attenuated SPR

immediate stabilization of the tendons. Thereafter, the postoperative course consists of 2 weeks non-weightbearing in a splint, then weightbearing in a boot for 6 weeks. During this time, gentle active dorsiflexion and plantarflexion are initiated. Straight line running activity commences at 8 weeks and cutting maneuvers by 12 weeks. The athlete is then cleared for all on-field or court activities and returns to full athletic participation when functional recovered.

Figures 24.10, 24.11, and 24.12 show a case example of peroneal subluxation gradually worsening with pain. Upon surgical exploration, the SPR was attenuated. The low lying and hypertrophic peroneus brevis was debrided and debulked.

Figure 24.13 depicts the MRI results of an 18-year-old basketball player with inversion injury. The patient presented with chronic lateral ankle pain and swelling. While the X-rays were negative, MRI results show peroneal tendon dislocation. Figures 24.14 and 24.15 show the indirect groove deepening technique being utilized to repair the torn tendon.

Fig. 24.12 Debride/debulk low-lying and hypertrophic peroneus brevis

Fig. 24.13 MRI on an elite basketball player confirming peroneal dislocation

Peroneus Longus Rupture/Os Peroneum Syndrome

A number of athletes sustaining these injuries are relatively pain free and functional after 4–6 weeks of immobilization and relative rest. However, those who have persistent pain and swelling in the Zone 3/C region of the hindfoot may require surgical intervention. This is particularly true in those with underlying cavovarus (Fig. 24.16).

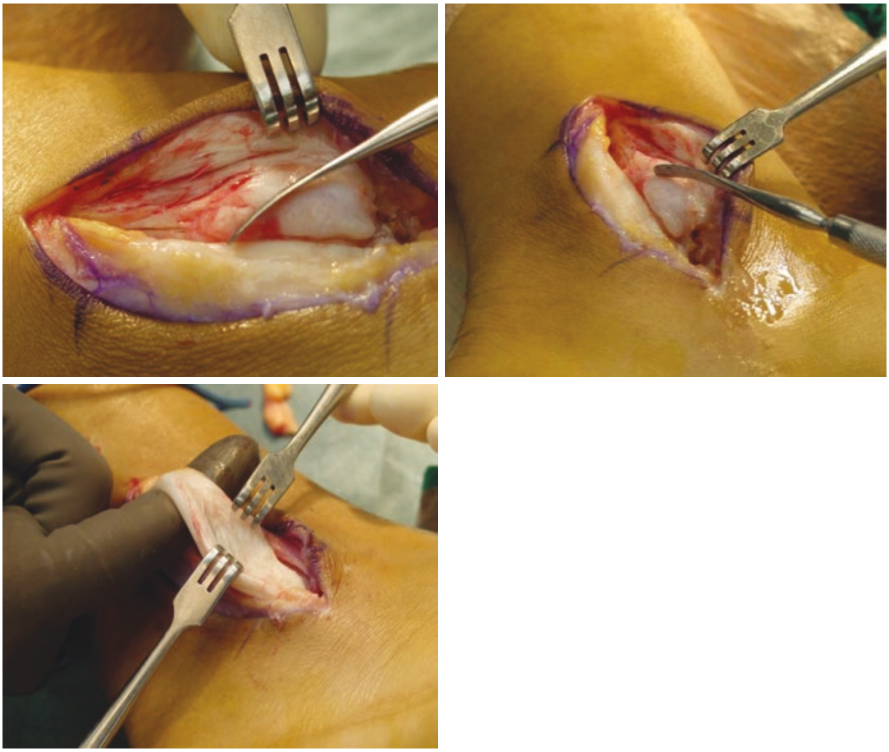

Fig. 24.14 Peroneal subluxation with tear

It is extremely difficult, and unsatisfying, to attempt a repair of a peroneus longus rupture in that location. Even maintaining a longus tendon while exercising a diseased os peroneum is problematic. Therefore, these situations are best addressed with a side-to-side tenodesis to the peroneus brevis tendon [19].

Figures 24.17 and 24.18 show a series of images treating a cavovarus patient with peroneus longus rupture in zone 3. A first metatarsal long oblique dorsiflexion osteotomy is performed with bicortical screw fixation, given the underlying cavovarus (Fig. 24.17). The peroneus longus rupture is then managed with debridement, and tenodesis to the brevis tendon (Fig. 24.18).

The anastomosis is performed with distal retraction on the longus to obtain appropriate tension. In the event the longus is still in continuity, it is best to create the tenodesis prior to excising the diseased distal portion. The peroneal tubercle is removed to avoid placing pressure on the anastomosis. Amniotic tissue products are often utilized in an effort to lessen adhesions. A non-weightbearing splint is applied in the operating room and the patient can be advanced to a weightbearing boot at 2 weeks. Gentle range of motion (ROM) is initiated but resistance exercises are avoided until 8 weeks postoperative. Most athletes can return to full participation by 16 weeks.

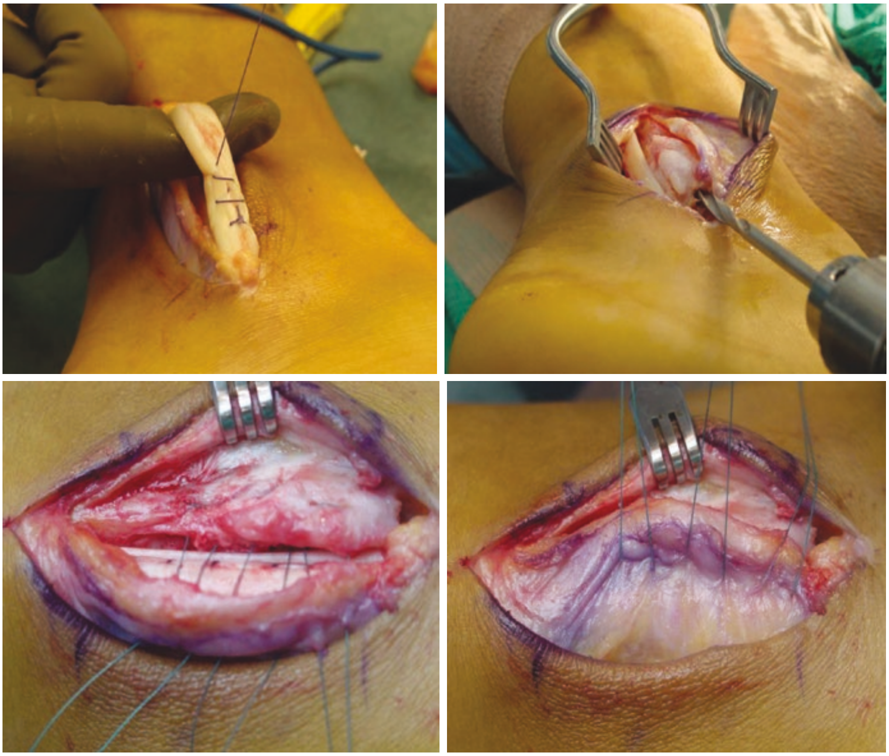

Fig. 24.15 Repair of tear with groove deepening and repair of SPR

Peroneus Brevis Split Tear in Association with Chronic Lateral Ankle Instability

Split tears of the peroneus brevis can occur in conjunction with subluxation, as previously mentioned, or with chronic lateral ankle instability, or both [6–9]. These tears can be located centrally, in the periphery, or may be complex in nature. Central tears can be debrided and repaired with a running suture, typically a PDS or proline type. Peripheral tears of even 60% can be excised and tapered [47]. As shown in Fig. 24.19, a tear less than 50% is excised and tubularized.

