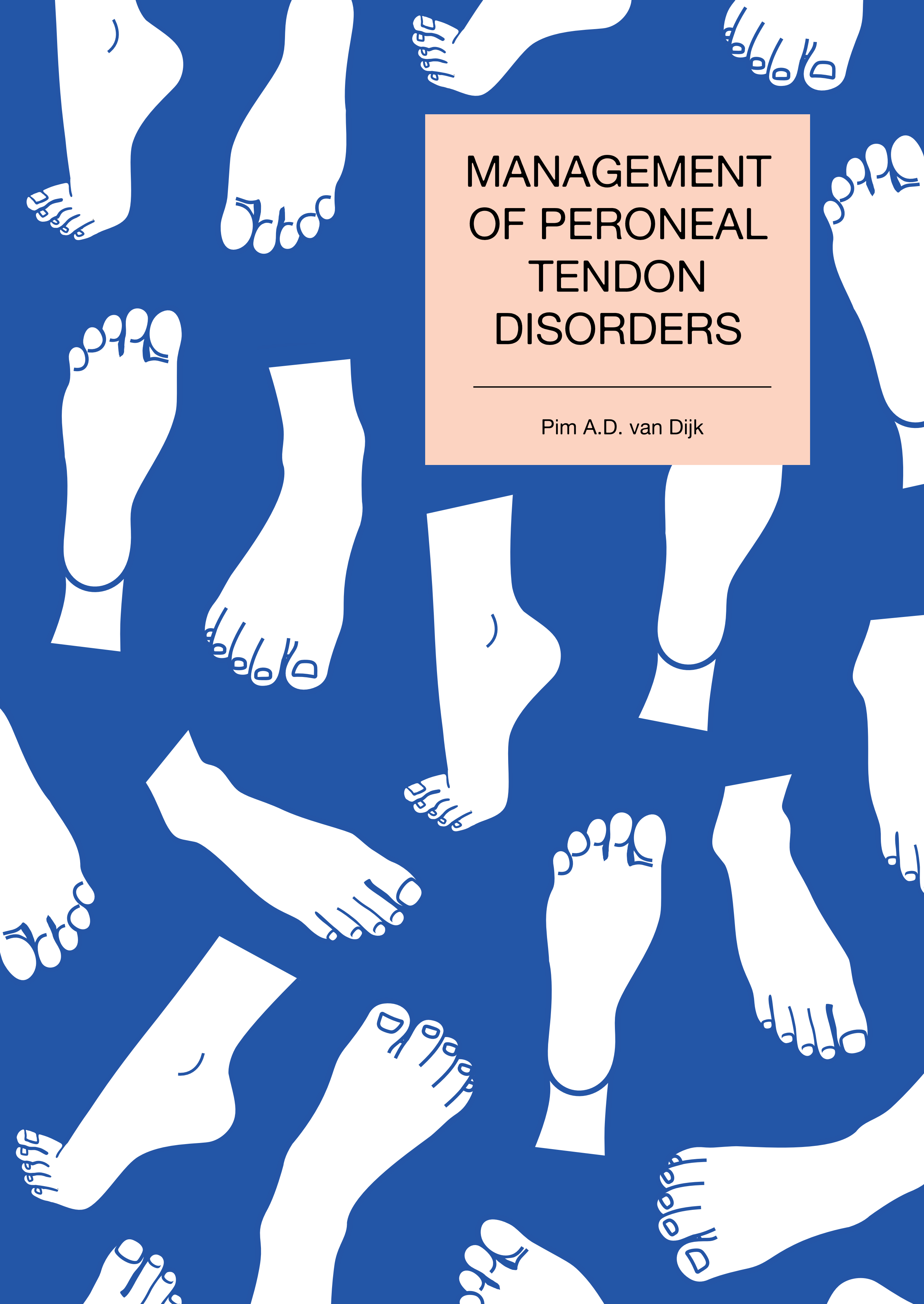
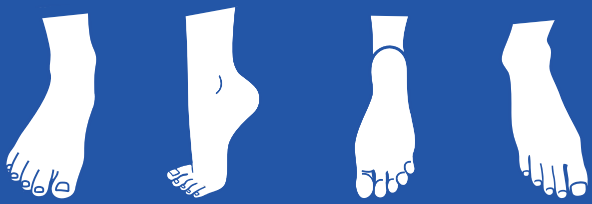


MANAGEMENT OF PERONEAL TENDON DISORDERS

Pim A.D. van Dijk



Boston New York Amsterdam Gerona

The research presented in this thesis was embedded in:

Amsterdam, the Netherlands: the Amsterdam Movement Sciences (AMS) Research Institute at the department of orthopedic surgery, Amsterdam UMC location AMC, University of Amsterdam

New York, USA: the foot and ankle service at the department of orthopedic surgery, Hospital for Special Surgery, Weill Cornell Medical School

Boston, USA: the Foot and Ankle Research and Innovation Lab (FARIL) at the department of orthopedic surgery, Massachusetts General Hospital, Harvard Medical School

Girona, Spain: the department of anatomy at the University of Girona

Propositions belonging to the thesis
‘Management of peroneal tendon disorders’

There is no simple peroneal tendon disorder.
This thesis

Overstuffing of the superior peroneal tunnel plays an important role in the development of peroneal tendon disorders.
This thesis

Peroneal tendoscopy is useful in patients with a high clinical suspicion of a peroneal tendon disorder, but with negative imaging findings.
This thesis

Care should be taken to leave the vincula intact during treatment of peroneal tendon disorders.
This thesis

Elite athletes with peroneal tendon dislocation should be surgically treated by a combination of repair of the superior peroneal retinaculum and deepening of the retromalleolar groove.
This thesis

Rehabilitation of peroneal tendon disorders, with the exception after superior peroneal retinaculum repair, should be goal based, striving for early range of motion and mobilization.
This thesis

Research is formalized curiosity.
Zora Neal Hurston (1942)

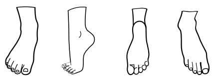
But do not hurry your journey at all, …, far better if it takes years, …, so you are old by the time you reach the island.
Oddyseus by Homer

If your dream doesn’t scare you, it’s not big enough.
Madame Ellen Johnson sirlead, first female president in Africa

Voor het leveren van goede zorg is het van belang dat je als specialist ook altijd generalist blijft.
Vrij naar prof. dr. Marcel Levi

Wêr ’t wy op ê wrald ek binne, oer ûs skynt deselde sinne.
Nijefurder sprekwurd

Luister naar de patiënt, de patiënt heeft altijd gelijk.
Prof. dr. C. Niek van Dijk



By Pim A.D. van Dijk
Monday May 9th, 2022
University of Amsterdam

MANAGEMENT OF PERONEAL TENDON DISORDERS

Pim A.D. van Dijk

Colofon

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Management of peroneal tendon disorders

ACADEMISCH PROEFSCHRIFT

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aan de Universiteit van Amsterdam
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Faculteit der Geneeskunde

Voor mijn lieve ouders

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INTRODUCTION

CHAPTER 1

General introduction

Chapter 1: General introduction

"There is no simple lateral ankle sprain"[1]

Ankle sprains remain the most common injury of the musculoskeletal system, especially within the young and active population.[2] Over the last 30 years, significant progress has been made in the field of foot and ankle, resulting in better management of its associated disorders. One group, however, has remained the underdog of the lateral ankle for too many years: peroneal tendon disorders.

The peroneal tendons owe their name to the shape of the bone they are related to: '*περονη*' (pronounced Pair-uh-knee) in old Greek, or '*fibula*' in Latin, meaning 'pin of a brooch'. There are two main peroneal tendons, the peroneus brevis and longus, which jointly form the lateral compartment of the lower leg. Both tendons run down the lateral side of the lower leg and curl around the distal tip of the fibula. The peroneus brevis then inserts on the base of the fifth metatarsal bone, the peroneus longus inserts on the plantar side of the first metatarsal and medial cuneiform bone. Together, the peroneal tendons work in concert to confer dynamic lateral ankle stability while stabilizing the medial foot column during stance. Hence, they both subsist under substantial loading during even routine activities such as walking, making the tendons prone for tissue deterioration.[3,4]

Once thought to be relatively harmless, recent literature points out that disorders related to the peroneal tendons can be considered a serious cause of posterolateral ankle complaints following both acute lateral ankle sprains as well as chronic ankle instability.[5-8] With ankle inversion, the peroneus brevis is squeezed in between the fibular bone and peroneus longus tendon, leading to high mechanical loads. Chronic ankle instability exacerbates these loads, predisposing the tendon to hypertrophic tendinopathy, stenosis, and eventually tears or ruptures.[8] On the other hand, sudden eccentric peroneal muscle contraction can lead to subluxation or dislocation of one or both tendons over the fibular bone.

Management of peroneal tendon disorders starts with a proper diagnosis based on thorough patients' history, physical examination, and additional diagnostic techniques such as magnetic resonance imaging (MRI) and ultrasound.[9,10] Treatment contains both conservative and operative strategies.[5,8,11-13] In general, non-operative treatment is attempted first, including 'Rest, Ice, Elevation and Compression' (RICE), immobilisation, non-steroid anti-inflammatory drugs, and physiotherapy. For patients whose symptoms persist after non-operative strategies, many surgical treatment options have been described depending on the type of pathology. Techniques diverge from direct repair or debridement of the damaged tissue to tenodesis, grafting, rerouting and groove deepening procedures.[14]

Present issues in the management of peroneal tendon disorders include delay in diagnosis, under- or overtreatment, and deficient rehabilitation. Numerous management strategies have been advocated in the literature without consensus or guidelines - yet. This thesis aims to review and advance management of peroneal tendon disorders by studying various issues throughout the whole spectrum of the peroneal tendons, from epidemiology and anatomy to diagnostics, treatment, and rehabilitation. These issues and their relevance are briefly introduced below.

Part 1 Epidemiology

Since prevention and/or early recognition are advantageous to limit tendon deterioration, sound understanding of the epidemiology of peroneal tendon disorders is critical as the first step to advance its management. With their function as active stabilizers of the lateral ankle, the tendons are at greater risk to become damaged in active individuals.[3,4] The true prevalence of peroneal tendon disorders, however, remains unclear. Cadaveric studies suggested a prevalence of peroneus brevis tears between 11 % and 38 %, with peroneus longus tears being less frequent.[15,16] Older clinical studies reported a peroneal tendon disorder in 23-77 % of patients with chronic ankle instability.[5-8] On the other hand, a recent clinical study among professional American football players found only 4.0 % of all disorders following an ankle sprain to be related to the peroneal tendons. **Chapter 2** evaluates the incidence and epidemiological characteristics of peroneal tendon disorders in a prospective study, using the UEFA Champions League database and the English Premier League database.

Part 2 Anatomy

Part 2 of this thesis aims to improve our understanding of the peroneal tendon's anatomy in relation to the pathophysiology of both the tendons itself as well as the surrounding structures.

Vascularization of the peroneal tendons
The vascularization of the tendons remains controversial.[5,17,18] Historically, it has been postulated that the peroneal tendons exhibited critical avascular zones around the lateral malleolus and cuboid, possibly contributing to the development of pathology.[17] Other studies question the existence of these avascular regions.[18] In order to create better understanding of the tendon's pathophysiology and healing tendency, **Chapter 3** presents the arterial anatomy of the peroneal tendons in cadavers.

Insertion of the peroneus brevis tendon in relation to Jones fractures
Better understanding of the peroneal tendon's surrounding anatomy helps to understand and prevent iatrogenic peroneal tendon damage related to pathologies of surrounding anatomic structures and vice versa. For example, in literature it has been suggested that forces exerted by the insertion of the peroneus brevis may contribute to the fracture pattern and mechanism of basilar type fifth metatarsal fracture fragments - also known as 'Jones fractures'.[19-22] Moreover, the peroneus brevis insertion may be at risk during surgical treatment of these fractures. Using cadavers, **Chapter 4** (i) analyses the peroneus brevis insertion on the fifth metatarsal base and (ii) quantifies optimal screw parameters for Jones fracture treatment given potential susceptibility of the surrounding structures such as the peroneus brevis tendon.

Part 3 Diagnostics and treatment

Lack of consensus on both diagnostic as well as treatment strategies remains an important issue in today's practice. Part 3 of this thesis focusses on the advancement of diagnostic tools and treatment in several peroneal tendon disorders.

Chronic peroneal tendon pathology
To create better insight on current clinical practice of common peroneal tendon disorders, **Chapter 5** provides a narrative review of the current evidence on management pertaining chronic peroneal tendon dysfunction.

MRI and tendoscopy in diagnosing and treating peroneal tendon disorders
For years, MRI has been used as the golden diagnostic standard to evaluate the peroneal tendons.[9,10] Due to challenges related to commonly used MRI techniques, however, the true extent of the disorder is often first seen during surgery. These challenges include difficulties to differentiate between specific peroneal tendon disorders and the so called 'magic angle effect'.[9,23]

Recent diagnostic attention has been directed towards both improved MRI techniques and minimally invasive surgical techniques combining diagnostic opportunities and treatment potential without the inherent risks of open surgery. **Chapter 6** evaluates the correlation of preoperative tesla 3.0 MRI diagnoses with intraoperative tendoscopic findings. In addition, functional outcomes after tendoscopic treatment of peroneal tendon disorders are evaluated.

Peroneal tendon dislocation
Numerous operative strategies have been described to treat peroneal tendon dislocation, including (i) repair or replacement of the superior peroneal retinaculum, (ii) deepening of the retromalleolar groove, (iii) bony procedures, and (iv) rerouting procedures.[24] While most techniques have demonstrated good outcomes, there is a lack of consensus on best management strategy for peroneal tendon dislocation. **Chapter 7** provides a systematic review evaluating the outcomes of different surgical treatment techniques used to treat peroneal tendon dislocation. Based on the results of this systematic review, **Chapter 8** proposes a specific technique for retromalleolar groove deepening and repair of the superior peroneal retinaculum.

Part 4 Rehabilitation

Appropriate rehabilitation of surgically treated peroneal tendon disorders is essential for optimal recovery. As flexor tendons in general tend to form adhesions between the repaired- and surrounding scar tissue, a balance between early range of motion and adequate healing is required.[25-28] **Chapter 9** provides a review of the best available evidence on rehabilitation following surgically treated peroneal tendon tears and ruptures. Subsequently, the chapter proposes an evidence- and personal experience-based algorithm for the rehabilitation of peroneal disorders in daily clinical practice.

Part 5 International consensus guideline

Chapter 10 proposes an international consensus statement on the management of peroneal tendon disorders pursuant to international and multidisciplinary agreement and supported by a systematic review of the literature.

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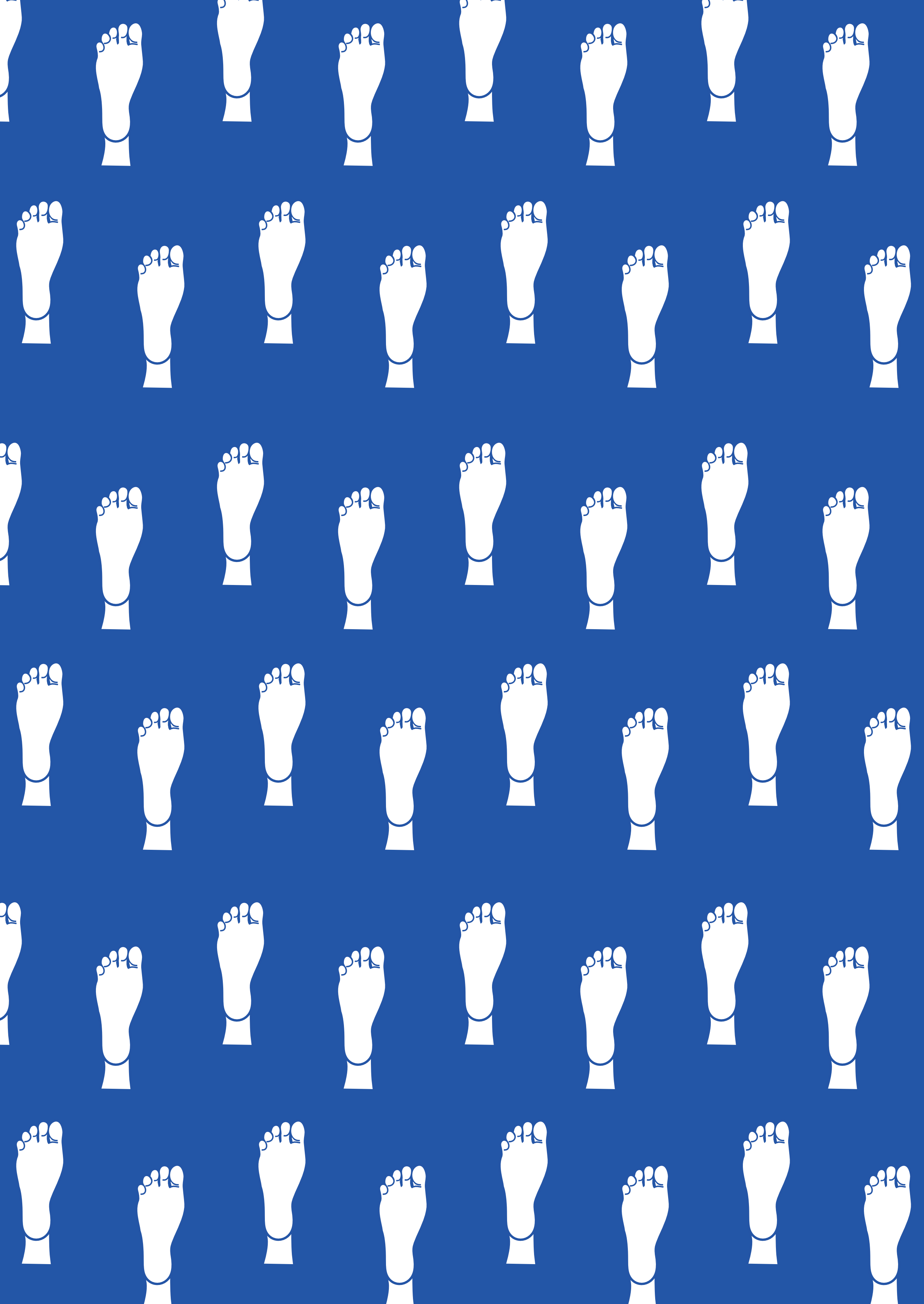
PART 1

EPIDEMIOLOGY



CHAPTER 2

Traumatic peroneal tendon injuries seldom in Pro-Football: a prospective cohort study in the UEFA Elite Club Injury Study

Pim A.D. van Dijk, Jan Ekstrand, Pieter d' Hooghe,
Håkan Bengtsson, James D. Calder, Gino M.M.J. Kerkhoffs

Manuscript submitted

Abstract

Background
Due to the debilitating nature of peroneal tendon injuries, it is critical to prevent or recognize and treat these pathologies as early as possible in order to facilitate early return to the field. Little is known, however, on the onset, epidemiology and etiology of peroneal tendon injuries in the active population.