Some complex tears can be salvaged with debridement and tuberization, while others may require excision with tenodesis or allograft interposition. The associated lateral ankle instability can be managed with any technique the surgeon feels comfortable with. This may be a modified Brostrom-Gould procedure, an artificial ligament augmentation, or allograft/autograft hamstring tendon weave. Given the already compromised peroneal tendon, an augmentation or transfer utilizing that structure is not recommended. The postoperative course is dependent on the extent

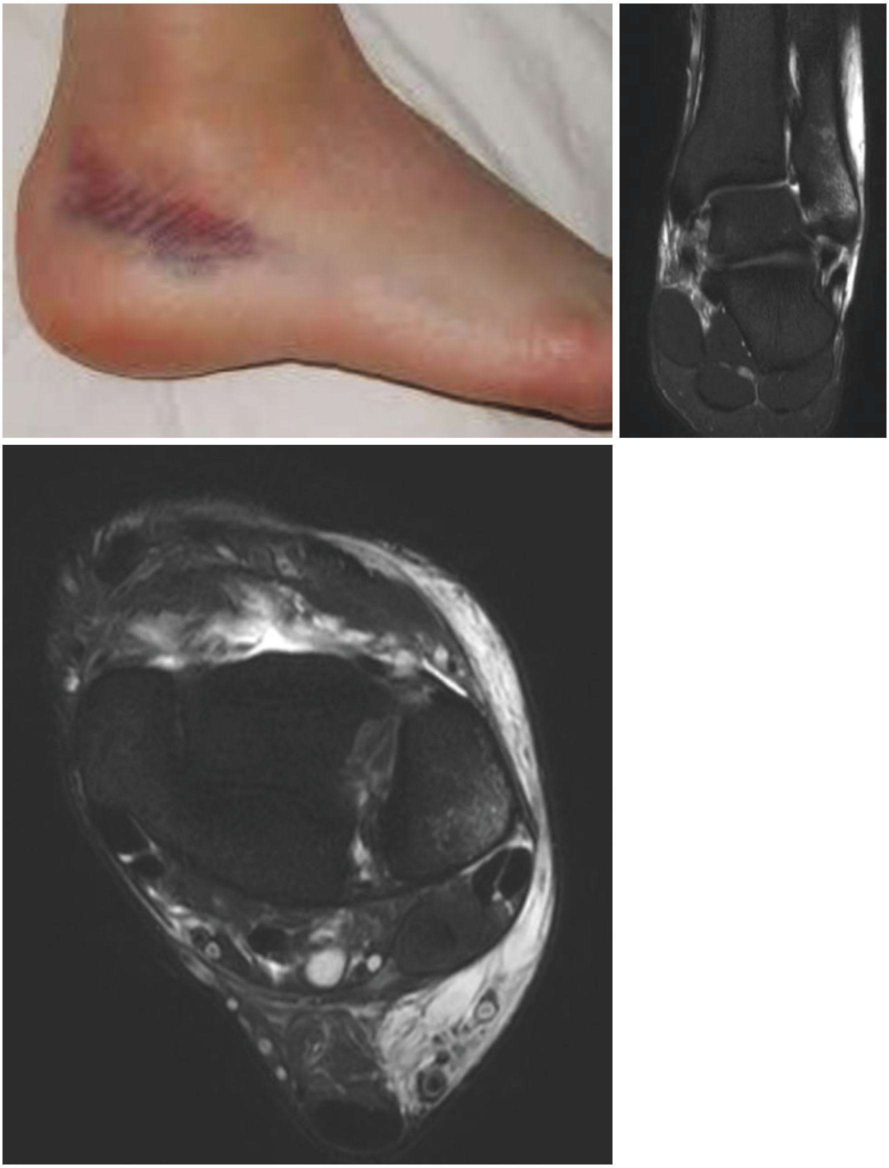

Fig. 24.16 Peroneal tendon rupture in professional football player with cavovarus. MRI often difficult to assess degree and extent

of the peroneal repair and durability of the lateral ligament reconstruction. To avoid tendon adhesions, gentle dorsiflexion and plantar flexion are initiated by 2–3 weeks, with weightbearing in a boot until 8–10 weeks postoperative. At that time, peroneal strengthening can be initiated while avoiding inversion until 14–16 weeks postoperative.

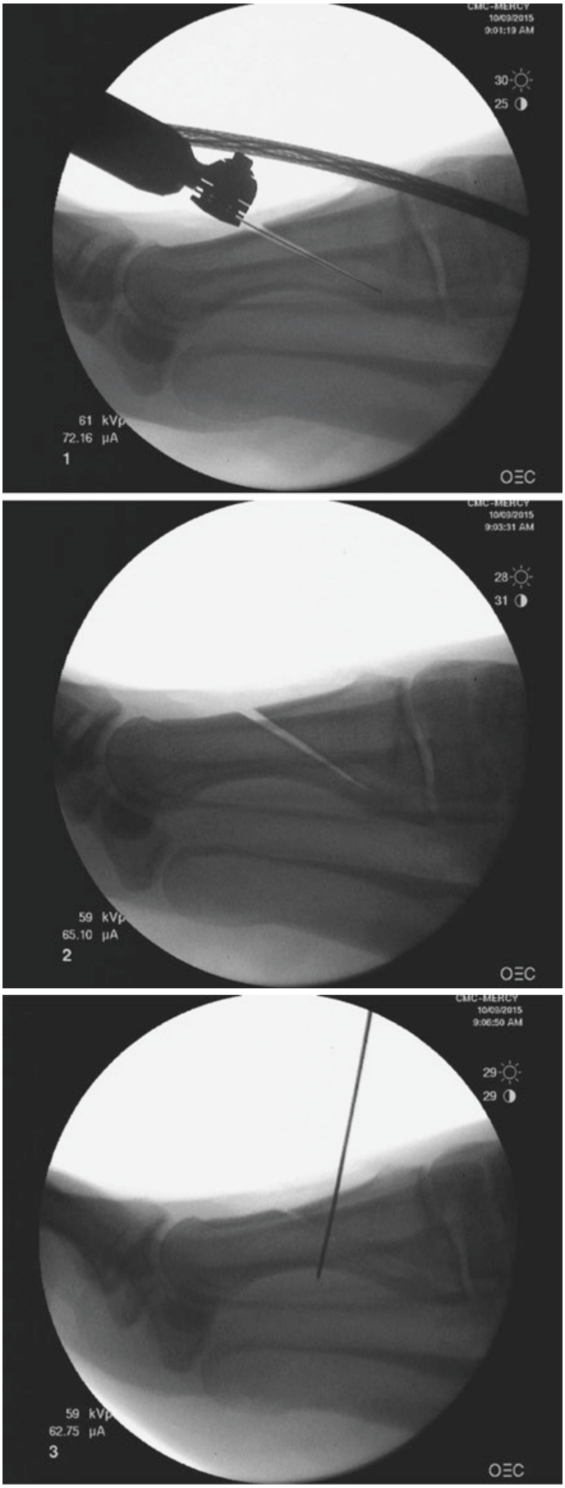

Fig. 24.17 A first metatarsal long oblique dorsiflexion osteotomy is performed with bicortical screw fixation, given the underlying cavovarus

Fig. 24.17 (continued)

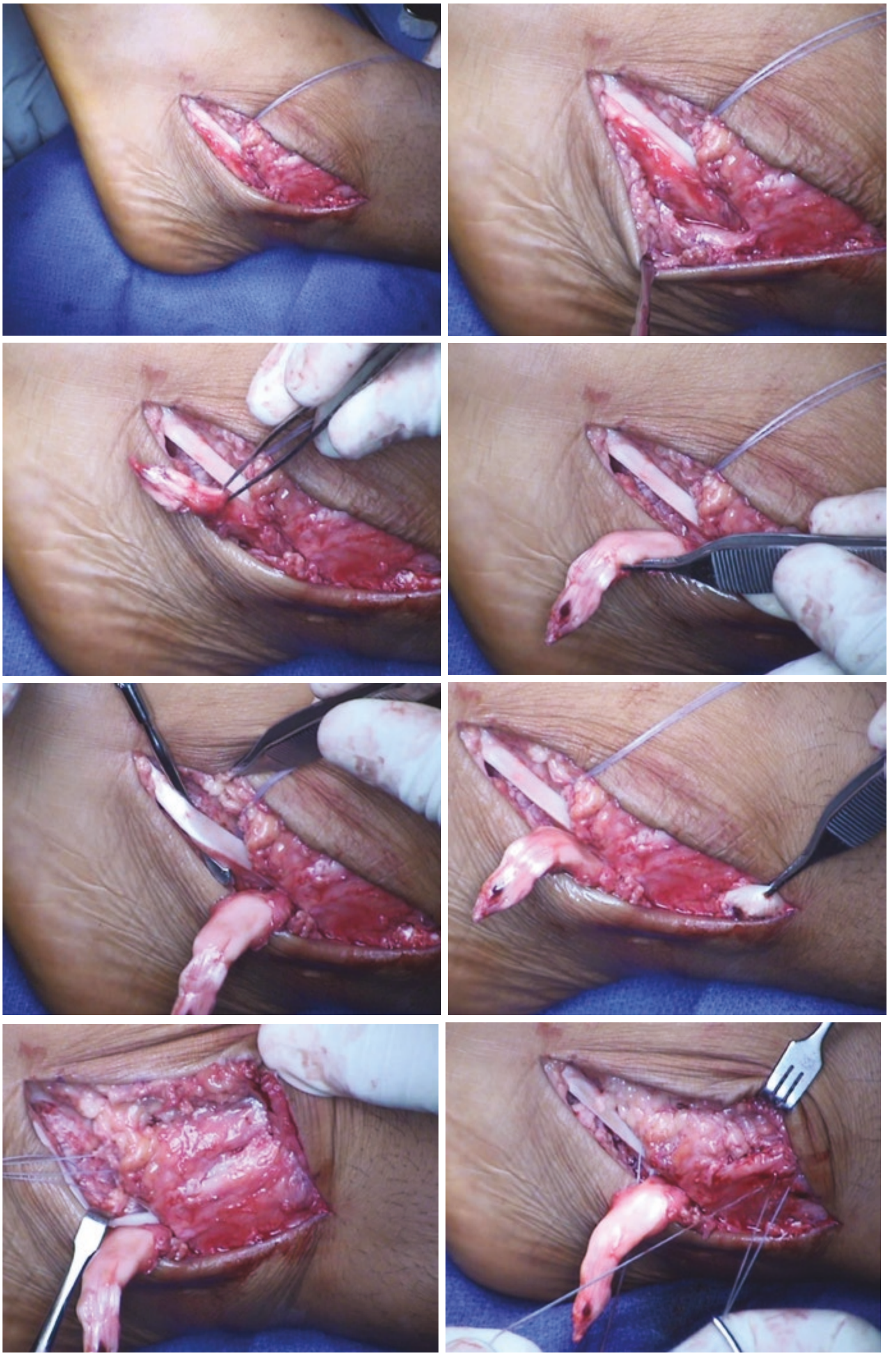

Fig. 24.18 Peroneus longus rupture in zone 3(C) managed with debridement, and tenodesis to the brevis tendon

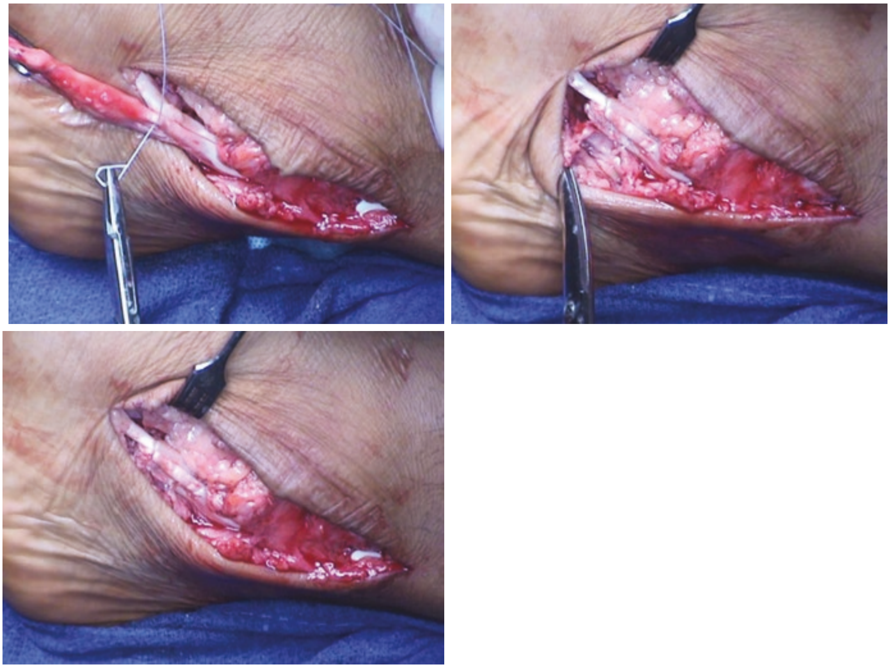

Fig. 24.18 (continued)

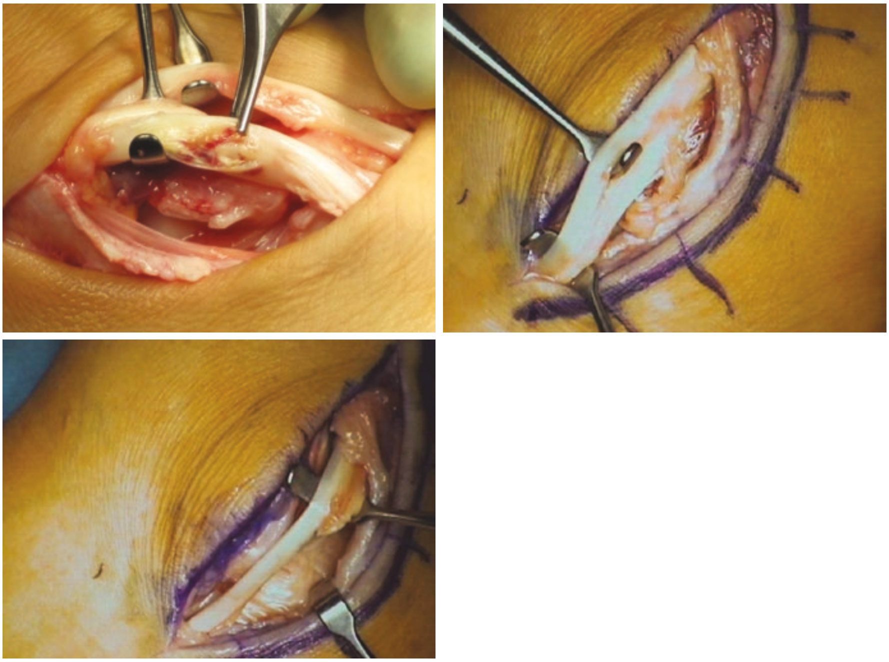

Fig. 24.19 Dislocation with tendon tears. Brevis or longus split tear from inversion

Isolated Peroneus Brevis Rupture

Maintaining integrity and function of the peroneus brevis is paramount in the athlete, particularly in the face of cavovarus. In the case of a rupture, options include tenodesis to the peroneus longus or allograft replacement. In the athlete, it is likely best to maintain the function of both tendons independently, thus avoiding a tenodesis. Unlike the distally located rupture of the longus, the brevis will rupture in zone 2/B and is amenable to salvage with an interposition allograft [25]. Hamstring autografts and allografts work well for this purpose. A pulvertaft weave is performed proximally and then the distal end can then be woven through the remaining stump of the brevis or secured to the base of the fifth metatarsal with an anchor or endobutton, similar to that of repairing a distal biceps rupture. It is important to adequately tension the reconstruction, typically maximum tension with the foot in eversion. It is rare to ever create too tight of a situation. Figure 24.20 shows an MRI of a complex brevis rupture and exemplifies the gracilis tendon allograft for its management. Postoperatively, a non-weightbearing splint is utilized for 2–3 weeks, and then, gentle motion of the ankle is initiated to create a protected excursion of the brevis. The patient weight bears in a boot until 8 weeks postoperative. It is recommended to avoid inversion for 8–10 weeks.