Hypothesis/Purpose
This study aims to determine the incidence, injury mechanism and burden of peroneal tendon injuries among professional male football players to create better insight in the onset, epidemiology and etiology of these injuries.

Methods
This long-term prospective study is based on two cohorts: data from 55 European elite football clubs collected over 19 consecutive seasons between 2001 and 2019 (UEFA Elite Club Injury Study), and data from 14 English elite football clubs collected over three seasons between 2011 and 2014. Team medical staff recorded player exposure and time loss due to peroneal tendon injuries. Injury incidence was defined as the number of injuries per 1000 player-hours and injury burden as number of days absence per 1000 player-hours. A χ^2 test was used to assess the relation between mechanism of injury and (re-)injury.

Results
The incidence of peroneal tendon injuries was 0.02 per 1.000 hours of exposure (95 % C.I. 0.02 – 0.03) or one injury per team every eight seasons. Injuries occurred more during matches compared to training, with a rate ratio of 4.16 (95 % C.I. 2.48-7.00). Most injuries were due to overuse (71 %), and 7 % of the injuries was defined as a reinjury. The injury burden of a peroneal tendon injury was 0.5 days of absence per 1000/hours of exposure. These days of absence were significant higher when the injury resulted from a trauma (p=0.024) and after a reinjury (p=0.077).

Conclusion
Peroneal tendon injuries are relatively rare within the professional football player population: a team of 25 players might expect a peroneal tendon injury every eight seasons. While most injuries resulted from overuse, players with a peroneal tendon injury after trauma or with a reinjury were out of the game significantly longer.

Chapter 2: Traumatic peroneal tendon injuries seldom in Pro-Football: a prospective cohort study in the UEFA Elite Club Injury Study

Introduction

While football is one of the world's most popular sports today, it is also associated with a high rate of ankle pathology.[1-3] As professional football players demand great ankle stability and quick ankle movements, the peroneal tendons seem prone to get injured. Chronic damage of the tendons gives rise to debilitating injuries causing reduced physical activity and endurance levels, lost game time and diminished athletic performance on the longer term.[1] Due to the debilitating nature of peroneal tendon injuries, it is critical to prevent or recognize and treat these pathologies as early as possible in order to facilitate early return to the field. Little is known, however, on the onset, epidemiology and etiology of peroneal tendon injuries in the active population. In fact, to the best of our knowledge, there is no literature available on the epidemiology of these injuries in the population of professional football players.

Football requires specific repetitive technical movements of the foot and ankle, with ball control enhancing both fine-tuned propriocepsis and neuromuscular control.[4] Hence, the tendons around the ankle are at high risk to become injured due to overuse.[5,6] Given their role as dynamic stabilizers of the ankle, the peroneal tendons subsist under substantial tension even during routine activity. A lot of strain is put on the peroneal tendons during pronation-supination, potentially leading to damage and deterioration of the tissue. During supination of the foot, the peroneus brevis tendon (PB) is squeezed in between the fibula and the peroneus longus tendon (PL), exacerbating the mechanical load of the tendon and predisposing the PB to hypertrophic tendinopathy, recurrent stenosis, and eventually tearing of the tendon.[7] On the other hand, sudden eccentric contractions may lead to dislocation of the tendons over the lateral malleolus.

Considering that peroneal tendon injuries are associated with long-term sequelae when addressed inadequately, adequate diagnosis and prompt treatment in an early stage are key. A better understanding of how and when peroneal tendon injuries occur in professional football players will help to develop preventive strategies as well as to optimize recognition and treatment at an early stage.[8]

This study aims to determine the incidence, injury mechanism and burden of peroneal tendon injuries among a homogeneous group of professional male football players to create better insight in the onset, epidemiology and etiology of these injuries.

Methods and Design

This is a sub study on data collected for long-term prospective studies of two cohorts:

1. Data from 55 elite football clubs from 20 European countries collected over nineteen seasons between 2001 and 2019, the UEFA Elite Club Injury Study.
2. Data from an additional fourteen English elite football clubs collected over three seasons between 2011 and 2014.

The same exact methodology was used in both cohorts and a total of 404 team-seasons were included from the two cohorts. All contracted players in the first teams of the included teams were invited to participate in the study. If a player left the team before the end of the season, the player was only included in the study during the time he spent with the team. Participation was voluntary, and written informed consent was obtained at the time of study inclusion.

The study design followed international consensus on definitions and data collection procedures in studies of football injuries. At the beginning of every season, a contact person within each medical team was appointed to be responsible for the collection of data and communication with the overarching study group. Exposure time was recorded using standard attendance records. In case of an injury, information regarding the type of injury, injury mechanism, affected side and possible reinjury were collected using standardized injury cards. An injury was defined as "any physical complaint sustained by a player that resulted from a football match or football training and led to the player being unable to take full part in future football training or match play". Based on the information on the injury card, the study group assigned diagnostic codes to all injuries using the Orchard Sports Injury Classification System (OSICS) 2.0). Full methodology and validation of the databases is published elsewhere.[9]

Definition of a peroneal tendon injury

In general, three types of peroneal tendon pathologies can be distinguished[10]: (1) tendinopathy, including tendinitis, tenosynovitis, tendinosis, and stenosis, (2) tears or ruptures of the tendon, and (3) subluxation or dislocation. Due to limitation of the database, in this study the different types of pathologies were combined using the term 'peroneal tendon injury'.

Outcome measurements and statistical analysis

Baseline characteristics included demographic data (age, height, weight, hours of exposure, position in the field, dominant leg), data on primary or re-injury, affected side (dominant or non-dominant leg), injury mechanism (overuse or trauma), severity of injury (mild, moderate, severe) and moment of injury (training or match) and were summarized using descriptive statistics. Continuous data were presented as mean and standard deviation if normally distributed, or as a median and range in case of skewed distribution.

A $\chi 2$ test was used to analyze the relation between the injured limb and the dominant leg, type of injury and position in the field. Moreover, a χ^2 test was used to assess the relation between mechanism of injury and reinjury. Injury incidence, defined as the number of reported injuries per 1.000 hours of exposure, was calculated based on total hours of exposure to training and matches and total number of peroneal tendon disorders. Injury burden was defined as the number of lay-off days per 1.000 hours of exposure and was also calculated based on total hours of exposure to training and matches. The number of peroneal tendon injuries a team can roughly expect every season was calculated using data on the mean total exposure hours per team and the injury rate.

All analysis were two sided and a *p*-value of less than 0.05 was considered as statistically significant. Statistical analyses were performed using Stata (version 13.0, STATA Corp., TX, USA).

Results

Incidence
Between 2001 and 2019, 69 teams were included in the study. Within this group, a total of 18.553 injuries during 424.441 hours of match exposure and 2.331.768 hours of training exposure were reported. Out of these injuries, 13 % affected the ankle. A total of 58 peroneal tendon injuries, 0.3 % of all reported injuries and 2.4 % of all reported ankle injuries, were registered. The total incidence of peroneal tendon injuries was 0.02 (95 % C.I. 0.02 – 0.03) per 1.000 hours of exposure. In other words, as the mean total exposure time of a team of 25 players is about 6.000 hours per season (240 hours per player), one team might expect a peroneal tendon injury every eight seasons.

Player characteristics
Players with a peroneal tendon injury had a mean age of 26.71 ± 4.29 years and a mean BMI of 23.51 ± 1.78 kg/m2. In most players, 76 % (44/58), the dominant or preferred kicking leg was right ($p < 0.001$). Of all players, 34 % (20/58) was defender, 40 % (23/58) included midfielders, 22 % (13/58) played forward and 3 % (2/58) was goalkeeper. There was no association between a specific player's position in the field and the occurrence of a peroneal tendon injury ($p = 0.30$).

Injury circumstances
57 % of the injuries occurred during a training while 43 % occurred during a match. Considering the total hours of exposure per season, the match incidence was 0.06 (95 % C.I. 0.04 - 0.09) and training incidence 0.01 (95 % C.I. 0.01 – 0.02). Peroneal tendon injuries occurred significant more during a match compared to a training, with a rate ratio of 4.16 (95 % C.I. 2.48-7.00). In cases where the injury occurred during the match, 58.82 % occurred in the second half, 29.41 % during the first half and 11.76 % was unknown.

Injury pattern
In 45 % (26/58) of the peroneal tendon cases, data was available on diagnostic methods: in most cases, 65 % (17/26), an MRI was made, 50 % (13/26) patients underwent an ultrasonography, 15 % (4/26) an X-ray and 8 % (2/26) was diagnosed based on clinical examination alone.

Of all peroneal tendon injuries, 63 % affected the dominant or preferred kicking leg. The odds ratio between the injured and the dominant leg was 1.17 (95 % C.I. 0.39 – 3.47), which was non-significant. Overuse was responsible for the majority of injuries (71 %, 41/58). The remaining 29 % (17/58) injuries were accounted for by trauma (an overview of traumatic causes is shown in table 1). In total, 7 % (4/58) of the injuries was considered a reinjury. The reinjury rate was significantly higher among players with a first injury due to overuse ($p=0.048$).

Figure 1
An overview of the moment of injury throughout the season.

Injury burden

The median days of absence following a peroneal tendon injury was 6.50 (range 1 – 134). In total, 1269 days of absence were reported over the eighteen football seasons, representing an injury burden of 0.5 days of absence per 1000 / hours of exposure. The days of absence were significant higher when the injury resulted from a trauma compared to overuse ($p = 0.024$), as the mean days of absence after an overuse injury were 16.46 ± 4.12 and after a trauma 34.94 ± 9. Moreover, in case of a reinjury the absence days were significantly higher ($p = 0.077$). There was no difference in days of absence when the dominant or the non-dominant leg was injured ($p = 0.97$).

Most peroneal tendon injuries were considered mild (37.93 %, 22/58) (see figure 2). There was no difference in injury burden reported by the player when the dominant or the non-dominant leg was injured ($p = 0.31$).

Figure 2
Most peroneal tendon injuries were considered mild.

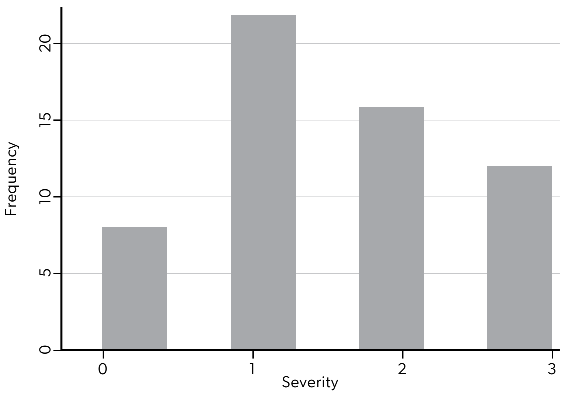


Table 1
29 % of all peroneal tendon injuries was traumatic. This table outlines the various traumatic injuries.

Type of trauma	Percentage
Being tackled	5 % (3/58)
Jumping / landing	5 % (3/58)
Twisting / turning	3 % (2/58)
Dribbling	3 % (2/58)
Running / sprinting	2 % (1/58)
Collision	2 % (1/58)
Passing / crossing	2 % (1/58)
Being kicked	2 % (1/58)
Unknown	5 % (3/58)

Discussion

The current study suggests that the reported incidence of peroneal tendon injuries in professional football players is low. While most injuries resulted from overuse, players with a peroneal tendon injury after trauma were out of the game significantly longer. Moreover, players with a peroneal reinjury had a higher injury burden. Although less common, the medical team should pay careful attention in football players with a peroneal tendon injury, especially after trauma or in case of a reinjury, to avoid a long rehabilitation and to get the players back on the field as soon as achievable. Moreover, preventing overload of the ankle has a major role to play in the reduction of peroneal tendon injuries.

Relatively low incidence

In the current study, an injury rate of only 0.02 peroneal tendon injuries per 1000 hours of exposure was reported. Since professional football players perform many repetitive ankle movements and demand great ankle stability which puts them at a higher risk for a peroneal tendon injury, this incidence seems rather low. Indeed, earlier studies found higher peroneal tendon injury rates. Cadaveric studies suggest a prevalence of peroneus brevis tears between 11 % and 37 % , with peroneus longus tears being less common.[11,12] In clinical studies, a peroneal tendon injury was found in 23 % – 77 % of the patients with chronic ankle instability.[7,13-15] On the other hand, in a recent study among professional American football players, 4.0 % of all pathologies following an ankle sprain was found to be related to the peroneal tendon injury.[16] To the best of our knowledge, no data is available on the incidence of peroneal tendon injuries in other athletes including professional and non-professional football players.

The low incidence of peroneal tendon injuries in professional football and American football players when compared to cadaveric and clinical studies could be a result of the fact that peroneal tendon injuries are often misdiagnosed as an ankle sprain.[17] Moreover, most reported peroneal tendon injuries are classified as mild.[14,18,19] With professional athletes having less incentive to report mild injuries in general, it could very well be that not all peroneal tendon injuries caused absence and were thus not reported . Therefore, the incidence of peroneal tendon injuries in professional football players – and professional athletes in general – could well be underestimated with a real incidence higher than observed.

Overuse is the big cruel pit

Most of the peroneal tendon injuries reported in the current study resulted from overuse. This contributes to the general thought that the limits of the physical capacity of today's football players are continued to being pushed.[20,21] When performing extensive or repetitive technical movements without sufficient recovery periods, the tendons around the ankle become at greater risk for chronic overload which in turn increases the risk of injury.[22] These injuries specifically happen when a football player is mentally and/or physically fatigued. A study by Laux et al suggested that monitoring of the recovery-stress balance plays an important role in prevention of injuries.[23] The current study once more underscores the importance of close monitoring and safeguarding the players' physical condition by the medical team in order to address, prevent and/or mitigate the risks of (peroneal tendon) overuse injuries.[24]

Sufficient healing time

A frequently asked question by both injured football players and their medical team is: 'When is he/she able to return to play?' In the current study, most players with a peroneal tendon injury went back to play in less than a week. This is in line with an earlier study by Ekstrand et al, showing that the majority of all injuries in professional football caused an absence of seven days or less.[25] These 'stay-and-play-injuries', however, mainly included contusions, joint injuries and lower extremity pain syndromes. Tendon injuries or ankle sprains were not classified as such. On the contrary, Wálden et al reported an average of sixteen days of absence after ankle injuries in general within the same population as our current study.[26]

Excessive or chronic tendon loading eventually results in microtears, which, if not repaired properly, may lead to inflammatory and degenerative responses.[27] This results in a weakened tendon structure and increased risk of macro tears and ruptures.[27-29] In tendon healing, only after approximately five days, migrated fibroblasts begin to synthesize collagen. Proper tendon healing even takes four to six weeks, and despite rehabilitation, once a tendon is damages it will almost never return to its old capacity.[30,31] Getting back on the field too early puts the tendon healing process at stake. This may result in failure of adequate healing, potentially leading to inadequate ankle stability or the ability to return pre-injury levels. Good care should thus be taken to decide whether a patient is truly ready to get back on the field.

Higher injury burden after traumatic injuries and re-injuries

While overuse injuries were most common within this peroneal tendon injury population, injuries following a traumatic event led to more days of absence and a higher reinjury risk. Moreover, patients with a reinjury reported a significant longer absence when compared to primary injuries. This suggests that team physicians should pay extra attention to patients suffering a traumatic peroneal tendon injury to reduce the risk of reinjuries and the prolonged absence that reinjuries seem to cause.

Role of prevention of peroneal tendon injuries

The current study suggests that prevention of chronic overload of the ankle could potentially help to reduce peroneal tendon injuries. In the prevention of lower extremity injuries, different prevention strategies focusing on proprioception, muscle strengthening, balance, and improved biomechanics were found effective.[32-34] In professional basketball players, for example, a randomized controlled trial found that a warm-up program including strengthening, stretching and balance exercises resulted in a significant lowered injury rate when compared to a control group (0.68 versus 1.4; P = .022).[32] Another randomized controlled trial found a proprioceptive exercise program to result in a nearly 65 % reduction of odds of an ankle sprain compared to a control group, with a number needed to treat of seven athletes to prevent one acute ankle injury.[35] Further epidemiological and clinical studies are needed, however, to determine which patients would benefit most from preventive strategies and which strategies would be most effective in the prevention of peroneal tendon injuries.

Methodological considerations
The strength of this study is that multiple professional football teams from Europe were prospectively studied. In this way, a large homogeneous study sample was created. Moreover, the methodology of the study is in line with earlier published consensus on methodology of epidemiological studies in professional football making the current study comparable to similar cohort studies.

The current study, however, is not without limitation. First, the authors of the current study had no influence on specific data collected. Relevant data on medical background of the patients, diagnostic methods and treatment, therefore, could not be included in the results of the study. Moreover, data on environmental conditions at the time of injury, such as weather conditions, surface type and specific shoe wear were not included in the database. To create better insight in future prevention and management of peroneal tendon injuries in professional football players, these data would have been useful. Another limitation of the database included the reportage of the injury severity on a three category scale. The recent IOC consensus statement recommends to use four categories of injury burden, and this recommendation could therefore not been met. Also, all peroneal tendon injuries were diagnosed and classified by physicians from the individual medical teams and therefore dependent on their respective experience. Last, although the included cohort was large, the total number of peroneal tendon injuries was relatively few due to the rarity of the injury.

Conclusion

The current study suggests that peroneal tendon injuries are relatively rare within the professional football player population. Based on current data, a team of 25 players might expect a peroneal tendon injury every eight seasons. While most injuries resulted from overuse, players with a peroneal tendon injury after trauma were out of the game significantly longer. Moreover, reinjuries were associated with a prolonged absence.