Combined Peroneus Brevis and Peroneus Longus Tendon Rupture

This is a very difficult scenario in any individual, especially the athlete and is magnified with underlying cavovarus. Rarely will a debridement and creation of one tendon unit provide adequate function for the active individual. Assuming that the ruptures are relatively acute (<6 months), the proximal musculature should be

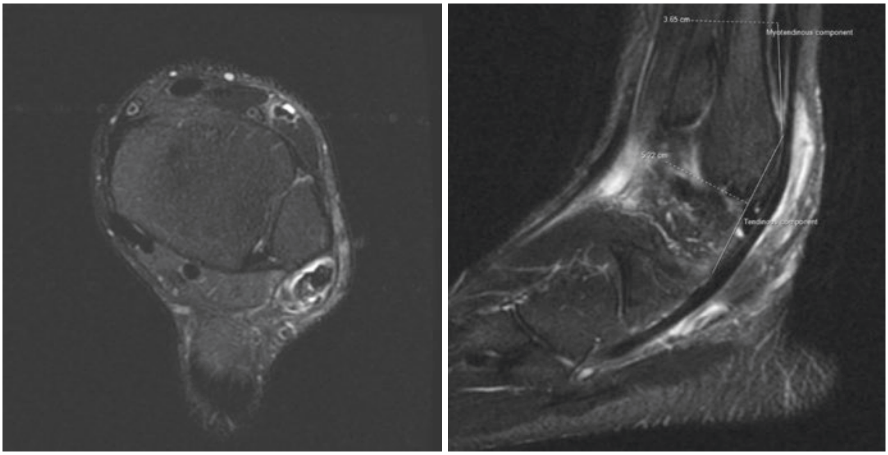

Fig. 24.20 MRI of elite athlete with peroneal tendon rupture. Example of using gracilis tendon allograft for management of this complex brevis rupture

Fig. 24.20 (continued)

Fig. 24.20 (continued)

healthy and functional, thus allowing for salvage with hamstring allograft interposition to each tendon, if possible. Figure 24.21 shows a case of rupture of both tendons in a 26-year-old professional football player. An allograft tendon interposition was used for both tendons, with indirect groove deepening.

In the event that the proximal muscles are fibrotic and nonfunctional, then a tendon transfer should be considered [24, 52, 53]. I prefer the FHL tendon as opposed to the FDL, due to ease of harvest and improved strength characteristics. Adequate length can be obtained by harvesting the tendon at the plantar aspect of the hallux and then locating it at the master knot of Henry. If necessary, a third incision is placed at the posteromedial ankle to identify and transfer along the posterior aspect of the joint. However, it is possible to identify and redirect the FHL from the posterolateral exposure used for the peroneal tendon exposure, bringing it into the lateral hindfoot region where is it anastomosed to the distal peroneus brevis with maximum tension applied. The postoperative course is similar to that outlined for the isolated brevis rupture and reconstruction. The patient needs to appreciate preoperatively that this is not a substantial transfer and may not rehab to a point that allows for return to a high level of athletic participation. In fact, a few will fail with ongoing inversion tendencies and may eventually require salvage via a subtalar arthrodesis. When faced with the situation where a patient has undergone tendon salvage surgery but has not improved functionally, one may wish to perform a

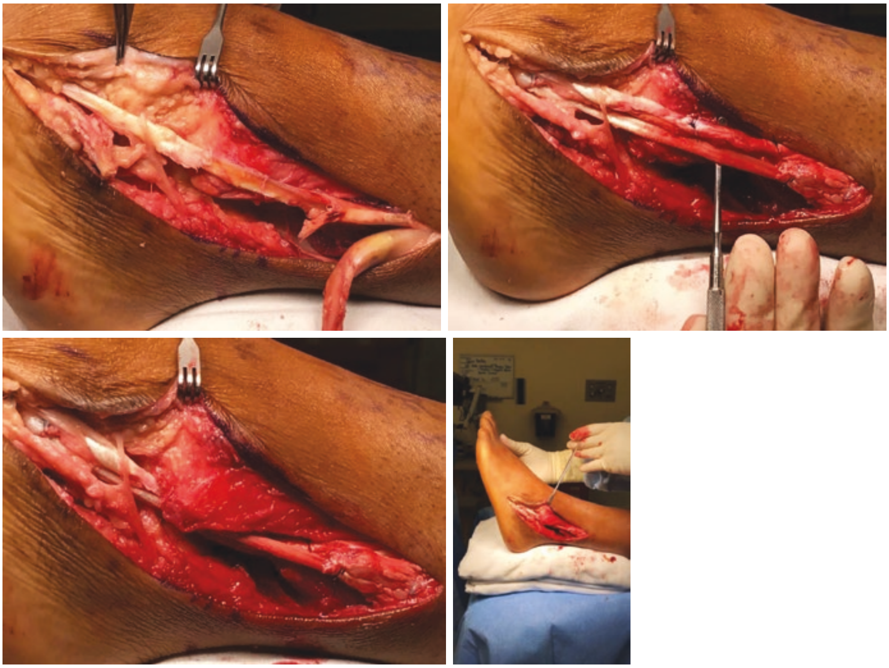

Fig. 24.21 Case: A 26-year-old professional football player. Chronic dislocation and ruptured both tendons. Allograft tendon interposition used for both tendons, with indirect groove deepening

Biodex quantitative strength test to determine whether adequate and successful rehab has been obtained. A baseline study can be followed by a second evaluation 12 weeks later to assess improvements.

Concominent Cavovarus Foot

As has been mentioned, frequently, the cavovarus foot plays a major role not only in the pathophysiology of peroneal tendon and lateral ankle disorders but also in the management and outcome [31]. Any soft tissue reconstruction performed on the lateral ankle and hindfoot region needs to be protected for the best long-term results. Based on careful preoperative evaluation, which includes a Coleman block test, either a lateralizing calcaneal or dorsiflexion 1st metatarsal osteotomy (or both) should be considered in the individual with a cavovarus presentation [48]. I prefer those techniques that include a substantial bone surface, compress with weightbearing forces and allow for screw fixation (i.e., bicortical in the 1st metatarsal). Figure 24.22 depicts an osteotomy for cavovarus. This is not for athletes in the primary situation. These osteotomies are generally protected from weightbearing forces for 3–4 weeks postoperative, after which weightbearing and tendon strengthening are advanced. The long oblique osteotomy and bicortical fixation are biomechanical advantages.

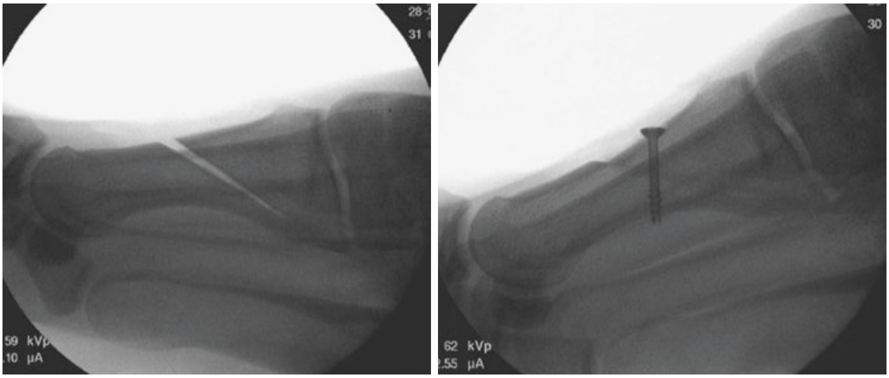

Fig. 24.22 First metatarsal long oblique osteotomy for cavovarus

Role for Peroneal Tendoscopy

Van Djik and others have advocated tendoscopy, particularly for the peroneal tendons. This minimally invasive procedure has been shown to be advantageous in diagnosing split tears and subtle subluxation (intra-sheath) where MRI may not [54, 55]. It is also very useful in the case of tenosynovitis, providing adequate working space to perform a thorough tenosynovectomy. There is a learning curve to this technique, and obvious limitations when dealing with frank tendon dislocation and tendon ruptures.

Postsurgical Rehabilitation

Rehab Protocol

Standardization of any rehabilitation protocol is difficult in any patient population. It is inherently critical that tissue healing, tissue stress, and consideration of concomitant procedures are taken into account when implementing a rehab protocol. However, there has been a shift in rehab philosophy over the recent years to more criterion-based protocols. This shift allows for a progressive approach, allowing for gradient increases in progression based upon the individual's abilities as well as respect for tissue stress and healing. In the athletic population, a detailed understanding of sport-specific demands is crucial to appropriately determine a return-to-sport plan. Figures 24.23 and 24.24 demonstrate an example of postsurgical protocols. Timeframes serve primarily as a reference.

Phase I - Immobilization

There is no consensus in today's literature with regard to an ideal postoperative immobilization time or initiation of range-of-motion exercises [3]. Postoperative

Phase I (0-2 weeks)

Goals

- Rest
- Control swelling and pain
- Activities of daily living

Guidelines

- Non weight bearing in cast or boot
- Sutures removed at 14 to 21 days
- Education: surgery, healing time, anatomy, phases of rehabilitation
- Encourage activities of daily living
- Rest and elevation to control swelling
- Control pain
- Hip and knee active range of motion
- Intrinsic foot muscle activation (per procedure)

Phase II: Week 3-6

Goals

- Full weight bearing in cast or boot with no swelling (early stage)

Guidelines

- Shower without boot
- Elevation to control swelling
- Start to weight bearing
- Massage for swelling
- Submaximal isometrics progressing to full isometric to active range of motion (AROM) ankle and foot: plantarflexion / dorsiflexion / inversion
- NO active eversion/NO Passive inversion
- Progress to stationary bicycle
- Hip strengthening in non-weightbearing

Phase III: Week 7-10

Goals

- Full weight bearing without boot
- Full plantar flexion and dorsi flexion

Guidelines

- Wean from walker boot by ± week 8
- Use an ankle brace during daytime (as indicated)
- Control swelling with elevation and modalities as required
- Stationary bike
- Active range of motion ankle and foot in all directions: gentle inversion & eversion
- Mobilization of foot and ankle in directions that do not directly stress repair (continue to avoid aggressive active eversion and passive inversion)
- Muscle stimulation to inhibition, inversion and eversion as necessary
- Implementation of progressive resistive exercise program
- Proprioceptive activities (NWB to WB as able)

Phase IV: Week 11-12

Goals

- Full active range of motion ankle and foot
- Normal gait pattern

Guidelines

- Manual mobilization
- Progression of proprioception and balance
- Continue Phase III rehab

Phase V: Week 13-16

Goals

- Full functional range of motion all movements in weight bearing
- Good balance on surgical side on even surface
- Near full strength lower extremity

Guidelines

- Emphasize proprioception: single leg stance on even surfaces, then progressing to single leg even surface with resistance to arms. Double leg stance on wobble board, Fitter, then progress to single leg stance on wobble board.
- Strength: Calf raises, lunges, squats, plyometrics and agility drills including jumping and hopping (14+ weeks), running (14+ weeks)
- Manual mobilization to attain normal glides and full physiological range of motion

Phase VI: Week 16+

Goals

- Full function • Good endurance

Guidelines

- Continue building endurance, strength and proprioception
- Plyometric training
- Sport specific training

Fig. 24.23 Sample postsurgical rehab protocol

rehabilitation programs should be designed around the individual patient's goals and prior level of function, pathology addressed, and the surgical technique performed to optimize recovery and reduce the risk of re-injury.

Immobilization and non-weightbearing period varies depending on the severity of the injury and surgical technique. General recommendations for immobilization timeframes and weightbearing restrictions are made with each surgery type. Of note, as the procedure allows, it may be advantageous to have patients start activities

	0–2 weeks[a]	2–4 weeks[a]	6–8 weeks[a]	8–12 weeks[a]	12–24 weeks[a]	>24 weeks[a]
Weight bearing:						
1. Non-weight bearing	x					
2. Partial weight bearing		x	x			
3. Full weight bearing				x	x	x
Active Range of Motion			x			
Strength exercises			x			
Proprioceptive training			x	x		
Eccentric/concentric exercises				x	x	
Isotonic exercises				x	x	
Running					x	x
Sport specific training						x
Provocation peroneal tendons						x

[a] Number of weeks after operation

Fig. 24.24 Overview of the proposed rehabilitation protocol of surgically treated peroneal tendon disorders, based on the evaluation of available protocols in literature. (Reprinted from Van Dijk et al. [3])

	Group A: primary repair (*n* = 28)	Group B: tenodesis (*n* = 21)	Group C: grafting (*n* = 16)	Group D: end-to-end suturing (*n* = 7)
Total immobilization in weeks	Median 6.0 (range 0–12)	Median 7.0 (range 3.0–13)	Median 6.3 (range 3.0–13)	Median 8.0 (range 6.0–11)
NWB in weeks	Median 3.5 (range 0–6.4)	Median 4.3 (range 0–8.0)	Median 4.0 (range 0–8.0)	Median 4.0 (range 2.0–8.0)
WB in weeks	Median 2.3 (range 0–8.0)	Median 3.0 (range 0–8.0)	Median 2.8 (range 0–10)	Median 4.0 (range 0–6.0)
Start ROM in weeks	*n* = 23[a] Median: 4.0 (range 2.0–12)	*n* = 20[a] Median: 4.5 (range 0–12)	*n* = 15[a] Median: 4.0 (range 0–12)	*n* = 4[a] Median: 5.5 (range 2.0–8.0)

Fig. 24.25 Overview of the non-weight-bearing and weight-bearing immobilization period and ROM initiation. (Reprinted from Van Dijk et al. [3])

such as toe crunches/wiggling, toe spreading, foot doming as able in the immobilizer. The aim is to maintain proprioceptive capacity, minimize atrophy, and potentially improve fluid movement.