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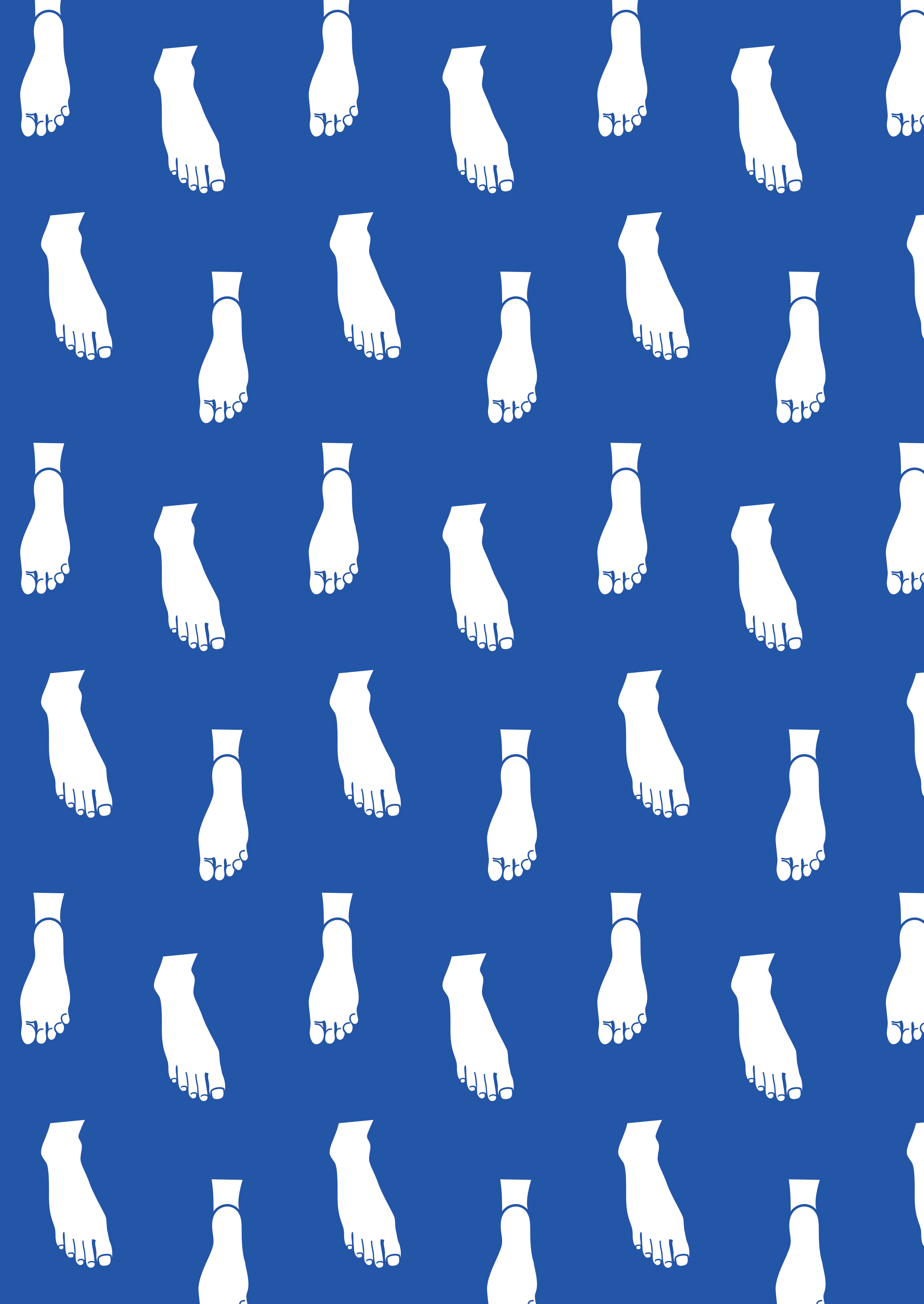
PART 2

ANATOMY



CHAPTER 3

Peroneal tendons well vascularized: results from a cadaveric study

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Abstract

Purpose
Peroneal tendon tears are relatively common injuries that seem to have a poor healing tendency. The discussion goes that peroneal tendons have avascular zones, contributing to the poor healing of those tears. The purpose of this study was to provide evidence on the vascularization pattern of the peroneal tendons.

Methods
Ten adult fresh-frozen cadavers were obtained from a university-affiliated body donation program. The femoral artery was injected with natural colored latex at the level of the knee. Macroscopic and microscopic dissections were performed to visualize the vascularization towards the peroneal tendons. To expose intratendinous vascularity, the tendons were cleared using a modified Spälteholz technique.

Results
In all specimens, blood was mainly supplied by the peroneal artery through a posterolateral vincula connecting both tendons. Branches were bifurcated every 3.9±1.8 cm, starting 24±5.3 cm proximal to the tip of the fibula. Eight out of ten (80 %) specimens had poor vascularized zones in the peroneus longus tendon. No avascular zones were found in the peroneus brevis tendon.

Conclusion
The peroneal tendons are well vascularized by the peroneal artery, via vessels running through a common vincula for both tendons. In the peroneus brevis, no avascular zones were found. To keep the tendons well vascularized and therefore to improve tendon healing, surgeons should be careful leaving the vincula intact during surgical procedures.

3

Chapter 3: Peroneal tendons well vascularized: results from a cadaveric study

Introduction

Peroneal tendon tears are relatively common disorders that seem to have a poor healing tendency. It has been discussed in the literature that the peroneal tendons have avascular zones at the level of the most common locations for tears, contributing to the pathogenesis and poor healing of those tears.[1-4] There is controversy, however, regarding the existence of avascular regions. To further understand different peroneal tendon pathologies, the first step is to understand the peroneal tendons' vascularization pattern.

Pathophysiology of peroneal tendon tears can be acute or chronic in nature.[1,5,6] While acute tears are mostly attributed to sports injuries and lateral ankle instability[7], chronic tears are more likely a result of impingement, chronic subluxation or stenosis.[7-11] Tendon degeneration is proposed as an underlying mechanism of injury.[10,12-14] Reduced blood supply seems to play an important role in tendon degeneration. Therefore, understanding of the blood supply of the peroneal tendons is essential to understand the pathway of pathophysiology and healing, and to optimize surgical treatment.

The literature attributes the vascularization of the peroneal tendons to different branches of the peroneal artery and the anterior tibial artery. Contribution of vessels from either the lateral tarsal artery or branches of the medial tarsal artery remains controversial in literature.[15-17] The blood vessels penetrate the tendons via one or two vincula from the posterolateral side to facilitate intratendinous blood supply.[2,17,18] According to van Dijk and Kort, the distal fibers of the peroneus brevis (PB) muscle belly transform to these vincula, ending approximately at the tip of the fibula.[18]

Petersen et al proposed that the peroneal tendons have three critical avascular zones.[2] One avascular zone was found in the region where the PB tendon curls around the lateral malleolus. In the peroneus longus (PL) tendon, two avascular zones were found: one where the tendon curls around the lateral malleolus and the other where the tendon curls around the cuboid bone. These zones are consistent with the locations where peroneal tendon tears occur most frequent and the healing tendency is poor.[2] In contrast, Sobel et al found no proof for avascular zones within the tendons.[17] Both aforementioned studies only contained few specimens, and the accuracy of injection techniques varied. Hence, the vascularization pattern of the peroneal tendons remains a subject of controversy and discussion.[7]

To create better insight in the blood supply of the peroneal tendons and thus to create a better understanding of the pathophysiology and healing, and to optimize treatment, the purpose of the current study is to analyze the arterial anatomy of the peroneal tendons in cadavers. The hypothesis is that the peroneal tendons are well vascularized and free of avascular zones.

Material and methods

Ten adult fresh-frozen cadaveric lower extremities were obtained from a university-affiliated body donation program following the legal procedures and ethical framework governing the body donation in Spain. All specimens were screened for scars at the lateral side of the ankle, macroscopically visible tears, ruptures and degenerative changes. Since all donations were anonymous, no information was available on gender or prior pathologies. Before starting the intravascular injection and dissection procedure, legs were thawed to room temperature.

Intravascular injection

The femoral artery was injected with natural colored latex at the level of the knee by a cannula. Injection was performed under pulsatile manual pressure similar to the arterial blood pressure. To promote perfusion through the smallest blood vessels, the lower legs were massaged thoroughly. Small incisions were made in the tip of the toes to check whether the latex penetrated the smallest vessels.

Dissection

Dissection was done at the posterolateral side of the lower limb using the fifth metatarsal, fibular groove and the fibular head as reference. First, the skin, the subcutaneous fat tissue and the fascia were removed to expose the arteries contributing to the vascularization of the peroneal tendons.

Microdissection was completed using a surgical microscope to expose the smaller vessels (Kaps SOM 62, Germany). The tendon sheaths were opened in a longitudinal direction and the vincula was carefully studied. Dissection was completed in a structured manner, with photographs taken during the dissection. The distances between the origin of the different vascular branches that vascularized the peroneal tendons were measured using a digital caliper (Digimatic Caliper, Mitutoyo, Japan; 0.01 accuracy). Three observers individually obtained the measurements to minimize intraobserver error. All measurements were rounded to millimeters.

Spälteholz technique

To visualize intratendinous vascularization, four specimens were prepared using the Spälteholz technique, which provides transparent three-dimensional structures. The peroneal muscles and tendons were isolated together with the peroneal artery and its branches after dissection and excised together with the fibula as an anatomical reference. After complete dehydration, benzyl benzoate and methyl salicylate were used to clear the specimens satisfactorily and to reveal the micro vascularization of the peroneal tendons. The tendons were studied with a surgical microscope by three independent observers, after which the tendons were photographed and measurements of the distances between the origin of the vascularizing branches were taken carefully.

Statistical analysis

Descriptive statistics were used in calculating means and standard deviations for distances between the origins of branches. One-way analysis of variance was used to compare group means in distance. A Bonferroni test was used when findings with the ANOVA model were significant. A *p*-value of less than 0.005 (0.05 divided by 10) was considered statistically significant. Statistical analysis was performed using Stata version 13.0 software (STATA Corp., TX, USA).

Results

All specimens were free of scars at the lateral side of the ankle, and tendons were free of macroscopically visible tears, ruptures or degenerative changes. The age of all specimens ranged from 65 to 78 years. In all specimens, both tendons were mainly vascularized by the peroneal artery (figure 1). In six cases, a communicating branch was found between the peroneal artery and the posterior tibial artery before entering the tendons (figure 2).

Figure 1
Main vascularization of the peroneal tendons is supplied by the peroneal artery.
Pa peroneal artery, *PTa* posterior tibial artery, *F* fibula, *Tn* tibial nerve, *PBt* peroneus brevis tendon, *PLt* peroneus longus tendon, *lm* lateral malleolus

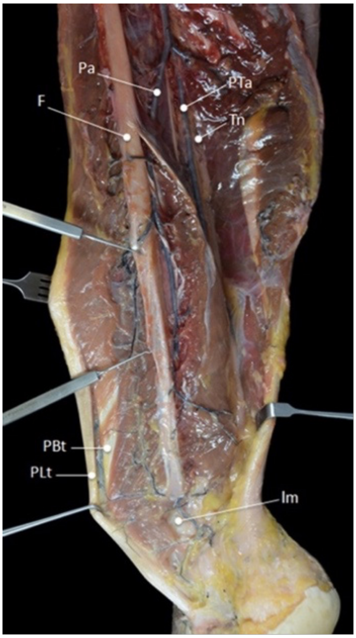
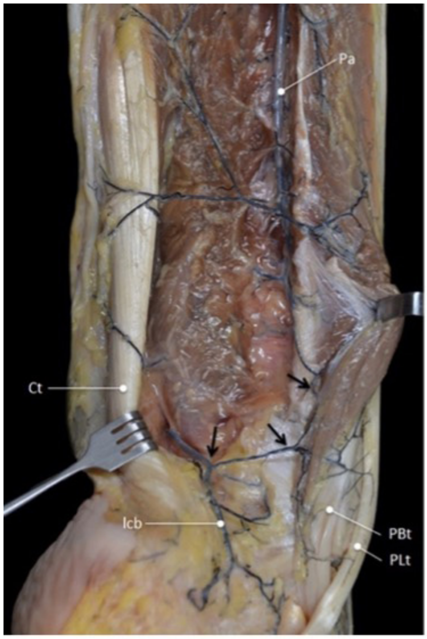


Figure 2
In six cases, a communicating branch was found between the peroneal artery and the posterior tibial artery (*arrows*).
Pa peroneal artery, *Ct* calcaneal tendon, *lcb* lateral calcaneal branch, *PBt* peroneus brevis tendon, *PLt* peroneus longus tendon



The anterior lateral malleolar branch of the anterior tibial artery was the main vessel supplying blood to the PL tendon at the dorsolateral area of foot (figure 3a). In four cases, vascularization of the PL tendon within the dorsolateral area was contributed by vessels from the perforating branch of the peroneal artery that crossed the interosseous membrane and anastomosed with the anterior lateral malleolar branch of the anterior tibial artery (figure 3b). Distances between the branches from the peroneal artery were measured (figure 4). The mean distance between the most proximal branch and the fibular tip was 24 ± 5.3 cm. The mean distance between the different branches was 3.9 ± 1.8 cm (table 1). There was no difference between distances of branches.

Figure 3

a In six cases, the main vascularization of the PL tendon at the dorsolateral area of the foot was supplied by the malleolar branch of the anterior tibial artery (*arrows*).

b In four cases, the PL was vascularized by vessels (*white arrows*) from the perforating branch of the peroneal artery (*red arrow*) that crossed the interosseous membrane and anastomosed with the malleolar branch of the anterior tibial artery (*black arrow*).

PBt peroneus brevis tendon, *PLt* peroneus longus tendon, *lm* lateral malleolus, *Im* interosseous membrane

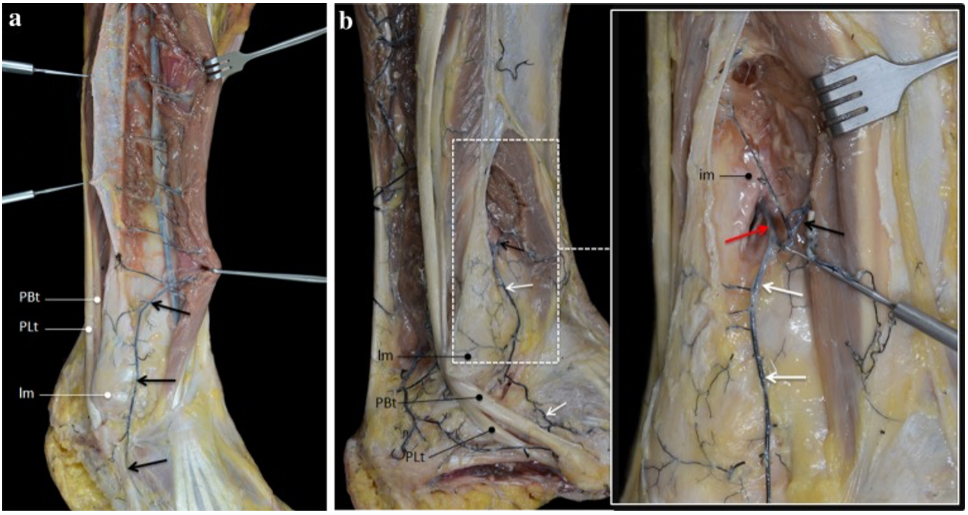


Figure 4

Peroneal artery splits of different branches (*arrows*) to enter the peroneal tendons.

Table 1

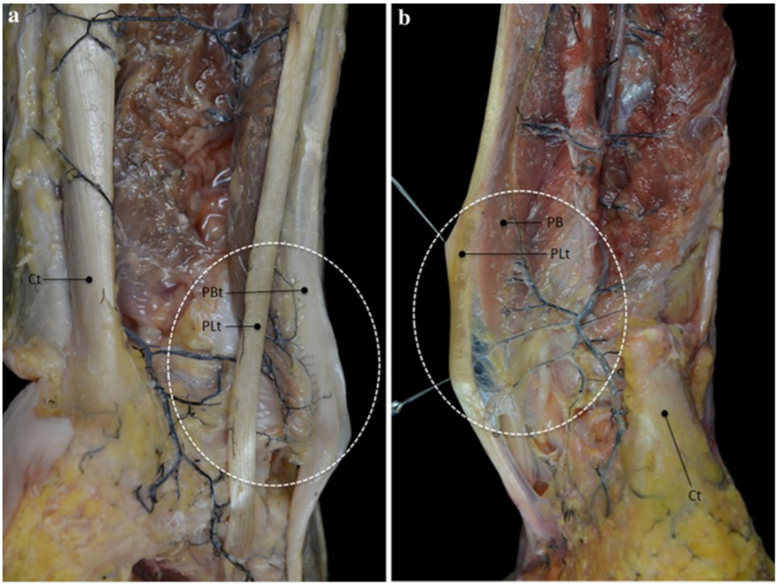
Distances between the different branches splitting off the peroneal artery

SD: standard deviation

Distance	Mean ± SD (cm)	Distance with distal branch (cm)
Fibular tip–arch	3.7 ± 2.0	–
Fibular tip–first branch	8.1 ± 2.6	4.2 ± 2.1
Fibular tip–second branch	13 – 4.0	4.9 ± 2.7
Fibular tip–third branch	17 ± 3.9	3.8 ± 0.94
Fibular tip–fourth branch	21 ± 5.3	3.7 ± 1.8
Fibular tip–fifth branch	24 ± 5.3	3.2 ± 1.1

A common vincula attached to the posterior side of the tendons connected both tendons and played an important role in their blood supply. Vessels reaching the vincula through the peroneal muscles could be distinguished into two different vascularization patterns: an arcuate pattern (figure 5a) or a weblike network (figure 5b).

Figure 5
a In eight cases, vessels from the peroneal artery formed an arcuate pattern on the vincula before entering the peroneal tendons.
b In two cases, branches of the peroneal artery formed a weblike structure on the vincula before entering the peroneal tendons. *PB* peroneus brevis muscle, *PBt* peroneus brevis tendon, *PLt* peroneus brevis tendon, *PLt* peroneus longus tendon, *Ct* calcaneal tendon



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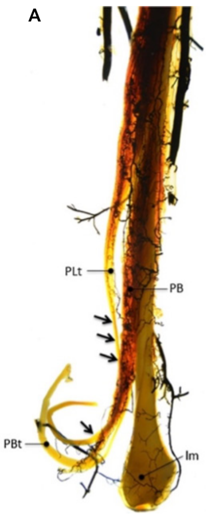

Figure 6
a In eight cases, the Spälteholz technique visualized well vascularization of the PB tendon along the whole course of the tendon. Poor vascularized zones within the PL were found in the retromalleolar groove and 2 – 3 cm proximal to the retromalleolar groove (*arrows*).
b In two cases, the Spälteholz technique showed well vascularization of both the PB and the PL along the whole course of the tendons (*arrows*).
PLt peroneus longus tendon, *PB* peroneus brevis muscle, *PBt* peroneus brevis tendon, *lm* lateral malleolus

B

Patterns of the arterial supply
In eight out of ten specimens, branches of the peroneal artery penetrated the muscles of both the PB and the PL. Vessels ran from proximal to distal, ending in the proximal part of the peroneal tendons. Some vessels entered the vincula, forming a dense arcuate pattern on the surface of the PB tendon and giving rise to small collateral vessels penetrating the PL tendon through the connective tissue that joins both tendons (figure 5a and b). Poor vascularized zones within the PL tendon were found in the retromalleolar groove and 2.0 – 3.0 cm proximal to the retromalleolar groove.

The PB tendon was well vascularized over the whole course of the tendon, without appearance of avascular zones. The vascular density within the PB tendon was clearly higher than in the PL tendon (figure 6a).

In two out of ten specimens, both muscles were directly vascularized by branches from the peroneal artery. Vessels entered the vincula, forming a weblike network over the whole length of both tendons. In these specimens, no avascular zones were found in both the PB tendon and the PL tendon (figure 6b).

Discussion

The results of the current study suggest that both peroneal tendons are well vascularized, with a clearly higher vascular density in the PB tendon relative to the PL tendon. The tendons are mainly vascularized by the peroneal artery, via small vessels running through a common vincula. After entering the vincula, two vascularization patterns could be distinguished: either (1) small vessels formed a dense arch on the surface of the PB tendon, giving rise to small collateral vessels penetrating the PL tendon, or (2) branches entered the vincula forming a weblike network and then perforated both tendons. No avascular zones could be distinguished in the PB tendon. In the PL tendon, poor vascularized zones were only found when an arcuate structure was distinguished.

To gain knowledge on the pathophysiology of peroneal tendon pathologies and aid surgical approaches, understanding of the vascularization of the peroneal tendons has been looked over previously.[2,17] The results of the current study regarding the major blood supply of the tendons are in line with previous findings. Both peroneal tendons are mainly vascularized by branches of the peroneal artery. Results of the current study suggest that not the medial tarsal artery but the lateral tarsal artery in some cases anastomoses with the perforating branch of the peroneal artery, contributing to the vascularization of the peroneal tendons at the dorsolateral region of the tarsus.

As proposed by Scholten and van Dijk, the current study found branches of the peroneal artery reaching the tendons trough a common vincula attached to the posterior side of both tendons.[19] Vincula are described as synovial tissue, connecting the tendon to their tendon sheath.[20] The vincula of the peroneal tendons is attached to the dorsolateral aspect of the fibula and continues until the distal insertion of the tendons.[18] In vascularization of the hands' flexor tendons and the anterior tibial tendon, vincula have been proven to be of great importance in blood supply.[9,21] Facilitating the vascularization of the peroneal tendons, surgeons should be aware of the location of the vincula and ensure that it remains intact.

In 1992, Sobel et al found vascular supply by the peroneal artery over the whole course of both tendons by injecting Indian ink into the arteries.[17] No evidence was found for avascular zones. Eight years later, Petersen et al reported three critical avascular zones within the tendons.[2] They stated that the method used by Sobel et al was not accurate. Ink may leak into the intervessel area due to high pressure or damaged vessels, creating false-positive results. On the other hand, micro-embolism, low pressure and hardening of the injection medium before it reaches the terminal arteries may cause inadequate filling of the vessels leading to false-negative results.[2] Petersen et al injected Indian ink combined with gelation in the arteries to visualize the vascularization.[2] Therefore, discrepancy between the two studies could be explained not only by false positives in the results from Sobel et al, but also by false negatives in the results from Petersen et al.[2,17]

In an anatomical study of Edwards, the general vascular network within tendons was determent as longitudinal vessels with transversal connections running through the entire length of the tendon.[22] Such distribution pattern was also found in the current study. Vascular injection showed a homogeneous vascular distribution and a dense vascular network in the PB tendon, corresponding to the study from Sobel et al.[17] In the PL tendon, poor vascularized zones were found around the lateral malleolus in the cases were small vessels first passed the PB tendon and the vincula before reaching the PL tendon. This is more in line with the study from Petersen et al.[2] Discrepancy between the results of the current studies and earlier studies could be explained by the false-negative and false-positive effects of injection techniques. Difference in accuracy of the different methods may also explain the difference.

PB tendinopathy mostly occur around the fibula.[3,23] Petersen et al found avascular zones corresponding with the most common sites of tendinopathy and concluded that poor blood supply is related to PB tendon tears.[2] The literature, however, shows controversy on the relation between blood supply and tendon ruptures.[24] In Achilles tendon ruptures, for example, several authors doubt the relationship between blood supply and frequency of ruptures.[24-28] In the current study, no avascular zones were found in the PB tendon. Therefore, the relationship between vascularization of the peroneal tendons and the location of tears is questioned. A different proposed mechanism of tendon injury is structural disturbance of the tendon due to stress.[24] With the PB tendon squeezed in between the PL tendon and the bony pulley at the level of the retromalleolar groove – this is the zone where most PB tendon tears occur – frequency of tears in different zones of the tendon may be explained by high stress and pressure in the groove.[3,29]

The literature shows that increased vascularization is often found in chronic tendinopathies. Chronic tendon pathologies seem to be a highly active process when it comes to neovascularization of the tissue. Tenosynovitis, the precursor of chronic PB tendon tears, is associated with neovascularization. It is unknown why healing of tendinopathies and their hyper vascular state tends to fail. It is known, however, that invasion and proliferation of new blood vessels may contribute to pain and chronicity of a tendon disorder.[30]

The limitations of this study should be taken into account. First, the use of cadavers carries possible inherent bias. Findings obtained from cadavers may differ from the in vivo situation. Also, freezing and thawing can damage the tendons and blood vessels, and therefore potentially influence results.[31] To determine the pattern of blood supply to and within a tendon, however, a cadaveric study seems to be the most accurate study design. Another limitation is the low number of specimens. Anatomical variations may have influenced our results, and therefore, a higher number of specimens would lower the possible change incidental findings. A third limitation is the lack of immunohistochemical demonstration of laminin within the tendon, which would have put more weight to our results.

Conclusion

The peroneal tendons are well vascularized by distal branches of the peroneal artery, running through a common vincula and no avascular zones could be distinguished in the PB tendon. Vessels from either the fibular artery or the perforating branch of the peroneal artery contribute to vascularization of the tendons on the dorsolateral region of the tarsus. To keep the tendons well vascularized and therefore improve tendon healing, surgeons should be careful leaving the vincula intact during surgical procedures.

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CHAPTER 4

Optimizing surgery of metaphysical-diaphyseal fractures of the fifth metatarsal: a cadaveric study on implications of intramedullary screw position, parameters and surrounding anatomic structures

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Injury (2020)

Abstract

Aims

Many advocate screw fixation of fractures to the metaphyseal-diaphyseal junction of the fifth metatarsal base, better known as Jones fractures, to facilitate quicker ambulation and return to sport. Maximizing screw parameters based on fifth metatarsal anatomy, alongside understanding the anatomic structures compromised by screw insertion, may optimize surgical outcomes. This study aims to (1) correlate the proximity of Jones fractures to the peroneus brevis and plantar fascia footprints and (2) quantify optimal screw parameters given the anatomy of the fifth metatarsal bone.

Materials and methods

3D CT-scan reconstructions were made of 21 cadaveric fifth metatarsal bones, followed by meticulous mapping of the peroneus brevis and plantar fascia footprints onto the reconstructions. Based on bone length, shape, narrowest intramedullary canal diameter, and surrounding anatomy, two traditional debated screw positions were modeled for each reconstruction: (1) an anatomically positioned screw, predicated on maximizing screw length by following the intramedullary canal for as long as possible, and (2) a clinically achievable screw, predicated on maximizing screw length without violating the fifth tarso-metatarsal joint or adjacent cuboid bone. Fixation parameters were calculated for all models.

Results

The peroneus brevis and plantar fascia footprints extended into the Jones fracture site in 29 % and 43 %, respectively. The anatomically positioned screw did not affect the peroneus brevis nor the plantar fascia footprint but required screw entry through the cuboid and fifth tarso-metatarsal joint in all specimens. The clinically achievable screw entry site, avoiding the cuboid and fifth tarso-metatarsal joint, partially compromised the peroneus brevis and plantar fascia footprints in 33 % and 62 % with a median surface loss of 1.6 % (range 0.2 – 3.2 %) and 0.81 % (range 0.05 – 1.6 %), respectively. Mean anatomically positioned screw length was 64 ± 3.6 mm and thread length 49 ± 4.2 mm. Mean clinically achievable screw length was 48 ± 5.8 mm and thread length 28 ± 6.9 mm.

Conclusion

This study underscores the challenges associated with the surrounding structures around the fifth metatarsal bone as they relate to optimal Jones fracture treatment. Both the extent of Jones fractures as well as a clinically achievable positioned screw violate the peroneus brevis and plantar fascia footprints – although the degree to which even partial disruption of these footprints has on outcome remains unclear. To minimize damage to surrounding structures, including the peroneus brevis and plantar fascia footprint, while allowing a screw length approximately two thirds of the metatarsal length, the clinically achievable screw position is recommended. This position balances the desire to maximize pull out strength while avoiding cortical penetration or inadvertent fracture site distraction.

Chapter 4: Optimizing surgery of metaphysical-diaphyseal fractures of the fifth metatarsal: a cadaveric study on implications of intramedullary screw position, parameters and surrounding anatomic structures

Introduction

Fractures at the metaphyseal-diaphyseal junction of the fifth metatarsal (MT5), also known as Jones fractures, are common athletic foot injuries.[1,2] While the mechanism behind this so-called type two MT5 fracture has been extensively debated, some hypothesize that the insertions of the peroneus brevis (PB) and plantar fascia (PF) play a role in both displacement and outcome.[3-10] Few, however, have discussed the implications of further damage to such structures during treatment with modern intramedullary screw fixation methods.[11-13]

Jones fractures can be problematic in the elite athlete. Research suggests earlier return to sports after surgical fixation of Jones fractures using intramedullary screw fixation[14-16], while fixation failure following the use of different screw types and sizes is reported in up to 40 % of cases.[16-18] Moreover, effective insertion of a straight implant is complicated by the curvilinear MT5 geometry, surrounding soft tissue structures, and adjacent bony structures such as the cuboid. For these reasons, controversy remains regarding optimal screw size and insertion location.

An improved understanding of the impact of (surrounding) MT5 anatomy on optimal screw parameters such as length, diameter, thread length, and ideal insertion trajectory should help the surgeon to improve technique and outcome, and potentially decrease iatrogenic damage to surrounding tissues during implant insertion.

This study, therefore, aims to (1) accurately define the relationship of the Jones fracture pattern to the PB and PF footprints and (2) better describe Jones fracture screw parameters and trajectory with its effects on surrounding MT5 anatomy. It is hypothesized that (1) the PB and PF footprints are both located within the Jones fracture zone and in this manner may participate in fracture mechanism and healing potential. Moreover, it is hypothesized that (2) a screw placed parallel to the cuboid bone and in line with the intramedullary cortex will create sufficient pull-out strength without sacrificing surrounding structures, albeit compromise length as compared to an anatomically positioned screw aimed straight down the MT5 diaphysis.

Material and methods

After local Institutional Review Board approval, 22 fresh frozen cadaveric lower legs were obtained from an anonymous donor program. The MT5 was harvested from each cadaver with the PB and PF carefully being identified, preserved and sacrificed several centimeters proximal to their insertion. Next, the base of each MT5 was proximally disarticulated and removed from the specimen. All specimens were macroscopically screened and excluded if any visible scarring, fracture, or soft tissue avulsion was present. Any remaining soft tissue adherence, except for the PB and PF, was dissected free from each MT5.

To facilitate accurate registration of the PB and PF footprints' location during further analysis, three stainless steel screws with a diameter of 0.2 mm were consistently placed within the MT5 and used as reference points. Screw locations were chosen carefully to avoid damaging the PB and PF or the bone: (1) proximally in the middle of the articular surface (AS), (2) at the most distal tip of the MT5, and (3) in the medial cortex.

A CT scan of each bone was used to reconstruct a corresponding 3D model, including the cortex, IMC and three reference screws using a 3D life science modeling software program (Amira 6.0.1 for Windows) (figure 1). Next, a digitizer was used to digitize the perimeter of the PB and PF footprints, the AS, and the reference screws. For evaluation of the inter- and intra-observer variation, digitization was done twice by an orthopedic foot and ankle fellowship-trained surgeon and once by the lead researcher. Using the reference screws, the location of the digitized PB, PF and AS were mapped onto their respective 3D bone model (figure 2). The perimeter and surface area of the footprints were measured.

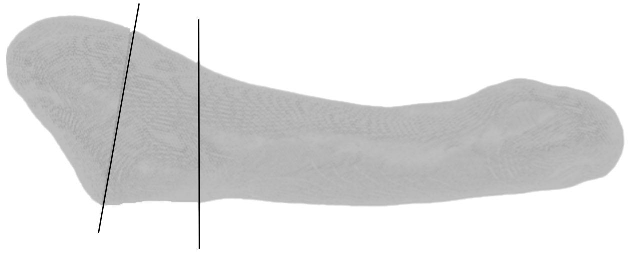
Figure 1
Based on a CT scan of each bone, a corresponding 3D model was re-created, including the cortex, the intramedullary canal and the three reference screws.

Figure 2
Using the reference screws, the digitized footprints of the PB and the PF, and the location of the AS were mapped on their respective 3D bone model.

To analyze each bone from the exact same view to create comparable measurements, an orthogonal coordinate system was created for each individual bone, consisting of an X-axis, Y-axis and Z-axis. The system was based on the points that were most reproducible in all bones: the X-axis was created along the longitudinal dimension of the bone, at the center of the IMC. The Y-axis was created at the cross point of the MT5-cuboid articulation and the fourth- and MT5 articulation. The Z-axis was found orthogonal to the X- and Y-axis (figure 3). Then, the Jones fracture zone was identified based on the classification of Lawrence and Botte.[19]

Figure 3
The coordinate system consisted of a Y-axis, X-axis and a Z-axis and was based on reference points that were most reproducible in all bones: the X-axis was created along the longitudinal dimension of the bones, the Y-axis in medial lateral direction and the Z-axis orthogonal to X and Y.

Figure 4
The different fracture zones were constructed according to the classification system of Lawrence and Botte.[19]



Based on the bone length, IMC shape, and narrowest canal diameter, the screw length and width were modulated for Jones fracture fixation of each bone model. A standardized general screw selection was considered to match the IMC diameter (i.e. 4, 4.5,5, 5.5, 6 mm). In total, two traditional screw positions were defined: (1) an anatomically positioned screw (AP), predicated on maximizing screw length by following the IMC for as long as possible without regard to the surround anatomic structures (cuboid, etc.), and (2) a clinically achievable screw (CA), predicated on maximizing screw length while entering the MT5 without violating the fifth tarsometatarsal joint or adjacent cuboid bone (which inherently limits medialization of the entry point) (figures 5 and 6).

Figure 5
Positioning of the AP screw
A. Total bone with the inserted AP screw
B. Intramedullary canal with the inserted AP screw
**The AS is indicated with the dots*

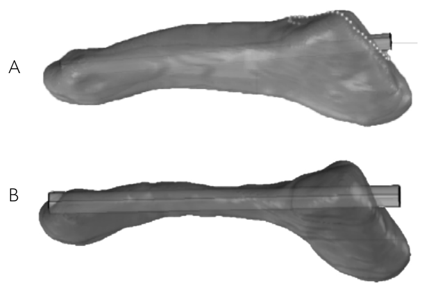
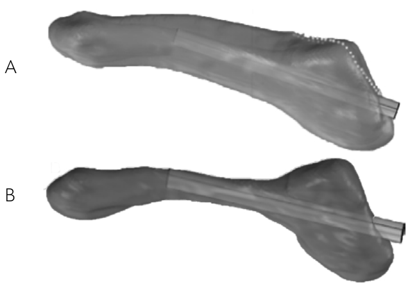


Figure 6
Positioning of the CA screw
A. Total bone with the inserted CA screw
B. Intramedullary canal with the inserted CA screw
**The AS is indicated with the dots*



Fixation parameters were calculated for all screws. Screw diameter was recorded as the diameter of the standardized general screw selection to match the IMC diameter. Screw length was defined as the maximum length achievable without piercing the (internal) IMC cortex. Thread length was calculated as the screw length distal to the fracture site: based on the proximal and distal border of the Jones fracture zone, minimal and maximal thread length was calculated by measuring the distance from the tip of the screw to the proximal- and to the distal border, respectively. It was presumed that maximizing thread length beyond the fracture provides optimal pullout strength as well as maximal compression of the fracture segments. Moreover, the location of each PB and PF footprint and its relation to the Jones fracture zone was investigated. The impact of the AP and CA screw insertion sites on the PB and PF footprints were recorded by calculating the percentage of each footprint obliterated by a hypothetical screw's drill site.

Statistical analysis
Statistical analysis was performed in STATA 13.0 statistical software (STAT Corp., TX, USA). Medians, ranges, means and percentiles were based on the two observations done by the first observant and calculated as descriptive data. To assess intra-observer variability, the Pearson correlation coefficient (r) was used. Interobserver variability was analyzed using the intraclass correlation coefficient through a two-way mixed effects model, according the guidelines proposed by Shrout.[20] Differences in screw parameters between the AP and CA screw were compared in a two-sided T-test. A p-value less than 0.05 was considered statistically significant.

Results

21 unpaired specimens were ultimately included for final analysis, with one excluded due to a visible scar along the lateral foot suggestive of prior injury. Eleven specimens were left- and ten were right sided, with a median age of 64 (range 22 – 88). Unintended but notably, 9.5 % (2/21) of the bones belonged to a female. No further demographic information was available because all donations were anonymous.

Calculated (fixation) parameters are shown in table 1. The mean diameter of the canal was 4.3 mm. In 14.3 % (3/21) of the bones, the narrowest portion of the IMC exceeded a diameter of 4.50 mm, requiring the use of a 5.00 mm screw. In all other models, a 4.5 mm screw was used (18/21).

Table 1
Parameters of the AP screw and the CA screw.