Phase II – Early Mobility/Weightbearing

A recent change to early ROM exercises can be found in operatively treated patients with peroneal tendon injuries [6, 43]. Demetracouplos et al. and Karlsson et al. have recently described a change in their postoperative management based on this information. In contrast to a previous protocol of 6 weeks cast immobilization followed by physical therapy, Demetracouplos et al. [43] implemented a postoperative protocol aiming at early ROM after 4 weeks of WB and NWB immobilization. Karlsson et al. [6] immobilized the patient 6 weeks in a plaster cast, but shortened the period in a study published 4 years later to 2 weeks plaster cast followed by a WB air cast brace to provide early ROM training. Figure 24.25 shows an overview of the non-weight-bearing and weight-bearing immobilization period and ROM initiation based upon the procedure performed.

Gentle early passive ROM is implemented in this phase. The program should focus on the protection of the surgical site and range of motion first, which will help to avoid postoperative adhesion of the peroneal tendons to the retinaculum and surrounding tissues. Gentle early muscle activation can occur in this phase with submaximal isometric contractions. Ideally, this is done concurrently with the initiation of the protected weightbearing in a boot. In a cast or boot, isometric contraction takes place (i.e., no change of muscle length and therefore no forced pull on the tendons) [56]. Early active motion helps to reduce swelling, stiffness, atrophy, pain, and muscle guarding following surgery.

Gentle active ROM can also be initiated. Exercises can be focused on ankle plantar flexors, dorsiflexors and inverters, as well extrinsic and intrinsic foot/toe musculature. Care should be taken to avoid active ankle eversion due to the healing repair. The peroneal tendons are ankle plantar flexors in addition to being everters. Since this is a secondary function, they may report some pulling in the lateral compartment of the leg with plantarflexion. Cardiovascular exercise can be initiated on the stationary bike, but the patient should remain in the boot when performing this activity until week 7.

Phase III – Full Weightbearing/Progressive Exercise

During the third phase of treatment, the patient should be weaned from the boot. Gait mechanics have been altered for the past 2 months with the boot, so it is very important to normalize gait biomechanics as quickly as possible. In order to ensure proper step and stride length, the patient should have full ankle dorsiflexion and plantarflexion by this phase of treatment. It is also important to recognize compensatory movements if ankle ROM is limited. These may include excessive mobility and toe out posturing in the foot and excessive frontal and transverse movement in the knee and hip. Additionally, asymmetric weightbearing from surgical to nonsurgical side can create additional risk in other areas. If ROM is not full, initiate joint mobilizations for dorsiflexion or plantarflexion at this time. Joint mobilizations should only be performed that do not directly stress the repair. Stationary bike can be performed without the boot and gentle active ankle eversion can be performed. If the patient is having difficulty initiating peroneal muscle contraction, electrical stimulation can be used.

Progressive resistive exercises are initiated in this phase, with emphasis on selective stress to each of the muscle groups of the lower limb. Band exercises, balance exercise, and proprioceptive exercises are all included here (Fig. 24.26). In this particular subset of athletes, peroneal tendon injuries often are associated with ankle sprains and chronic ankle instability. It is imperative to identify proprioceptive deficits associated with these injuries. Alteration in gait kinematics, particularly during the early stance phase of gait, has been demonstrated by individuals with chronic ankle instability [57–59]. Overly inverted ankle position is a particular deficit that can lead to recurrent ankle sprains. This position shifts the center of mass laterally,

Fig. 24.26 Progressive resistive exercises of the peroneal muscle group. Left picture demonstrates with an elastic band, whereas the right picture demonstrates manual graded resistance

Fig. 24.27 1-lb weight was placed on the dorsal–lateral side of the foot as a perturbation. (Reprinted from Yen et al. [60])

creating potential increased inversion torque during loading response [59]. Efforts at improving inversion positioning during this phase may lead to a reduction in ankle sprain risk. A variety of proprioceptive and gait retraining strategies can be used to improve this. Additionally, taping strategies to influence a more everted position may be beneficial [59]. Error-driven approaches to gait retraining have demonstrated some success as well [60]. Figure 24.27 demonstrates the use of a lightweight on the dorsal lateral aspect of the foot during walking to improve eversion positioning.

By the start of phase four around 3 months, the patient should have normal gait pattern, full ankle range of motion, and the remainder of rehabilitation is focused on strength, balance, proprioception, and return to physical activity.

Phase IV – Optimize Gait/Balance/Proprioception

During this phase of the rehabilitation process, the athlete should demonstrate normal gait mechanics. Any deviations in gait need to be addressed before the implementation of plyometric, agility, and running activities can begin. Additionally, once balance and strength are within approximately 75% of the uninvolved side, functional testing/training can be performed.

Progression of strengthening and balance training are the primary focal points of this phase. Exercises should look to challenge muscle strength throughout the full ROM and muscle endurance.

After surgery, afferent pathways can be impaired, affecting joint proprioception and neuromuscular reaction time. Improving reaction time improves dynamic stabilization of the ankle and surrounding joints, minimizes stress to the surgically repaired tissues, and prevents further injury. Balance activities should progress through variations in surface and environmental challenges. Y-balance testing and star excursion balance tests are objective single-leg balance measures that can be utilized [61]. Progressions include unilateral weightbearing, use of multiplanar surfaces, and perturbation training. Attempts should be made to challenge systems by altering information obtained through visual, vestibular, and somatosensory systems. Replication of sports-specific sensory inputs may be useful as return to sport progressions is made.

Phase V – Full Functional Activity

Initiation of plyometric and agility activities is primary in this stage. Training with focus on impact control, symmetrical limb loading, and multiplanar movements serve as precursors to sport specific training. Plyometric training should be progressing, with attention being paid to its component parts: speed, intensity, volume, and frequency. Progressions should have sport-specific demands in mind. They should incorporate moving from single leg, to double leg, involve varying jumping heights, and incorporate multiplanar movements. Agility activities should follow similar progressions, with consideration given to both acceleration and deceleration activities.

As the athlete demonstrates the ability to accept and manage impact loads effectively, a return-to-running program can be initiated. Return-to-running programs exist in a variety of forms in literature.

General recommendations for return to running are as follows:

- Body weight-supported treadmills (i.e., Alter-G Anti Gravity Treadmill™) is a useful tool to resume running activity, as impact load can be matched to the

patient's ability and can be used to incrementally progress loading in a forward running progression.
- Initiation of running requires full sagittal plane ankle ROM. Functional testing for readiness may include a forward step down off an 8″ step to ensure adequate weightbearing dorsiflexion ROM.
- Progression rates of no more than 10% distance per week to allow tissues to attenuate to stress loads.
- Avoid consecutive days of running. Cross-training strategies should be utilized to prevent overuse/stress-related issues.

Phase VI – Return to Sport-Specific Activity

The final phase of rehabilitation involves continued strength, endurance, plyometric, and agility training, leading to sport-specific training. Return to sport training is not currently well defined in the literature with regard to peroneal tendon surgeries. It is acknowledged that both physical readiness and psychological readiness are significant factors in determining a successful return to prior level of sport function. Literature is not specific to peroneal tendon surgeries for return to sport testing. Return to sport functional and psychological testing is well studied in the postoperative anterior cruciate ligament rehabilitation. Though mechanics of surgery and injury are different, principles may be applied to testing after peroneal tendon surgery to optimize objective and safe return to sport testing.