	AP screw			CA screw			
	Mean	SD	Range	Mean	SD	Range	*p-value*
Overal bone length (mm)	74.4	3.6	67.5 – 82.5	74.4	3.6	67.5 – 82.5	
Overal screw length (mm)	64.2	3.6	57.4 – 71.2	47.8	5.8	36.1 – 61.3	<0.001
Ratio screw length to overall bone length (%)	86.5	2.4	80.9 – 91.5	64.2	5.9	50.7 – 74.3	<0.001
Maximum thread length (mm)	58.7	3.7	51.5 – 64.4	37.4	6.5	22.5 – 51.1	<0.001
Minimum thread length (mm)	48.5	4.2	41.2 – 56.1	28.2	6.9	13.0 – 42.0	<0.001
Narrowest point intramedullary canal (mm)	4.3	0.69	2.9 – 5.4	4.3	0.69	2.9 – 5.4	

The orientation of the AP screw required an intra-articular entry point at the fifth tarso-metatarsal joint in all models. Both screw length and achievable thread length distal to the fracture site were significantly longer ($p<0.0001$) in the AP screw compared to the CA screw, as shown in tables 1 and 2.

In all specimens, the PB insertion was oval shaped and located on the dorsal side of the MT5 base. The PF was also oval shaped, but situated around the tip of the tuberosity. Mean surface areas are summarized in table 3. In 33 % (7/21), the insertions abutted each other without overlap. The PB and PF were (partially) located within the Jones fracture zone in 29 % (6/21) and 43 % (9/21) of the bones, respectively. The CA screws' entry points was found to partially sacrifice the PB in 62 % (13/21) and the PF in 33 % (7/21) of the specimens, with a mean surface loss of 1.5 ± 0.9 mm2 (1.6 %, range 0.2 – 3.2 %) and 1.3 ± 0.8 mm2 (0.81 %, range 0.05 – 1.6 %), respectively. In the AP screw, none of the footprints were compromised.

The intraclass correlation coefficient was 0.882 (95 % CI 0.671 – 0.995) for the PB and 0.830 (95 % CI 0.463 – 0.938) for the PF, indicating a low interobserver variability. There was a strong intraobserver correlation for both the PB ($r = 0.973$) and PF ($r = 0.950$).

Table 2
Loss of screw- and thread length when using the CA screw instead of the AP screw.

	Mean length loss (mm)	95 % confidence interval (mm)
Overall length AP screw versus CA screw	16.5	13.5 – 19.5
Minimal thread length AP screw versus CA screw	20.3	16.7 – 23.8
Maximal thread length AP screw versus CA screw	21.3	18.0 – 24.6

Table 3
Inter- and intra observator measurements of the footprint of the PB and the PF.

	Interobserver mean ± SD	Intraobserver mean ± SD
Circumference PB	36.5 ± 7.77 mm	35.6 ± 7.88 mm
Area PB	88.1 ± 46.4 mm^2	92.6 ± 48.4 mm^2
Circumference PF	41.2 ± 5.14 mm	40.4 ± 5.33 mm
Area PF	150.7 ± 53.6 mm^2	138.4 ± 50.7 mm^2

Discussion

This study underscores the challenges associated with surrounding MT5 anatomy as they relate to optimal Jones fractures treatment and outcome. Both the PB and PF footprints were found to frequently overlap the Jones fracture location. These insertions have been hypothesized as potential contributors to the Jones fracture injury mechanism by virtue of a contractile or tethering force that might potentiate displacement or delay healing.[3-8] It is also possible that outcomes may be affected by unrealized tissue interposition in the fracture site or by iatrogenic damage to these soft tissue structures during surgical intervention. In turn, careful screw insertion was found to minimally compromise the footprints – although the degree to which even partial disruption of these footprints has on outcome remains unclear. Care should nonetheless be taken to consider this anatomy carefully during implant insertion and under circumstances of significant fracture displacement. Furthermore, the use of straight IMC implants remains anatomically challenging because in order to maximize screw fit, the implant must enter through the fifth tarso-metatarsal joint that is functionally obstructed by the cuboid. This current study found that a CA screw, avoiding damage to the cuboid, covers 64 % of the total bone length and allows a minimal diameter of 4.5mm. In this manner, it balances the desire to maximize pull out and bending strength while avoiding iatrogenic diaphyseal cortical penetration or inadvertent fracture site distraction.

A better understanding of relevant anatomy surrounding the MT5 is helpful for improving surgical management of Jones fractures and may have an as yet unstudied impact on outcome. Several authors suggested that eccentric or tension forces exerted by the insertional locations of the PB and PF may contribute to fracture pattern and mechanism.[13,21,22] A study by DeVries et al stated that Jones fractures are likely to be subjected to the dynamic forces of the PB and therefore require appropriate treatment to account for this muscle action.[22] The current study confirms that the anatomic footprints of the PB as well as the PF are located within the traditionally represented Jones fracture zone, in respectively 29 % and 43 %, and therefore corroborates this theory.

Morris et al suggested that deforming forces of the PB contributes to the higher risk of malunion in Jones fractures, recommending that such patients should be immobilized accordingly.[7] It remains unclear, however, whether short-term immobilization subjects a Jones fracture to fewer deforming forces from pull of the PB or PF, or whether current methods of fracture fixation can mitigate this concern. Willegger et al investigated the pull effect of the PB on the mechanical stability of Jones fracture fixation and concluded higher preliminary failure rates when PB load on the fracture was high.[10] Our study corroborates with these findings and underscores the impact of Jones fracture immobilization since it appears that both the PB and PF footprints could cause a distraction force on the Jones fracture location.

In general, today's literature favors surgical fixation of Jones fractures in active and high functioning patients, mainly because of the purported higher risk of delayed and non-union in comparison to nonoperative treatment.[12,23-26] A recent systematic review by Rikken et al found higher union rates and faster time to union in surgically treated Jones fractures when compared to conservative treatment.[27] While many surgical techniques have been proposed in literature, including ulna hook plating and tension band wires, intramedullary screw fixation remains the gold standard without general consensus on best screw placement technique. A recent cadaveric study by D'Hooghe et al suggested intramedullary fixation in combination with a fiber wire suture in basal MT5 fractures for reduction of malunion and quick return to sports.[28] The current study analyzes the remaining gold standard by emphasizing the use of correct screw parameters and careful screw placement to minimize damage to surrounding structures while maximizing pull-out strength.

When considering Jones fracture fixation, use of straight IMC implants is anatomically challenging given that any ideal entry point, which simultaneously avoids the PB and PF while maximizing screw length, becomes obstructed by the cuboid. In turn, more lateral entry sites that are clinically attainable limit screw length due to the inherent need to accommodate the radius of MT5 curvature—and risk greater violation of the PB and PF footprints. This study corroborates that anatomically attainable screw trajectories result in inherently shorter overall screw lengths as well as thread lengths. To avoid both cortical penetration and fracture distraction, most studies limit screw length to 70 % of the total MT5 length.[11,29,30] Desandis et al favored screw lengths approximating 40 mm in most cases, and rarely larger than 50 mm, to avoid fracture gapping and cortical disruption.[13] In turn, a study by Kelly et al suggested using the shortest possible screw length that permitted threads distal to the fracture site to avoid cortical blowout.[12] This study contributes to the theory that screws should be no longer then 70 % of the total bone length. We found a mean screw length of 64.2 % of the bone, affording an average overall screw length of 48 ± 5.8 mm. The use of these parameters balances the desire to maximize pull out and bending strength while avoiding iatrogenic diaphyseal cortical penetration or inadvertent fracture site distraction.[12,29,31,32]

Today's most commonly employed method of fracture fixation is a partially threaded screw with a diameter ranging from 4.5 to 6.5mm.[11,29,30,33] [Some authors suggest that these screws should not be smaller than 4.0 mm due to a risk of fatigue failure.[34] A 4.5 mm diameter screw remains the most commonly reported screw used in clinical practice.[12,30,33] This present study, however, found that three (14 %) cadaveric models possessed an IMC larger than 5 mm, hypothetically, allowing a larger diameter implant. Indeed, Ochenjele et al recently corroborated that a larger screw appears to be necessary in the majority of patients, demonstrating that a coronal diameter larger than 4.5 mm was present in 81 % of males and in 74 % of females.[11] A study by Porter et al, alternatively, compared radiological and clinical healing after the use of 4.5 mm and 5.5 mm cannulated screws and found no significant difference, concluding that use of a smaller screw is not more effective for Jones fracture fixation.[35]

A recent study by Watson et al found the PB and PF to be at risk of injury when inserting an intramedullary screw, but reported that these soft tissues were not damaged with what they described as correct placement.[36] However, the authors positioned the entry of the screw at the MT5 base, thereby interfering with the cuboid. The current study demonstrated that a CA screw damaged the PB insertion in 62 % of specimens and the PF in 33 %. While such screw placement avoids damage to the surrounding bony anatomy, our findings suggest that this tradeoff comes with the disadvantage of obligatory violation of both the PF and PB footprints—and the long-term impact of this tradeoff is not known. Fortunately, the overall footprint damage appears to be small. Surgeons should nonetheless remain acutely aware of this potential issue because the amount of damage identified in this study represents best-case scenario.

The current study is not without limitation. While it represents the largest cadaveric study to date examining IMC fixation of Jones fracture[6-8,12,28,29,32,36-38], additional numbers and greater gender balance of our cadaveric specimens may have heightened our understanding of the natural variability. The cadavers were, by chance, disproportionately male — making the findings more difficult to apply to female who may have smaller and narrower MT5s. Second, as a cadaveric study the clinical implications of these results can only be hypothesized and further clinical outcome assessment will be necessary to examine the relative outcome effectiveness of these proposed screw parameters and insertional location during clinical practice. While the study closely examined the attachment sites of the PB and PF at the MT5 base relative to the known sites of Jones fractures, it did not replicate the fracture mechanisms, nor simulate loading of these structures in the setting of an iatrogenic fracture to truly visualize displacement. Another potential shortcoming is that additional MT5 base attachments, such as the adductor digiti quinti and the peroneus tertius, were not evaluated, and we cannot comment on the implications of screw entry site choice on the integrity of these structures. Given the robust nature of the PB and PF, however, it is presumed that the structures preferentially examined in this study are likely to have the predominant effect.[8,38]

Conclusion

In summary, Jones fractures remain a challenging injury with arguably high reported rates of nonunion and in some cases ongoing pain after surgical treatment. This study found both the PB and PF footprint to frequently overlap the Jones fracture location, potentially contributing to the fracture injury mechanism, displacement of the fragment and delayed healing. In turn, careful screw insertion was found to minimally compromise the surface area of the footprints – although the degree to which even partial disruption of these footprints has on outcome remains unclear. A clinically achievable posited screw appears to cause the least amount of damage to the PB and PF footprint while simultaneously preserving other surrounding structures and allows a screw approximately two thirds of the metatarsal length. It does, however, sacrifice screw length as compared to an anatomically positioned screw. Nonetheless, the use of a CA screw in Jones fracture fixation balances the desire to maximize pull out strength while avoiding cortical penetration or inadvertent fracture site distraction.

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PART 3

DIAGNOSTICS AND TREATMENT

CHAPTER 5

Chronic disorders of the peroneal tendons: current concepts review of the literature

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Abstract

Chronic disorders of the peroneal tendons are a common cause of posterolateral ankle pain, including tendinopathy, tendon instability, and chronic tendon tears. They are often preceded by ligamentous instability or predisposing anatomic abnormalities such as a shallow fibular groove or a cavovarus foot deformity. Given the substantial disability associated with chronic peroneal tendon disorders, it is important for orthopaedic surgeons to optimize the diagnostic and treatment strategies of these entities based on contemporary studies. This article reviews both classic and recent scientific evidence regarding the diagnosis and treatment of patients with chronic peroneal tendon disorders.

Chapter 5. Chronic disorders of the peroneal tendons: current concepts review of the literature

Introduction

Peroneal tendon disorders account for a substantial proportion of posterolateral ankle complaints and are often associated with chronic lateral ankle instability or predisposing anatomic abnormalities.[1-5] In a recent study among professional football players in America, peroneal tendon pathology was found in 4.0 % of all ankle injuries.[6] Moreover, peroneal tendon pathology has been described in 23 % to 77 % of patients with lateral ankle instability.[1] Peroneal pathology can cause considerable disability, therefore warranting close attention to timely identification and management.[7] This article reviews the current science regarding diagnosis and management pertaining to chronic peroneal tendon dysfunction.

Functional Anatomy

The peroneal muscles form the lateral compartment of the lower leg. Where the peroneus longus (PL) muscle becomes tendinous 3 to 4 cm proximal to the distal fibular tip, the peroneus brevis (PB) muscle usually extends 0.6 to 2 cm more distally.[8] In some cases, the musculotendinous junction transitions beyond the fibular tip, a phenomenon known as a low-lying muscle belly. Whether this variation results in pathologic symptomatology remains unclear.[5] At the level of the fibular tip, the PB tendon is located anteromedially to the PL tendon and both share a common fibro-osseous tunnel formed by the superior peroneal retinaculum (SPR), posterolateral fibrocartilaginous ridge, investing deep posterior compartment fascia, and retromalleolar groove within the fibula. A cadaveric study by Edwards found this groove to be concave shaped in 82 % of specimens, flat in 11 %, and convex in 7 %.[8] Notably, this shape is predicated more by the fibrocartilagenous ridge than by the osseous groove. The SPR plays a critical role in maintaining tendon stability within the retromalleolar groove, and it is advocated that the integrity of the SPR is the most important factor in preventing the tendons to subluxate or dislocate.

After traversing the fibular tip, the tendons become separated by the lateral calcaneal tubercle to enter their own fibrous tunnel, secured by the inferior peroneal retinaculum. This tubercle is considered prominent in 29 % of cadaveric specimens[5], where it can become a source of pain.[9] The tendons then course posteroinferolaterally as the PB inserts along the fifth metatarsal base and the PL continues plantarly past the cuboid groove to insert along the plantar aspect of the medial cuneiform and the base of the first metatarsal bone. An os peroneum (OP), consisting of bony and fibrocartilaginous components, is located within 4 % to 30 % of the distal PL tendon.[3,4] Technically, the OP can be considered a sesamoid, protecting the tendon from damage at the level of the cuboid tunnel where it redirects from lateral to medial.[10] The OP can predispose the PL to pathology.[3,4]

Accessory muscles such as a peroneus quartus and quintus muscle are reported within the peroneal tunnel of 10 % to 34 % of the population. They have been linked to symptoms like pain and swelling, resulting from tunnel overcrowding, possibly leading to tendon tearing or dislocation.[2] Both muscles share origins from the PL, the PB, the fibula, and/or the peroneus tertius. Their insertion points, however, typically differ; the peroneus quartus variably inserts on the extensor digitorum longus slip or along the retrotrochlear tubercle of the calcaneus, whereas the peroneus quintus usually inserts on the dorsal aspect of the fifth metatarsal bone.

Both the PB and PL tendon are innervated by the superficial peroneal nerve and vascularized by the posterior peroneal artery and branches of the anterior tibial artery. Branches run through a common vincula formed by the distal fibers of the PB muscle belly; they penetrate both tendons over their entire length along the posterolateral side.[11] Historically, it has been postulated that the peroneal tendons exhibited critical avascular zones around the lateral malleolus and cuboid, contributing to the development of pathology.[12] Recent evidence, however, argues against this once held dogma, suggesting that these areas of the tendons are relatively well perfused with vascular inflow.[11]

Although the peroneal tendons clearly work in concert to preserve lateral ankle stability and eversion strength while stabilizing the medial column of the foot during stance, it remains unclear as to whether one harbors significantly greater contractile strength than the other. Early research found the force generating capacity of the PL to be twice as high as that of the PB; yet, a more recent study suggested that the PB is the more effective foot evertor.[13]

Clinical presentation

Chronic peroneal tendon pathology usually presents with lateral ankle swelling, pain, and tenderness. Complaints associated with the PB most often localize to the retromalleolar region and fibular tip, whereas those associated with the PL more often localize to the peroneal tubercle and the cuboid groove. In case of an OP disorder, patients may refer to a feeling of "stepping on a pebble."

Passive plantar flexion and inversion of the foot and active plantar flexion and eversion of the foot may provoke tenderness or pain. Moreover, single stance heel rise testing and active plantar flexion and eversion of the foot against resistance may reveal weakness and pain. In situ subluxation or frank dislocation can either present overtly on initial examination or be exacerbated by a provocative maneuver such as the resisted eversion test (figure 1).

Patient gait and hindfoot alignment should be examined in conjunction with the range of motion (ROM) of surrounding joints. Any presence of cavovarus malalignment or metatarsus adductus should be carefully noted, even if subtle, because hindfoot varus may experience exacerbated tendon overload due to malalignment of the hindfoot and an associated medial shift of both ankle's mechanical access and the moment arm of the Achilles tendon.[14] If cavus alignment is bilaterally, neurologic conditions that result in muscle imbalance—such as an occult syrinx or Charcot-MarieTooth disease—should be considered.

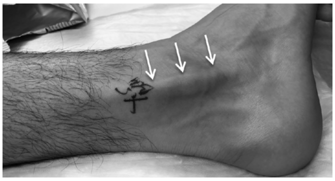
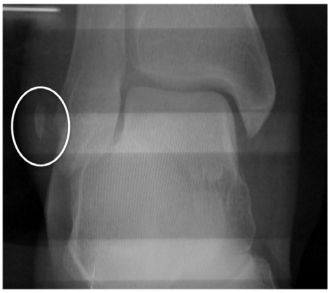


Figure 1
Dislocation of the peroneal tendons over the fibular tip during physical examination.

Imaging

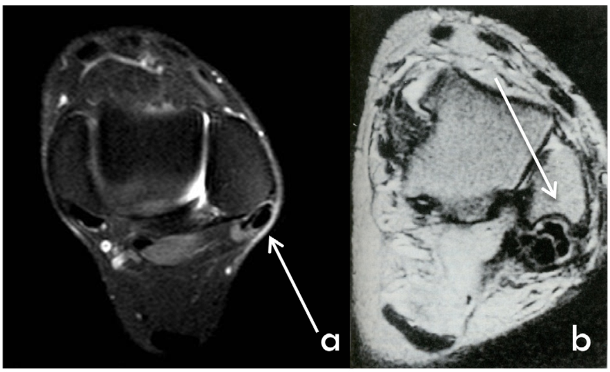
Although additional diagnostics are usually not necessary to diagnose peroneal tendon pathology, routine weight-bearing radiographs should be obtained to rule out other pathologies associated with posterolateral ankle complaints—including fractures, arthritic changes, calcifications, malalignment, congenital or traumatic OP or peroneal tubercle abnormalities. On lateral radiographs, separation of the OP fragment ⇢ 6 mm or OP displacement ⇢ 10 mm relative to the calcaneocuboid joint is associated with full-thickness PL tears.[15] A so-called fibular sleeve avulsion fracture is suggestive of SPR avulsion, potentially leading to peroneal tendon dislocation (figure 2). Enlargement of the peroneal tubercle is best assessed on the Harris heel view.[16]

Figure 2
Antero-Posterior X-ray of the ankle showing a 'fleck' sign of the distal fibula.



Magnetic resonance imaging (MRI) has become a standard diagnostic tool in evaluating the peroneal tendons and their surrounding structures.[7,16] Findings suggestive for pathology of the peroneal tendons include edema and thickening within the tendon or synovium, flattened or C-shaped tendon, irregularities of the surrounding tissue, and excessive fluid within the tendon sheath (figure 3 A and B).[16] MRI has a relatively high sensitivity and specificity of 83 % to 90 % and 72 % to 75 %, respectively.[17]

Figure 3
MRI Imaging of peroneal tendon tears
A. MRI showing a longitudinal peroneus brevis tendon tear and a flat retromalleolar groove
B. Irregularity of the peroneus brevis tendon and a concave shape of the retromalleolar groove



Dynamic ultrasonography is gaining popularity because of its in-office availability, lower cost, speed of use, and dynamic capabilities. It can readily demonstrate tendon swelling, defects, thickening, and peritendinous irregularity, and can be used to elicit instability during provocative maneuvers.[16] Moreover, ultrasonography is useful in differentiating the various causes of the disorders related to the OP.[16] The accuracy of this evolving technology, however, remains highly operator and machine dependent.

Chronic disorders of the peroneal tendons

Given their role as dynamic stabilizers of the lateral ankle and hindfoot, the peroneal tendons subsist under substantial tension even during routine activity. With ankle inversion, they are exposed to high mechanical loads at the level of the fibula. Recurrent ankle sprains and overuse may exacerbate these loads, predisposing the tendons to hypertrophic tendinopathy, recurrent stenosis, and interstitial tearing.[1] As discussed earlier, several anatomic abnormalities may predispose the tendons to pathology, including hindfoot malalignment, accessory muscles, and a low-lying muscle belly.[5,14]

Although tendinopathy can arise anywhere along the course of the tendons, it is most often found within the areas of greatest stress and angular change—around the lateral malleolus (PB), along the peroneal tubercle (PB and PL), or within the cuboid groove (PL). Pathology linked to the peroneal tendons is generally categorized into three types[15,18]:
(1) tendinopathy, including tendinitis, tenosynovitis, tendinosis, and stenosis
(2) tears and ruptures
(3) in situ subluxation or overt dislocation.

Peroneal Tendinopathy

Chronic peroneal inflammation may result in degeneration of each tendon's collagen fibrils, better known as tendinosis. In general, tendinosis is associated with increase in mucoid ground substance, loss of collagen continuity, tenocyte or fibroblast hyperplasia, increase in vascularization, and cell necrosis. Macroscopically, this mucoid degeneration changes the tendon's surface from firm, glistening white to dull, predominantly brown/grey and irregular thickening. Eventually, chronic tenosynovitis may lead to fibrosis and synovial proliferation around the tendon, causing spongy hypertrophy and stenosis of the tendon within its sheath.

Treatment
Nonsurgical treatment should always be the first step in the management of peroneal tendinopathy. A short period of rest and immobilization can be helpful in quelling symptoms. In case of flexible hindfoot malalignment, a corrective orthotic should be considered. This may incorporate a lateral hindfoot post, lateral forefoot wedge, heel cushion, and/or recess for the first metatarsal head. After several weeks of rest, physical therapy can be initiated to strengthen the peroneal tendons and surrounding muscles.

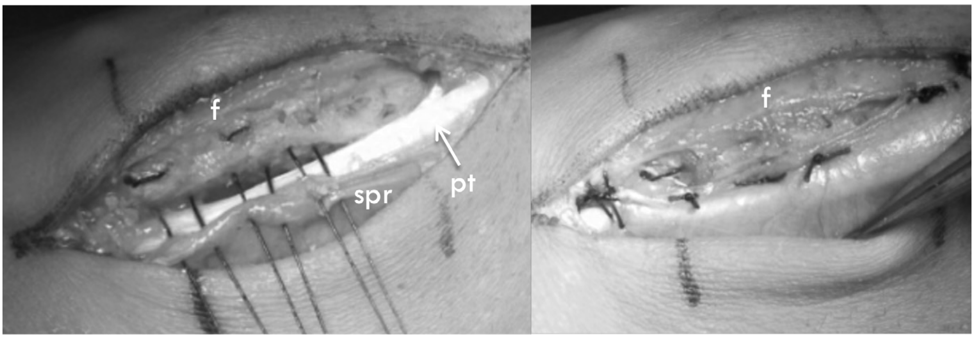
The use of platelet-rich plasma has been reported by several authors, but the effect on peroneal healing has not been convincingly demonstrated.[17,19] Steroid injections are not recommended because they may accelerate the degenerative process and potentially lead to rupture. Similarly, the effect of other recently popularized modalities on diseased peroneal tissue — such as stem cell treatment or extracorporeal shockwave therapy — is also still questionable due to the lack of sufficient prospective, comparative science.

Surgical debridement should only be considered when conservative management fails. After retinacular release and resection of associated inflammatory tenosynovium, the underlying tendons are inspected for disease and unhealthy tissue is resected. Some authors suggest that either tendon transfer, tenodesis, or allograft replacement becomes necessary if > 50 % of the tendon must be removed. Poor evidence is available, however, and today it is still considered arbitrary.[7,20] The recent European Society of Sports traumatology, Knee surgery and Arthroscopy - Ankle and Foot Associates (ESSKA-AFAS) international consensus statement concluded that it is generally preferred to attempt to preserve the tendon tissue with primary debridement and tubularization when there can be at least some reasonable native tendon left behind in the repair, even if < 50 %.[15]

After addressing any peroneal tendon pathology, the SPR must be carefully reapproximated —particularly at its most distal extent—to prevent tendon instability.[17,18] Many techniques have been described to do this, including repair to a cuff of retinaculum left along the posterolateral fibula during initial exposure, use of bone tunnels, incorporation of suture anchors, or even graft augmentation when the retinaculum is deemed insufficient (figure 4).[21]

Peroneal tendoscopy has been increasingly used for both diagnosis and treatment purposes. Relatively low complication rates, reduced costs, and earlier recovery have been documented in comparison with traditional open procedures, although the ideal indications for this evolving technique remain unclear.[17,22] A detailed step-by-step description of the procedure was first published by van Dijk and Kort in 1998.[22]

Figure 4
Reapproximation of the superior peroneal retinaculum after primary repair of the peroneal tendons
f = fibula, spr = superior peroneal retinaculum, pt = peroneal tendons



Outcomes
Available literature supports that peroneal tendinopathy generally responds well to conservative treatment and surgical management is often unnecessary.[7,18] When known predisposing anatomic abnormalities are found or patients continue to suffer chronic symptoms despite appropriate conservative measures, however, surgery often improves outcome. In a study by Gray and Alpar, sixteen of nineteen patients treated with decompression of chronic peroneal tendinopathy remained symptom free eight weeks postoperatively.[23] Kennedy et al found a significant functional improvement after treatment with tendoscopic debridement and platelet-rich plasma.[17]

Peroneal tendon tears

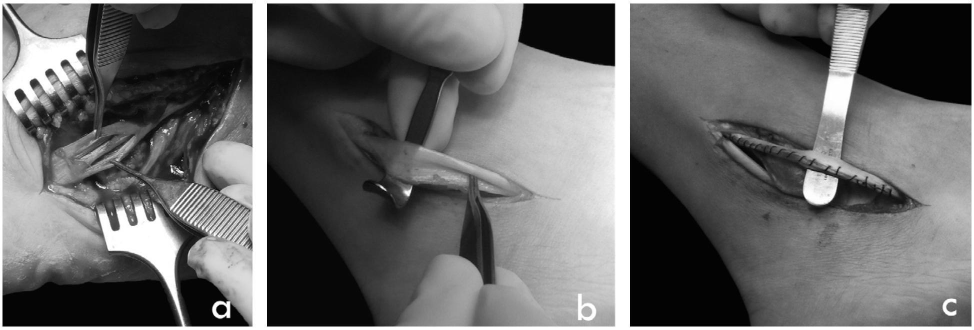
Due to its vulnerable position between the fibula and the PL, the PB tendon is most prone to tear. Looking at 40 patients surgically treated for peroneal tendon tears, Dombek et al found PB tearing in 35 patients but PL tearing in only five.[20] Another study found concomitant tears of both tendons in 38 % of patients.[24]

Treatment
Initial treatment of peroneal tendon tears should entail rest, activity modification, and graduated physical therapy to promote healing. When conservative treatment fails, various surgical techniques have been described based on the extent and nature of the tear.[20,24] Dombek et al suggested debridement and tubularization if > 50 % of the cross-sectional area of the tendon is involved; as previously stated, however, this 50 % threshold is not based on substantiated data and today it is recommended to always try debridement and tubularization if some reasonable native tendon is left behind, even if < 50 %.[15]

The traditional approach to peroneal tendon tears is open. After debridement, the remaining tendon is repaired to itself, typically resulting in tubularization of the tendon (figure 5 A – C). Peroneal tendoscopy has been increasingly used for surgical debridement without tubularization, and the authors have reported early similar outcomes.[17] There are as yet, however, no controlled studies comparing open with tendoscopic management of peroneal tears. After tendon repair by either method, consideration should be given to groove deepening. The SPR should also be repaired and advanced if needed to eliminate tendon instability.

Irreparable tears
Dombek et al suggested that when > 50 % of the tendon's cross-sectional area is involved, one should consider tenodesis of the remaining intact tendon to the functional adjacent tendon.[20] Moreover, Redfern and Myerson proposed tenodesis in cases where only one tendon is torn.[24] Recent work by Pellegrini et al, however, found insufficient restoration of PB function after tenodesis when compared with allograft reconstruction and concluded that tenodesis may lead to substantial foot imbalance.[25] Early clinical results with allograft reconstruction have in fact begun to challenge the role of tenodesis.[26]

Figure 5
Images showing intraoperative findings of a longitudinal peroneal tendon tear
A Multiple longitudinal split tears within the PB tendon
B Debridement of a simple PB tendon split tear
C Tubularization of a simple PB tendon split tear



When both tendons are non-reconstructible but the muscle bellies remain acceptably healthy with reasonable excursion, interposition tendon grafting of both tendons may be indicated.[24,27] The use of either autograft or allograft is supported in the literature, with only little comparative data available. A recent case series by Mook et al found good clinical outcomes in patients treated with allograft reconstruction.[26] Allografts however, have a higher risk of delayed graft incorporation, limited strength, and is associated with disease transmission, and therefore, the use of an autograft gracilis or semitendinosus tendon is often considered even though this procedure has the downside of potential donor site morbidity and further surgical risk.[26]

When performing allograft interposition, surgeons should consider post-reconstruction creep. Whereas little attention has been paid to this potentially confounding variable in the ankle, evidence in sports literature suggests 20 minutes of graft pre-stretching before insertion; according to recent anterior cruciate ligament literature, this may lead to approximately 1 to 2 mm of tendon narrowing and up to 4 to 8 mm of tendon lengthening.[28] Although no specific data are available for the foot and ankle, it would seem that either of these changes left unaddressed could potentially compromise the biomechanical outcome of surgical reconstruction.

In cases of complete irreparable tears, including insufficient tendon excursion, significant scarring, abnormal muscle atrophy, fatty infiltration, and/or frank rupture with large gap defects, no evidence exists to provide good treatment recommendations. The use of both allograft and autologous flexor hallucis longus (FHL) or flexor digitorum longus (FDL) transfer has been proposed.[29] Whereas relatively good outcomes have been described with this technique, it is important to keep in mind that these patients still suffer from restricted eversion capability and that FHL relocation is associated with a higher rate of tibial nerve compression due to its anatomic relationship with the posteromedial neurovascular bundle.[26,29]

Finally, recent data questions the surgeon's ability to accurately declare a tendon to be irreparable —mostly because of the inability to perform a reliable intraoperative assessment of the quality of the musculature. Goutallier et al studied surgical outcomes of rotator cuff disease treatment and suggested that preoperative MRI may be the best way to make this determination; they documented high accuracy in evaluating the degree of fatty infiltration in muscles and correlated this to poorer function postoperatively.[30] By proxy, these data suggest that when significant muscle disease is identified on preoperative MRI, perhaps frank tendon transfer should be considered in lieu of interposition tendon grafting.[30] A recent pilot study by Res et al suggested that this technique might also be beneficial for the peroneal tendons, but further research is needed to confirm these findings.[31]

Outcomes
Simple reconstruction of relatively straightforward peroneal tendon tears has been associated with excellent return to full activity and patient reported outcome scores. Recent case series reported a significant increase in the functional outcomes and a return to sports rate of 83.1 % and 94 %, respectively.[32,33]

The outcome of more complex pathology is harder to predict; due to lack of evidence, differences between allograft interposition, autograft interposition, and tendon transfer have yet to be demonstrated. Most data emanate from singular case reports or small case series, and better levels of evidence are necessary to draw more definitive conclusions regarding the variously proposed treatment algorithms that are currently available.

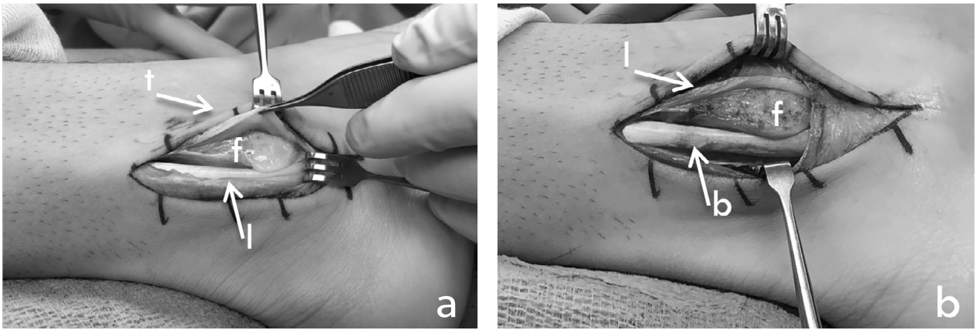
Peroneal tendon dislocation

Peroneal tendon dislocation is most prevalent in athletes who participate in sports requiring short cutting movements, such as skiing, soccer, basketball, ice-skating, and gymnastics. Dislocation occurs when one or both tendons displace from the retromalleolar groove — often subsequent to rupture or avulsion of the SPR, typically provoked by a sudden eccentric contraction of the peroneal muscles against an acutely plantarflexed, inverted foot or from a forced dorsiflexion during eversion. The PL tendon is more laterally located within the retromalleolar groove and thus far more prone to dislocation than the PB (figure 6). Different types of dislocation are identified, based on the mechanism of injury:[34]

1. In most cases (51 %), due to the relative weak connection of the fibrocartilagenous ridge to the anterior part of the periosteum of the fibula, the SPR is subperiosteally elevated from the fibula while the ridge remains in place.
2. Elevation of the SPR together with avulsion of the fibrocartilagenous ridge, accounting for 33 % of cases.
3. In 13 % of cases, the SPR is ripped off the fibula together with a cortical fragment.
4. Later added by Oden, in rare cases the SPR ruptures in the posterior part.[35]

Raikin et al proposed a subclassification of intrasheath subluxation, whereby the SPR remains intact but the tendons fluctuate their natural position within the groove dependent on the active foot position.[36] In type A, the PL tendon lies deep in relation to the PB tendon, and in type B, the PL tendon subluxates through a PB tendon tear.

Figure 6
Images showing intraoperative findings of dislocation of the peroneal tendons over the fibular tip.
A. Normal situation, both tendons are located within the superior peroneal tunnel.
B. The PL tendon is dislocated out of the retromalleolar groove.
t = tendon sheath, f = fibula, l = PL tendon, b = PB tendon



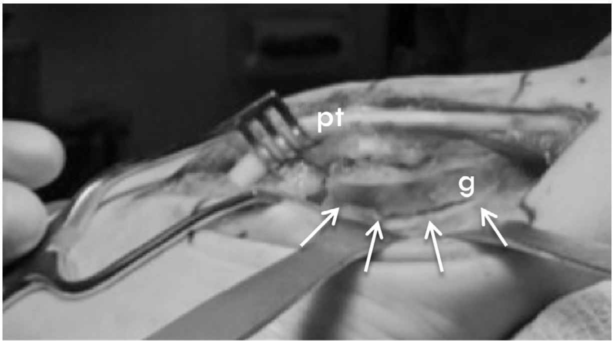
Treatment
For optimal treatment, one should take into consideration whether the pathology is acute or chronic, severity of the injury, age and activity level of the patient, and any predisposing abnormalities. Conservative treatment can be attempted after acute dislocation and primarily consists of repositioning the tendons back into the retromalleolar groove, followed by immobilization in a lower leg cast for 6 weeks while the foot is slightly plantarflexed and inverted.[21]

In patients with chronic dislocation, conservative treatment failure rates have been reported in over 50 %.[7] In these cases, or when the tendons are irreducibly dislocated in the acute setting, surgical management is recommended. More than 20 surgical techniques have been described in the literature, all with the primary purpose of (re-)stabilizing the tendons in the retromalleolar groove by attempting to restore the natural anatomy. In general, four categories can be identified:

1. SPR repair or replacement
2. Deepening of the retromalleolar groove
3. Boneblock procedures
4. Enhancement of the SPR by rerouting of other soft-tissue structures.

SPR repair and groove deepening have both demonstrated excellent outcomes and satisfaction rates.[21] SPR repair aims to restore the structural physical restraint that keeps the peroneal tendons from dislocating (figure 4), whereas groove deepening provides a more stable, anatomically configured bed for harboring the tendons over the course of their distal excursion (figure 7). Along with decompression of any extraneous tissue in the peroneal tunnel, this latter procedure also serves to decompress tension on the tendons where they pass around the distal fibula. Although some authors believe that groove deepening is only necessary in patients with a flattened groove, others believe that increasing the volume of the retromalleolar tunnel reduces the risk of redislocation while improving return to sports and rehabilitation of patients for the reasons cited earlier.[37] With literature showing heightened complication rates—including nonunion, tendon adherence to the underlying bone, and tendon irritation in bone-block procedures and rerouting of other soft-tissue, these procedures should be considered a salvage or revision.[21]

Figure 7
Image showing groove deepening of the retromalleolar groove in a patient with peroneal tendon dislocation.
g = deepened retromalleolar groove, pt = peroneal tendons



Outcomes
Most studies using repair of the SPR — with or without concomitant groove deepening — demonstrate good to excellent outcomes, high satisfaction rates, and favorable rates of return to sports (83 % to 100 %). That said, however, a recent systematic review found that combining SPR repair and retromalleolar groove deepening provides a significant higher return to sports rate when compared with SPR repair alone (P = 0.022).[21] In athletes it is therefore recommended to perform an additional groove deepening procedure.[15]

Painful os peroneum syndrome

First described by Sobel et al, the so-called painful os peroneum syndrome (POPS) has become an umbrella term for several types of disorders associated with the OP[4]:

1. Entrapment of the OP and PL tendon as a result of a hypertrophic peroneal tubercle
2. PL tendon tear
3. Frank PL tendon rupture
4. Acute OP fracture or diastasis of a multipartite OP
5. Chronic OP fracture associated with PL stenosing tenosynovitis.