Functional testing for safe return to sport are being utilized to assist the clinician, physician, trainers, and patient in making safe return to sport decisions. Functional hop testing, balance testing, strength assessments, and movement quality assessments, in addition to subjective outcome measures, are available to assist in this process. Figure 24.28 demonstrates the functional hop testing [62]. Collaboration

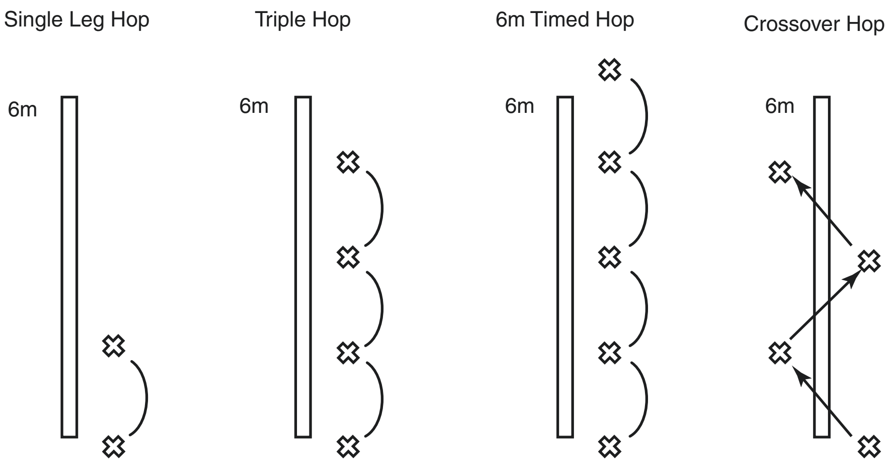

Fig. 24.28 Diagrammatic representation of 4 commonly used hop tests to determine asymmetries

among providers and coaches involved in the athlete's care is crucial in this phase of the rehabilitation process. Successful return after clearance for return will require graded exposure back to full participation with close monitoring.

Psychological readiness has been demonstrated to be a significant factor in the return to sport decision-making process, particularly in the postoperative ACL population [63]. Anxiety and fear can have a significant impact on the rehabilitation process, especially in traumatic injuries such as ACL injury and fractures. In the case of peroneal injuries, there is not necessarily significant trauma associated with the initial injury. Psychological readiness for return may be influenced by the nature of the initial injury.

Surgical factors will also influence return to sport timeframes. Timeframes have been reported with averages from 3 to 5 months [64]. The nature of the surgery will have significant influence on the return to sport time as well as the rate of successful return to prior level of competition. Superior retinacular repairs, groove deepening, tendon repair, etc. can all influence return to sport. Concomitant procedures such as lateral ankle ligament reconstruction can further complicate return to sport rehabilitation.

The single-leg hop requires 1 maximal jump landing on the same limb. Failure to land without falling over or "bouncing forward" requires the test to be retaken. The triple hop assesses maximal distance for 3 hops in a rebounding pattern. A stable landing must also be demonstrated for the final hop. The 6-m timed hop positions timing gates at 0 and 6 m asks subjects to hop on 1 limb as fast as they can for the total distance, thus reporting the outcome of time. The crossover hop requires 3 maximal hops (for distance) in a diagonal pattern. A stable landing must also be demonstrated on the final hop (reprinted from Bishop et al. [62]).

Summary

Successful outcomes in surgical management and subsequent rehabilitation of athletes involve many factors and extensive collaboration among providers. Nature of injury, surgical procedure, sport demands, and even timing of a particular event can all influence return to sport rate. Training should be targeted at sport-specific demands as the healing process allows.

References

1. Porter D, Mccarroll J, Knapp E, Torma J. Peroneal tendon subluxation in athletes: fibular groove deepening and retinacular reconstruction. Foot Ankle Int. 2005;26:436–41.
2. Steel MW, Deorio JK. Peroneal tendon tears: return to sports after operative treatment. Foot Ankle Int. 2007;28:49–54.
3. Dijk PADV, Lubberts B, Verheul C, Digiovanni CW, Kerkhoffs GMMJ. Rehabilitation after surgical treatment of peroneal tendon tears and ruptures. Knee Surg Sports Traumatol Arthrosc. 2016;24:1165–74.

4. Heckman DS, Pedowitz D, Parekh SG, Reddy S, Wapner K. Operative treatment for peroneal tendon disorders. J Bone Joint Surg Am. 2008;90:404–18.
5. Sobel M, Geppert MJ, Warren RF. Chronic ankle instability as a cause of peroneal tendon injury. Clin Orthop Relat Res. 1993;296:187–91.
6. Karlsson J, Wiger P. Longitudinal split of the peroneus brevis tendon and lateral anlkle instability: treatment of concomitant lesions. J Athl Train. 2002;37:463–6.
7. Karlsson J, Brandsson S, Kälebo P, Eriksson BI. Surgical treatment of concomitant chronic ankle instability and longitudinal rupture of the peroneus brevis tendon. Scand J Med Sci Sports. 2007;8:42–9.
8. Bonnin M, Tavernier T, Bouysset M. Split lesions of the peroneus brevis tendon in chronic ankle laxity. Am J Sports Med. 1997;25:699–703.
9. Digiovanni BF, Fraga CJ, Cohen BE, Shereff MJ. Associated injuries found in chronic lateral ankle instability. Foot Ankle Int. 2000;21:809–15.
10. Brandes CB, Smith RW. Characterization of patients with primary peroneus longus tendinopathy: a review of twenty-two cases. Foot Ankle Int. 2000;21:462–8.
11. Sobel M, Bohne WH, Levy ME. Longitudinal attrition of the peroneus brevis tendon in the fibular groove: an anatomic study. Foot Ankle. 1990;11:124–8.
12. Davis WH, Sobel M, Deland J, Bohne WH, Patel MB. The superior peroneal retinaculum: an anatomic study. Foot Ankle Int. 1994;15:271–5.
13. Mick CA, Lynch F. Reconstruction of the peroneal retinaculum using the peroneus quartus. A case report. J Bone Joint Surg. 1987;69:296–7.
14. Sobel M, Bohne WHO, Obrien SJ. Peroneal tendon subluxation in a case of anomalous peroneus brevis muscle. Acta Orthopaedica Scan. 1992;63:682–4.
15. Sobel M, Geppert MJ, Olson EJ, Bohne WHO, Arnoczky SP. The dynamics of peroneus brevis tendon splits: a proposed mechanism, technique of diagnosis, and classification of injury. Foot Ankle. 1992;13:413–22.
16. Palmanovich E, Laver L, Brin YS, Kotz E, Hetsroni I, Mann G, Nyska M. Peroneus longus tear and its relation to the peroneal tubercle: A review of the literature. Muscles Ligaments Tendons J. 2012;1:153–60.
17. Bruce WD, Christoferson MR, Phillips DL. Stenosing tenosynovitis and impingement of the peroneal tendons associated with hypertrophy of the peroneal tubercle. Foot Ankle Int. 1999;20:464–7.
18. Pierson JL, Inglis AE. Stenosing tenosynovitis of the peroneus longus tendon associated with hypertrophy of the peroneal tubercle and an os peroneum. JBJS Am. 1992;74:440–2.
19. Sobel M, Pavlov H, Geppert MJ, Thompson FM, Dicarlo EF, Davis WH. Painful os peroneum syndrome: a spectrum of conditions responsible for plantar lateral foot pain. Foot Ankle Int. 1994;15:112–24.
20. Stockton KG, Brodsky JW. Peroneus longus tears associated with pathology of the os peroneum. Foot Ankle Int. 2014;35:346–52.
21. Raikin SM, Elias I, Nazarian LN. Intrasheath subluxation of the peroneal tendons. J Bone Joint Surg Am Vol. 2008;90:992–9.
22. Alanen J, Orava S, Heinonen OJ, Ikonen J, Krista M. Peroneal tendon injuries. Ann chir gynaecol. 2001;90:43–6.
23. Heckman DS, Gluck GS, Parekh SG. Tendon disorders of the foot and ankle, part 1: peroneal tendon disorders. AmJSports Med. 2009;37:614–25.
24. Wapner KL, Taras JS, Lin SS, Chao W. Staged reconstruction for chronic rupture of both peroneal tendons using hunter rod and flexor hallucis longus tendon transfer: a long-term followup study. Foot Ankle Int. 2006;27:591–7.
25. Mook WR, Parekh SG, Nunley JA. Allograft Reconstruction of Peroneal Tendons. Foot Ankle Int. 2013;34:1212–20.
26. Brodsky JW, Zide JR, Kane JM. Acute peroneal Injury. Foot Ankle Clin. 2017;22:833–41.
27. Sammarco G, Mangone P. Diagnosis and treatment of peroneal tendon injuries. Foot Ankle Surg. 2000;6:197–205.