Treatment
Conservative treatment of POPS is successful in most cases, mainly consisting of immobilization and rest.[18] Surgery can be considered when nonsurgical treatment fails, although the OP is rarely amenable to fixation. Moreover, its excision can lead to residual PL tendon defects, making it difficult to repair. When necessary, though, excision of a small sesamoid may be successfully performed in combination with tenosynovectomy and tendon tubularization. In case of significant tendinopathy comprising damage to > 50 % of the PL, or when the defect left behind from OP excision is large, tenodesis to the PB tendon can be performed.[7,18]

Outcomes
Recommendations are only based on case reports and small case series. Smith et al found excellent outcomes and full return to sports after nonsurgical management of a minimally displaced OP fracture in a high-level athlete.[38] In a small case series of patients with a PL tear surrounding an OP, tenodesis combined with excision of the damaged tissue and OP improved function and pain symptoms.[3]

Combined surgical procedures

Inadequate treatment of predisposing abnormalities possible contributing to peroneal tendon disorders almost surely destines an otherwise good reconstruction to eventual failure in an active patient and should therefore be addressed carefully. Examples include hindfoot malalignment, a hypertrophic peroneal tubercle, retromalleolar tunnel overcrowding, a cavus foot, or ankle instability.[5,14,39] Additional procedures such as a lateralizing calcaneal osteotomy, corrective metatarsal osteotomy, exostectomy, or fibular groove deepening may therefore be necessary.[39]

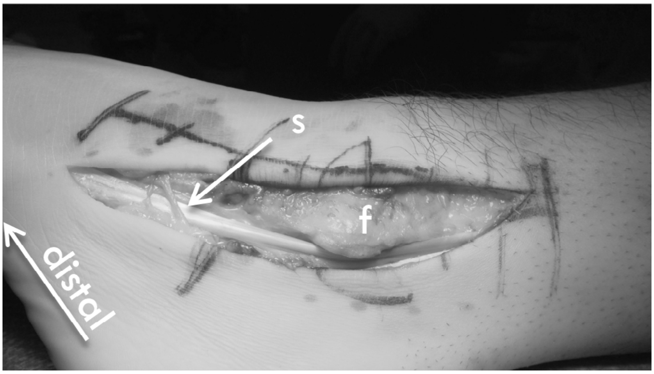
Rehabilitation

An appropriately tailored functional rehabilitation program is an important key to successful management of any peroneal tendon surgery.[40] Although early ROM is important, progression to full weight bearing depends on both the nature of the pathology and the type of surgical approach (open versus tendoscopic, bony versus soft-tissue reconstruction). Based on a recent systematic review, the ESSKA-AFAS consensus statement proposed a rehabilitation protocol.[15] After a tendoscopic procedure, they suggested immobilization for two days in a compressive dressing with the foot slightly inverted and the ankle in 90°, followed by full weight bearing and active ROM as tolerated. In case of open surgery, including repair of the SPR, the ankle may be immobilized up to six weeks, followed by physical therapy to regain ROM and muscle strength. For optimal functional recovery, rehabilitation should be tailored to the individual patient.[15]

Complications

The sural nerve is perhaps the structure most prone to damage or scarring during or after surgery given its adjacent course (figure 8). Other complications include post-surgical scarring with further inflammation or stenosis, redislocation, persistent pain, wound healing problems, and deep vein thrombosis.[39] Retinacular repair requires close attention to prevent overtightening, possibly leading to symptomatic stenosis or inadvertent incarceration of one or both tendons. Moreover, persistence of any predisposing anatomical abnormality may lead to persistent pain and dysfunction.[5,14,39]

Figure 8
Image showing the sural nerve, which is perhaps the structure most prone to damage or scarring during or after peroneal surgery given its adjacent course.
f = fibula, s = sural nerve.



Summary

Peroneal tendon disorders account for a significant degree of posterolateral ankle complaints and can be debilitating when left untreated. To prevent progressive tendon deterioration and ankle dysfunction, early identification and appropriate management is essential. Although advanced imaging can be helpful in diagnosing the location and severity of the pathology, patient history, physical examination, and weight-bearing radiographs are also paramount for accurate diagnosis and proper treatment. Promising outcomes have been reported after surgical intervention when conservative measures fail, whereas poor results may be due to a persistence of unaddressed predisposing factors such as pes cavus, hindfoot varus, accessory tendons, or ankle instability. To date, most available treatment recommendations are based on level IV and level V studies, and more high-level studies are necessary to provide more potent evidence-based recommendations for the ideal management of chronic peroneal tendon disorders.

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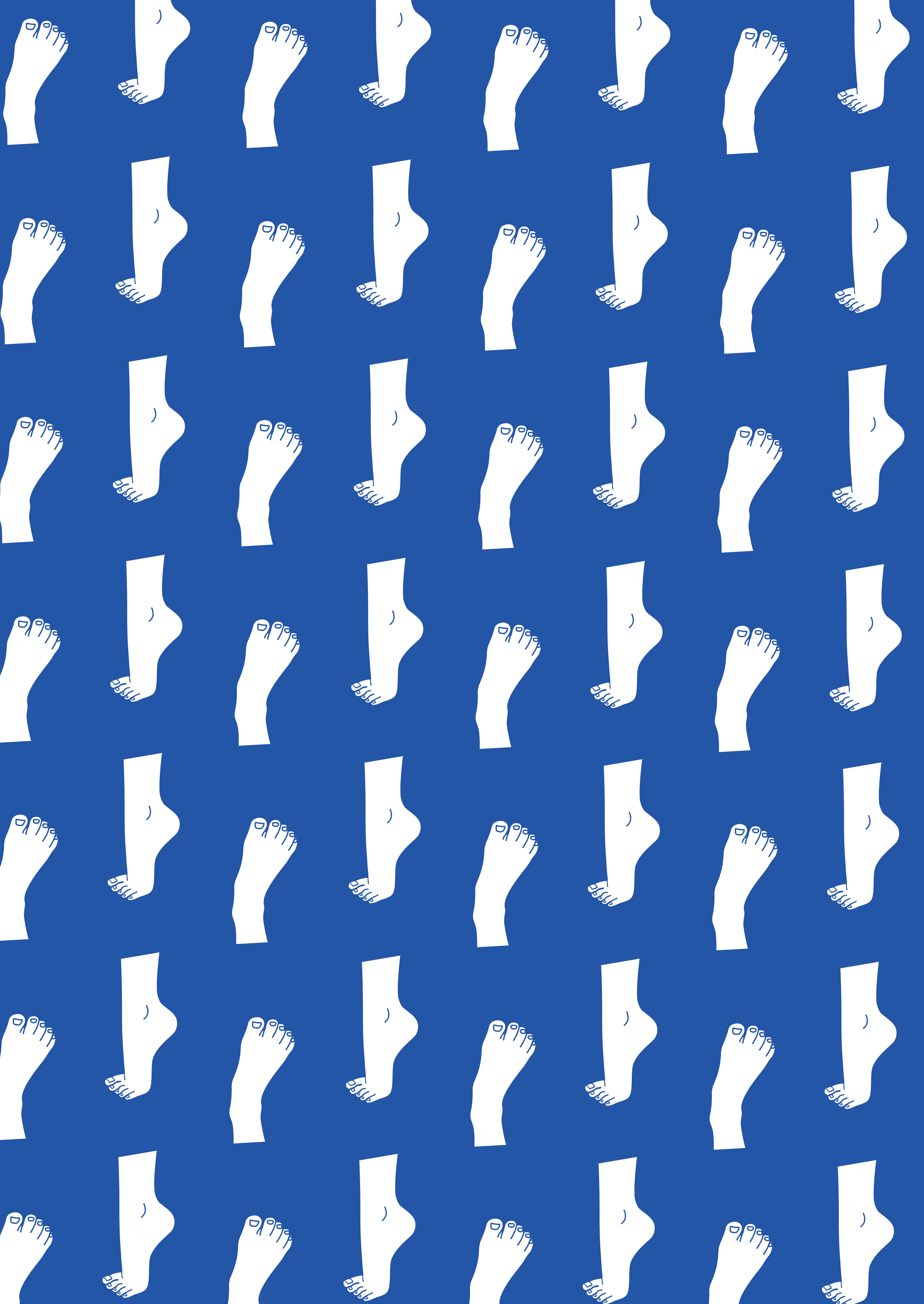

CHAPTER 6

Functional outcomes after peroneal tendoscopy in the treatment of peroneal tendon disorders

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Abstract

Purpose

The primary purpose of this study was to evaluate clinical outcomes following peroneal tendoscopy for the treatment of peroneal pathology. Correlation between pre-operative magnetic resonance imaging (MRI) and peroneal tendoscopic diagnostic findings was also assessed.

Methods

Twenty-three patients with a mean age of 34 ± 8.8 years undergoing peroneal tendoscopy were pre- and post-operatively assessed with the foot and ankle outcome score (FAOS) and the Short Form-12 (SF-12) outcome questionnaires. Follow-up was over 24 months in all patients. The sensitivity and specificity of MRI were calculated in comparison with peroneal tendoscopy, including the positive predictive value (PPV).

Results

Both the FAOS and the SF-12 improved significantly ($p < 0.05$) at a mean follow-up of 33 ± 7.3 months significantly. MRI showed an overall sensitivity of 0.90 (95 % CI = 0.82 – 0.95) and specificity of 0.72 (95 % CI 0.62 – 0.80). The PPV for MRI diagnosis of peroneal tendon pathology was 0.76 (95 % CI 0.68 – 0.83).

Conclusions

The current study found good clinical outcomes in patients with peroneal tendon disorders, treated with peroneal tendoscopy. Although a relatively small number of patients were included, the study suggests good correlation between tendoscopic findings and pre-operative MRI findings of peroneal tendon pathology, supporting the use of MRI as a useful diagnostic modality for suspected peroneal tendon disorders.

Chapter 6. Functional outcomes after peroneal tendoscopy in the treatment of peroneal tendon disorders

Introduction

Peroneal tendon disorders frequently result in refractory posterolateral ankle and hindfoot pain that disables patients from routine activity and sport.[1,2] Tendon pathology may range from tenosynovitis, tendinosis, stenosis, subluxation, and dislocation to overt tear.[3-5] In certain cases of peroneal tendon pathology, diagnosis can be challenging. Only 60 % of patients with peroneal tendon disorders are diagnosed accurately upon initial clinical examination[2], and the diagnostic accuracy of magnetic resonance imaging (MRI) has been inconsistent.[6-9] The so-called magic angle effect may further reduce the specificity of MRI findings.[10,11] Standard open surgery of the peroneal tendons has been associated with complications including post-surgical scarring with further stenosis and inflammation of the tendons and injury to the sural nerve.[12,13] Post-surgical scaring may cause further stenosis and inflammation of the tendons as they course through their fibro-osseous tunnel. While good results following surgery with traditional open approaches have been documented[14-17], Steel and DeOrio reported that only 46 % of the operatively treated patients were able to return to sports activity at a mean follow-up of 31 months.[18]

6

In response to the diagnostic challenges and potential clinical consequences associated with traditional open approaches, recent attention has been directed towards developing less invasive surgery that might afford diagnostic clarity and treatment potential without the inherent risk of these complications during management of common peroneal tendon pathologies. Tendoscopy has been proposed as one such minimally invasive technique that might fulfil this need.[19-21] The primary purpose of the current study was to report on functional outcomes after tendoscopic management of peroneal tendon disorders. In addition, the current study sought to correlate pre-operative MRI diagnoses with intraoperative findings. It was hypothesized that the use of peroneal tendoscopy would lead to good functional outcomes and there is a high correlation between tendoscopic and pre-operative MRI.

Materials and methods

Subjects

This retrospective study was approved by the Institutional Review Board at the Hospital for Special Surgery (Protocol #29124). Twenty-four consecutive patients who underwent peroneal tendoscopy between 2010 and 2013 were identified using the institutional foot and ankle registry. A single surgeon performed all surgical procedures and provided pre- and post-operative care. Surgical intervention was indicated for those who had failed a minimum three months of non-surgical management, including physiotherapy, immobilization, and non-steroidal anti-inflammatory drugs. Contraindications for surgery included any patient identified as a smoker or having associated medical comorbidities such as diabetes, autoimmune disease, and/or active infection.

The inclusion criteria for this study were patients who had (1) a peroneal tendoscopy; (2) an evaluable pre-operative MRI; (3) a minimum post-operative follow-up time of 24 months, and (4) an age between 16 and 70 years at the time of surgery. Patients were excluded if they had (1) a peroneal tendoscopy as part of a combined procedure and (2) a subsequent surgery that confounded meaningful post-operative outcome analysis.

Clinical evaluation
Patients were assessed pre- and post-operatively using patient-reported and general health outcome questionnaires, including the foot and ankle outcome score (FAOS) and Short Form-12 (SF-12), respectively.[22,23] All patients in the study had 24-month questionnaires available in the database, so no further patient contact was necessary because all data were retrievable from existing records.

MRI assessment
MRI was acquired with the foot and ankle in a neutral position using a 3-Tesla clinical imaging system (GE Healthcare, Milwaukee, WI, USA). The senior musculoskeletal radiologist reviewed all MRI images and was blinded to both surgical findings and clinical outcome. Musculoskeletal morphology of peroneal tendon pathology was evaluated using a combination of T1, high-resolution proton density, fat-suppressed T2-weighted, and fast spin echo inversion recovery sequences performed in coronal, sagittal, and trans-axial planes. Diagnoses provided from the MRI reports were compared to tendoscopic findings as part of the current study. Any discrepancy between the presence of tenosynovitis, tendinosis, or tendon tears was considered as disagreement between diagnostic modalities. No patient underwent tendoscopy if the MRI report showed no evidence of peroneal pathology.

Surgical technique
All patients underwent a standard surgical procedure. Patients were placed in a lateral position, allowing access to the anterior and posterior aspects of the ankle were an open procedure to be required. A two-portal technique with a skin bridge of greater than 30 mm was standard in all cases. Portals were made in accordance with the area of pathology identified on MRI. In this regard, a 22-gauge needle was used to identify the peroneal sheath and 5.0 cc of saline was injected to confirm correct placement and orientation of the proposed portal. A 15-gauge blade was then used to open the skin, and two skin hooks were used to lift the subcutaneous tissue from the tendon. Once the tendon was protected from the blade, the tendon sheath was opened and the 2.7-mm obturator was inserted (Smith & Nephew, Inc., Memphis, TN, USA). A low-pressure, low-flow pump of 50 – 70 mmHg was used in all cases.

Once the area of pathology was visualized, a 22-gauge needle was used to guide the second portal in exactly the same fashion as the first one. A small vincula was typically seen initially, and where appropriate this was shaved with a 2.9 mm shaver to allow better visualization and access. Once full visualization was established, areas of pathology were divided into three regions (figure 1).[24] The fourth zone, from the cubital tunnel into the plantar surface of the foot, was not evaluated in the current study.[25] All pathologies were evaluated by the senior surgeon and entered into the operative report.

Figure 1
Areas of peroneal tendon pathology divided into four anatomic regions

In patients with stenosis, subluxation, and tendon tear, peroneal groove deepening was performed using a 3.5 mm burr in the retromalleolar groove. The burr was used to create a concavity to allow the peroneus brevis tendon to lie within the groove. Sharp edges were smoothened to prevent tendon fraying, and tendons were held out of the way with two Kirschner wires. After burring, the ankle and subtalar joints were moved to assess tendon stability within the bony trough. Any evidence of subluxation prompted further burr resection until the tendon was stable and secure.

A longitudinal peroneal tendon tear was found in four patients. The two patients with less than a 10 mm tear were treated with debridement under tendoscopy. The other two patients had tears greater than 10 mm and therefore underwent a mini-open incision using an extended portal. The tendon was brought into the wound, debrided of any remaining degenerative debris and sutured with a 4-0 prolene suture using buried sutures knot and a running technique.

Platelet-rich plasma (PRP) was used to augment biologic healing in all cases. PRP was obtained from the patient at the time of surgery, with whole blood being drawn and then centrifuged in a standard fashion for fifteen minutes using a commercially available system (Arteriocyte, Inc., Hopkinton, MA, USA). The supernatant, a buffy coat containing a leucocyte-depleted PRP, was obtained. Twenty-six milliliters of whole blood was typically procured to produce 2 – 3 mL of PRP, with 1.5 mL used for tendon injection. PRP was injected into the site of tendon pathology with a 22-gauge needle under tendoscopic visualization. The needle was withdrawn and reinserted every 2 – 3 mm along the length of the affected tendon. At the time of wound disclosure, the remaining PRP was injected into the tendon sheath. At the time of surgery, note was made regarding the area of intervention related to the different zones of pathology (figure 3).

Post-operative treatment
All patients were instructed to utilize a standardized post-operative protocol. For those who underwent peroneal tear debridement, a soft dressing was applied in the acute phase. Sutures were removed seven –ten days after surgery. Patients advanced their weight bearing as tolerated. Physiotherapy included phased muscle firing, balance, and proprioceptive training. Once the patient demonstrated competence, they were progressed to sport-specific training. For patients receiving tendon repair, a lower leg splint was applied for two weeks, followed by weight bearing that progressed by 10 % bodyweight each day. At the four-week time point,

sport-specific physiotherapy was initiated to regain full range of motion and strength. Patients were allowed to return to sport after six to ten weeks, depending on individual progression and sporting demands.

Statistical analysis
All analyses were performed using SAS software version 9.3 (SAS Institute, Inc., Cary, NC). Paired t-tests were used to determine significant difference between the pre- and post-FAOS and SF-12 scores. Linear regression was performed to determine whether the mean pre- or post-FAOS/SF-12 scores and the mean change between pre- and post-FAOS/SF-12 scores differed by age. Means and standard deviations were calculated for descriptive statistics of the cohort or were reported in frequencies. Significance level was set at a p-value < 0.05 for all analyses. Sensitivity and specificity of MRI and arthroscopic findings were assessed. In addition, positive and negative predictive values were calculated.