28. Sammarco GJ, Diraimondo CV. Chronic peroneus brevis tendon lesions. Foot Ankle. 1989;9:163–70.
29. Krause JO, Brodsky JW. Peroneus brevis tendon tears: pathophysiology, surgical reconstruction, and clinical results. Foot Ankle Int. 1998;19:271–9.
30. Redfern D, Myerson M. The management of concomitant tears of the peroneus longus and brevis tendons. Foot Ankle Int. 2004;25:695–707.
31. Manoli A, Graham B. The subtle cavus foot, "the Underpronator," a review. Foot Ankle Int. 2005;26:256–63.
32. Sobel M, Mizel MS. Peroneal Tendon Injury. In: Pfeffer GB, Frey CC, editors. Current practice in foot and ankle surgery. New York: McGraw-Hill, Health Professions Division; 1993.
33. Dombek MF, Lamm BM, Saltrick K, Mendicino RW, Catanzariti AR. Peroneal tendon tears: a retrospective review. J Foot Ankle Surg. 2003;42:250–8.
34. Ogawa BK, Thordarson DB, Zalavras C. Peroneal tendon subluxation repair with an indirect fibular groove deepening technique. Foot Ankle Int. 2007;28:1194–7.
35. Khazen GE, Adam N, Wilson MD, Schon LC (2005) Peroneal groove deepening via a posterior osteocartilaginous flap: a retrospective analysis. presented at the 21st Annual American Orthopaedic Foot and Ankle Summer Meeting, Boston, 15–17 July 2005
36. McGarvey W, Clanton T. Peroneal tendon dislocations. Foot Ankle Clin. 1996;1:325–42.
37. Bassett FH III, Speer KP. Longitudinal rupture of the peroneal tendons. Am J Sports Med. 1993;21:354–7.
38. Saxena A, Pham B. Longitudinal peroneal tendon tears. J Foot Ankle Surg. 1997;36:173–9.
39. Saxena A, Cassidy. Peroneal tendon injuries: an evaluation of 49 tears in 41 patients. J Foot Ankle Surg. 2003;42:215–20.
40. Squires N, Myerson MS, Gamba C. Surgical treatment of peroneal tendon tears. Foot Ankle Clin. 2007;12:675–95.
41. Mason RB, Henderson IJP. Traumatic peroneal tendon instability. Am J Sports Med. 1996;24:652–8.
42. Dijk PAV, Miller D, Calder J, et al. The ESSKA-AFAS international consensus statement on peroneal tendon pathologies. Knee Surg Sports Traumatol Arthrosc. 2018;26:3096–107.
43. Demetracopoulos CA, Vineyard JC, Kiesau CD, Nunley JA 2nd. Long-term results of debridement and primary repair of peroneal tendon tears. Foot Ankle Int. 2013;35:252–7.
44. Selmani E, Gjata V, Gjika E. Current concepts review: peroneal tendon disorders. Foot Ankle Int. 2006;27:221–8.
45. Shawen SB, Anderson RB. Indirect groove deepening in the management of chronic peroneal tendon dislocation. Tech Foot Ankle Surg. 2004;3:118–25.
46. Coughlin MJ, Schon LC. Chapter 24, Disorders of Tendons. In: Coughlin MJ, Saltzman CL, Anderson RB, editors. Mann's surgery of the foot and ankle, vol. 24. Philadelphia: Saunders, an imprint of Elsevier Inc; 2014. p. 1232–75.
47. Wagner E, Wagner P, Ortiz C, Radkievich R, Palma F, Guzmán-Venegas R. Biomechanical cadaveric evaluation of partial acute peroneal tendon tears. Foot Ankle Int. 2018;39:741–5.
48. Krause FG, Guyton GP. Chapter 26, Pes Cavus. In: Coughlin MJ, Saltzman CL, Anderson RB, editors. Mann's surgery of the foot and ankle, vol. 24. Philadelphia: Saunders, an imprint of Elsevier Inc; 2014. p. 1362–82.
49. Eckert W, Davis E. Acute rupture of the peroneal retinaculum. J Bone Joint Surg. 1976;58:670–2.
50. Maffulli N, Ferran NA, Oliva F, Testa V. recurrent subluxation of the peroneal tendons. Am J Sports Med. 2006;34:986–92.
51. Raikin SM, Elias I, Nazarian LN. Intrasheath subluxation of the peroneal tendons. J Bone Joint Sur Am Vol. 2008;90:992–9.
52. Jockel JR, Brodsky JW. Single-stage flexor tendon transfer for the treatment of severe concomitant peroneus longus and brevis tendon tears. Foot Ankle Int. 2013;34:666–72.
53. Seybold JD, Campbell JT, Jeng CL, Short KW, Myerson MS. Outcome of lateral transfer of the FHL or FDL for concomitant peroneal tendon tears. Foot Ankle Int. 2016;37:576–81.

54. Dijk CV, Kort N. Tendoscopy of the peroneal tendons. J Arthroscopy Related Surg. 1998;14:471–8.
55. Bare A, Ferkel RD. Peroneal tendon tears: associated arthroscopic findings and results after repair. Arthroscopy. 2009;25:1288–97.
56. Espinosa N, Maurer M. Peroneal tendon dislocation. Eur J Trauma Emerg Surg. 2015;41(6):631–7.
57. Delahunt E, Monaghan K, Caulfield B. Altered neuromuscular control and ankle joint kinematics during walking in subjects with functional instability of the ankle joint. Am J Sports Med. 2006;34(12):1970–6.
58. Monaghan K, Delahunt E, Caulfield B. Ankle function during gait in patients with chronic ankle instability compared to controls. Clin Biomech (Bristol, Avon). 2006;21(2):168–74.
59. Yen SC, Folmar E, Friend KA, Wang YC, Chui KK. Effects of kinesiotaping and athletic taping on ankle kinematics during walking in individuals with chronic ankle instability: A pilot study. Gait Posture. 2018;66:118–23.
60. Yen SC, Gutierrez GM, Wang YC, Murphy P. Alteration of ankle kinematics and muscle activity during heel contact when walking with external loading. Eur J Appl Physiol. 2015;115(8):1683–92.
61. Gribble PA, Bleakley CM, Caulfield BM, et al. 2016 consensus statement of the International Ankle Consortium: prevalence, impact and long-term consequences of lateral ankle sprains. Br J Sports Med. 2016;50(24):1493–5.
62. Bishop C, Turner A, Jarvis P, Chavda S, Read P. Considerations for selecting field-based strength and power fitness tests to measure asymmetries. J Strength Cond Res. 2017;31:2635–44.
63. Webster KE, Nagelli CV, Hewett TE, Feller JA. Factors associated with psychological readiness to return to sport after anterior cruciate ligament reconstruction surgery. Am J Sports Med. 2018;46(7):1545–50.
64. Van Dijk PA, Gianakos AL, Kerkhoffs GM, Kennedy JG. Return to sports and clinical outcomes in patients treated for peroneal tendon dislocation: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2016;24(4):1155–64.