Results

Of the 24 patients who satisfied the inclusion criteria of the study, one female patient was excluded because she declined entry to the study for personal reasons, but at latest clinical follow-up was reported a good post-surgical outcome. Twenty-three patients were therefore included in the study. Patient demographics and clinical characteristics are shown in table 1.

Table 1
Patient demographics and clinical characteristics

Demographic	Value
Patients (n)	23
Males/females (n)	10/13
Age, year (mean ± SD)	34 ± 8.8
Follow-up, month (mean ± SD)	33 ± 7.3
Duration symptoms, month (mean ± SD)	14 ± 7.6
Injured leg (n, left/right)	14/9
History of trauma (percentage)	48 %

Clinical evaluation
The FAOS score improved from a pre-operative mean of 57 ± 14 points to a post-operative mean of 86 ± 8.4 points at final follow-up (p < 0.01). The mean SF-12 score improved from 54 ± 14.4 points pre-operatively to 81 ± 7.8 points post-operatively at final follow-up (p = 0.01). The pre- and post-operative scores and the differences between them for both SF-12 and FAOS did not differ by gender, age, or duration of symptoms (p > 0.05) (table 4).

Post-operative complications were identified in only two patients, including one who had persistent lateral ankle pain and did not return to play soccer by two years. No further follow-up beyond two years was available for this patient. A second patient reported hypertrophic scar formation over the wound after a mini-open repair. Four months after surgery, however, the complaint was resolved.

Correlation between tendoscopic findings and MRI

Twenty-one patients were eligible for comparison of MRI and tendoscopic findings. Two patients with external MRIs were excluded from analysis because comparison between MRI qualities did not allow for meaningful analysis.

Zone A, including the superior peroneal retinaculum (SPR) and distal fibula, had the greatest degree of pathology (table 2). This was followed by zone B, including the inferior peroneal retinaculum (IPR) at the level of the peroneal tubercle. The least amount of pathology was found in zone C, located at the level of the cubital tunnel.

Table 2

Pathologies identified on peroneal tendoscopy (*n* = 21)

**PB = Peroneus Brevis, PRP = Platelet-Rich Plasma, SPR = Superior Peroneal Retinaculum, CBAM = Concentrated Bone Marrow Concentrate Aspirated*

Location	Pathology	Number of patients	Treatment
Zone A	Tenosynovitis	10	Debridement
(n=12)	Tendinopathy	10	Debridement, PRP injection
	Stenosis	4	PB muscle debridement, SPR partial resection, fibular groove deepening
	Subluxation	2	Debridement, fibular groove deepening
	Tear < 1 cm	2	Debridement, PRP inject, fibular groove deepening
	Tear > 1 cm	1	Mini open repair, PRP injection, fibular groove deepening
Zone B	Tenosynovitis	6	Debridement
(n=6)	Tendinopathy	6	Debridement, PRP/BMC injection
	Stenosis	2	Resection of tubercle with a burr
	Tear > 1 cm	1	Mini-open repair with PRP
	Prominent suture	1	Removal of suture knot
Zone C	Tenosynovitis	2	Debridement
(n=3)	Stenosis	1	Debridement, burr of cubital tunnel

Close correlation was found between the presence or absence of pathology within the peroneal tendons and MRI findings, indicating a high MRI sensitivity in detecting peroneal pathology (table 3). Compared to tendoscopic findings, MRI showed 0.90 sensitivity (95 % CI 0.82 – 0.95), 0.72 specificity (95 % CI 0.68 – 0.83), 0.76 positive predicative value (95 % CI 0.68 – 0.83), and 0.88 negative predictive value (95 % CI 0.78 – 0.94) (table 4). The one pathology that showed poor sensitivity and specificity on MRI was stenosis with 0.33 (95 % CI 0.23 – 0.43) and 0.66 (95 % CI 0.56 – 0.75), respectively. Specificity remained the same between the three zones, indicating that the magic angle effect in zone A was not a factor in masking peroneal pathology in this cohort.

Table 3
Sensitivity and specificity for MRI detection of peroneal tendon pathologies
**PB = Peroneus Brevis, PL = Peroneal Longus, 95 % CI = 95 % Confidence Interval*

Pathology	Sensitivity (95 % CI)	Specificity (95 % CI)	Positive predictive value (95 % CI)	Negative predictive value (95 % CI)
Overall	0.90 (0.82 – 0.95)	0.72 (0.62 – 0.80)	0.76 (0.68 – 0.83)	0.88 (0.78 – 0.94)
PB Tear	0.77 (0.67 – 0.84)	0.90 (0.82 – 0.95)	0.89 (0.80 – 0.94)	0.80 (0.71 – 0.86)
PL Tear	0.80 (0.71 – 0.87)	1.00 (0.96 – 1.00)	1.00 (0.95 – 1.00)	0.83 (0.7 – 0.89)
Tenosynovitis	1.00 (0.96 – 1.00)	0.90 (0.82 – 0.95)	0.90 (0.83 – 0.96)	1.00 (0.96 – 1.00)
Tendinopathy	0.88 (0.80 – 0.94)	1.00 (0.96 – 1.00)	1.00 (0.96 – 1.00)	0.89 (0.82 – 0.94)
Stenosis	0.33 (0.23 – 0.43)	0.66 (0.56 – 0.75)	0.49 (0.37 – 0.61)	0.49 (0.41 – 0.58)

Table 4
Patient clinical outcomes (*n* = 23)
*Preop. = pre-operative, Postop. = Post operative

Outcome		Mean (SD)	*P value*
FOAS	Preop.	57 (14)	
	Postop.	86 (8.4)	
	Change pre- to postop	30 (11)	< 0.01
	Female	31 (12)	
	Male	25 (11)	
SF-12	Preop.	53 (14)	
	Postop.	81 (7.8)	
	Change pre- to postop	28 (7.7)	< 0.01
	Female	29 (9.7)	
	Male	27 (6.2)	

Discussion

The most important finding of the current study was that peroneal tendoscopy is an effective treatment in improving functional outcome scores for a variety of peroneal tendon pathologies. Peroneal tendon pathology is often misdiagnosed, partly due to difficulty in clinical differentiation between a range of posterolateral ankle pathologies and interpreting conventional MRI and ultrasound findings of the lateral ankle.[13,26-29] While traditional open surgical techniques have shown good outcomes across a range of peroneal tendon pathologies, these are associated with a degree of post-operative morbidity that can frustrate uniformly good outcomes for many peroneal tendon pathologies.[2,14-18] Post-operative stenosis, adhesions, tendon luxation, synovitis, and nerve damage can all occur following open surgical exposure.[2,16-18] In contrast, tendoscopic intervention in peroneal pathology offers a minimally invasive method of surgical intervention that can potentially reduce the risk of these complications and confer unique advantages including shorter hospital stays, reduced cost, improved cosmesis, and earlier recovery than seen in traditional open procedures.[20,30-34]

In the current study, the most common pathology identified was tenosynovitis. This is in agreement with the literature.[20,30-34] Typically, tenosynovitis was associated with concomitant pathology of stenosis, tendon hypertrophy, or small tendon tears. Synovitis was addressed with arthroscopic debridement of the inflamed synovium. In nine of twenty cases, a fibular groove deepening was also performed. When tears were seen, a fibular groove deepening was performed in addition to biologic augmentation of the tendon and mini-open repair when necessary. Previous cadaveric studies have shown that groove deepening of the middle and distal peroneal grooves significantly reduces pressure on the tendons running within the groove, thereby reducing pain in patients with inflammation or small tendon tears.[35] The authors advocate that this supplemental treatment thus addresses not only the symptom generator at the time of tendoscopy but also the presumed primary pathology. Contrary to other studies reported, no evidence of tearing within the superior peroneal retinaculum was identified in this series, either via MRI or tendoscopy. This was a curious observation in the study cohort and might only be explained by a lack of patients with defined peroneal subluxation. Guillo and Calder have reported successful endoscopic retinaculum repair when a tear is identified, and this technique has shown promising results when required.[30]

The use of PRP to treat tendon pathology has been substantiated by in vivo and in vitro systematic reviews.[36] Both a neoangiogenic response to PRP and a tenoproliferative effect mediated by tenocyte growth factor have been demonstrated.[37] The technique of multiple stab incisions to promote tendon healing has also been previously established.[38,39] In the current study, small tears less than 1 cm in length were treated with a combination stab incision technique and intratendinous injection of 1 – 2 mL of leucocyte-depleted PRP. The outcome from those patients with tendon tears was found to be uniformly excellent, with no recurrence of symptoms. Unfortunately, however, this study cannot establish that PRP, multiple stab incisions, or decompression of the tendon by fibular groove deepening was the primary cause of such good outcomes.

MRI correlated well in this study with overall tendoscopic findings. This is at variance with several previous studies. O'Neill et al demonstrated that just 56 % of peroneal tendon tears diagnosed at the time of surgery were seen on pre-surgical MRI.[7] Giza et al found a PPV of only 48 %.[6] The variance between these outcomes may in part be due to the 3-Tesla MRI scanning equipment used with the current study due to its improved sequencing and visualization. It may also be due to differences in patient selection between the studies. Peroneal pathology was investigated alone in the current study, whereas in previous reports, peroneal pathology was part of a spectrum of lateral ankle pathology; inherent bias could therefore be conferred when comparing the two outcomes. In two separate studies by Park et al, evaluating solely peroneal pathology with MRI and clinical findings, the outcomes were in greater agreement with the current study's findings.[8] In a study of 97 patients, Park et al found that MRI sensitivity to peroneus brevis and longus tears was, respectively, 44 % and 50 %, and specificity, respectively, 99 % and 96 %.[9] In another study, Park et al demonstrated that sensitivity and specificity to peroneal pathology using MRI and clinical correlation was 84 % and 75 %, respectively.[8] These findings are in accordance with the current study's finding of 90 % sensitivity and 72 % specificity. No study to date has commented on any correlation between clinical peroneal stenosis and MRI evidence of this pathology. The current study demonstrates 33 % sensitivity for this pathology, indicating that MRI may not be the best modality to diagnose what may be a dynamic pathology that requires real-time dynamic testing such as ultrasound. However, this suggestion is based on a relatively small number of included patients in the current study and with the surgeon unblinded to pre-operative MRI findings. Therefore, further research study is needed to investigate the correlation between MRI and tendoscopic findings.

Limitations of this study should be considered. The retrospective study design carries possible inherent bias. While lack of a control group is unfavourable, adding a control group would mean exposing a healthy population to tendoscopic surgery, which was considered unethical. A third limitation is the absence of ultrasound images, since this diagnostic method is gaining popularity as the test of choice for dynamic tendon pathology.

Conclusion

This current study found that peroneal tendoscopy is an effective minimally invasive technique in the treatment of a variety of peroneal tendon pathologies. Moreover, the current study revealed the possibility of good correlation between tendoscopic findings and pre-operative MRI findings of peroneal tendon pathologies, with the exception of peroneal tendon stenosis.

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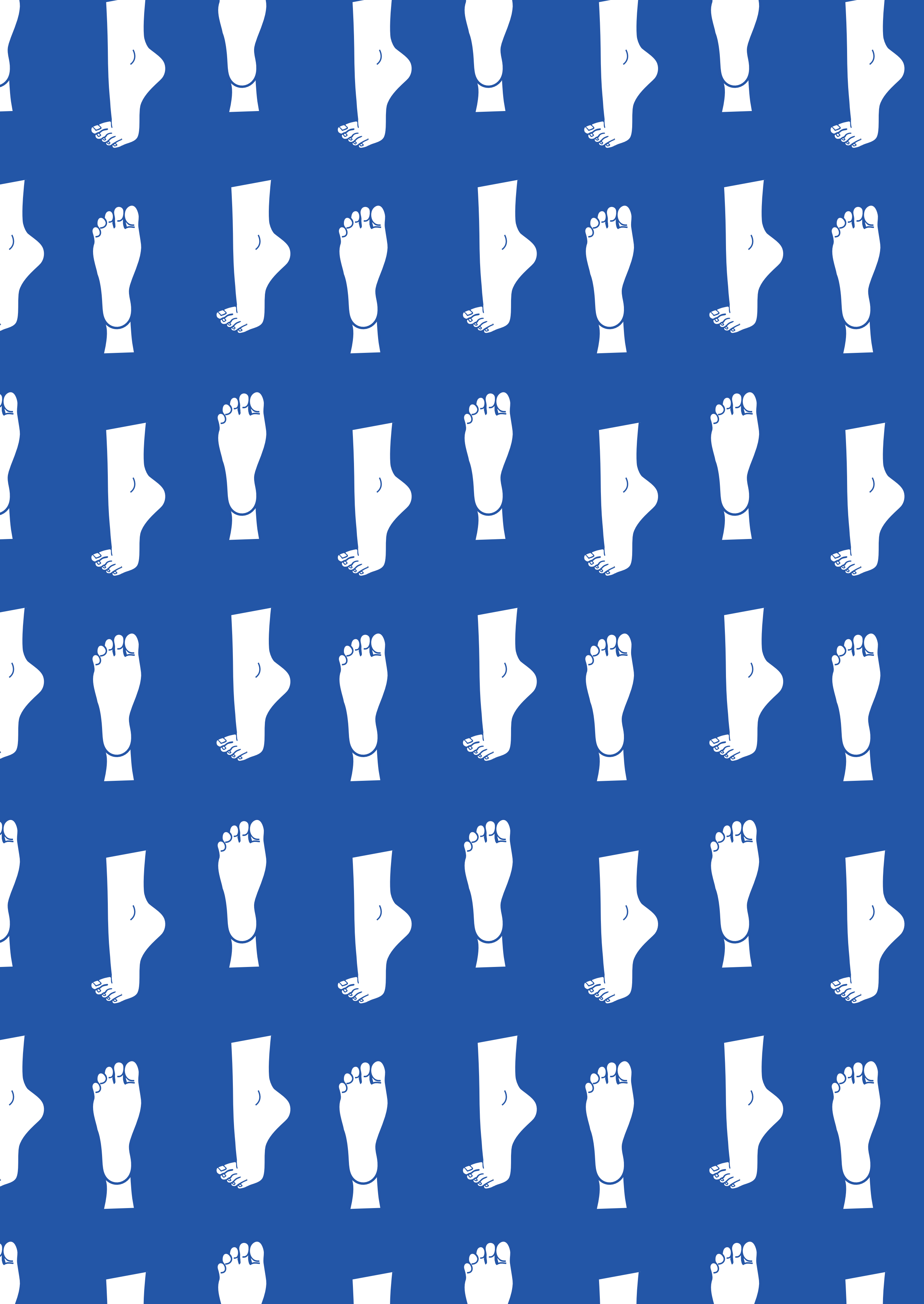

CHAPTER 7

Return to sports and clinical outcomes in patients treated for peroneal tendon dislocation: a systematic review

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Abstract

Purpose
The aim of this study was to determine the outcome following different surgical treatment techniques in the treatment of peroneal tendon dislocation and to establish whether return to sports was achieved universally following the procedures.

Methods
A systematic review and best-evidence synthesis were performed. PubMed and EMBASE were searched for eligible studies. The last search was done in March 2015. Quality assessment of pooled data was performed using a modified Macleod scale and a best-evidence synthesis was performed. In total, fourteen studies were included.

Results
Surgical treatment provides improvement in the post-operative AOFAS score ($p < 0.0001$) and high satisfaction rates. The redislocation rate is less than 1.5 % at long-term follow-up. Patients treated with both groove deepening and SPR repair have higher rates of return to sports than patients treated with SPR repair alone ($p = 0.022$).

Conclusions
Surgical treatment of peroneal tendon dislocation provides good outcomes, high satisfaction, and a quick return to sports. Rates in return to sports are significantly higher in patients treated with both groove deepening and SPR repair. To optimize treatment, the surgical management should involve increasing the superior peroneal tunnel volume by groove deepening and stabilizing the tendons by SPR repair.

Chapter 7. Return to sports and clinical outcomes in patients treated for peroneal tendon dislocation: a systematic review

Introduction

Peroneal tendon dislocation occurs in 0.3 – 0.5 % of all traumatic ankle events and is often misdiagnosed and therefore underreported.[1] Peroneal tendon dislocation is most prevalent in the athletic population, primarily in sports which require cutting movements including skiing, soccer, basketball, ice skating and gymnastics.[2,3] Patients may report a snapping or popping sensation around the lateral malleolus and complain of significant functional impairment. To provide early return to sports (RTS), optimal treatment is critical. Although many treatment options are described in the literature, consensus on the best treatment algorithm has yet to be established.[4]

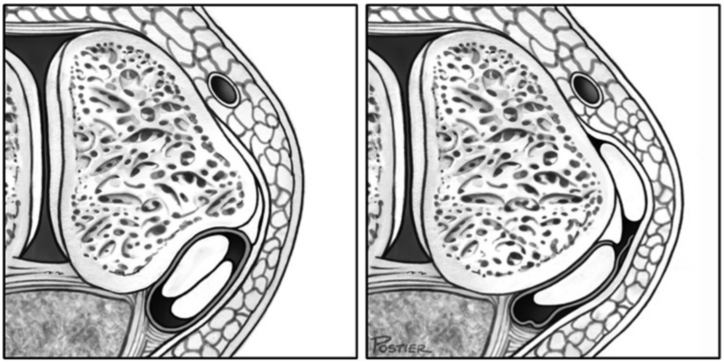
Peroneal tendon dislocation typically occurs when the peroneal muscles suddenly eccentrically contract on acute dorsiflexion of the foot, with or without inversion, or during forced dorsiflexion of the everted foot. This can result in a rupture of the superior peroneal retinaculum, allowing the peroneal tendons to dislocate anteriorly over the lateral malleolus. Previous studies have demonstrated that flat or convex retromalleolar grooves may predispose patients to luxation of the peroneal tendons.[5-7] The presence of a peroneus quartus muscle or a low-lying muscle belly makes individuals also more susceptible for peroneal tendon dislocation.[8-10] Normal anatomy of the lateral ankle is shown in figure 1.

7

Figure 1
The anatomy of the lateral ankle

Conservative treatment may be attempted in patients with acute dislocation, but the literature reports a failure rate of 50 – 76 %.[11,12] Surgical procedures have become the preferred method of treatment, especially in young, active people and athletes.[13] More than twenty surgical techniques have been recommended for stabilizing the peroneal tendons. These procedures attempt to repair the superior peroneal tunnel, which is formed by the superior peroneal retinaculum (SPR), retromalleolar groove and dorsal intermuscular septum (figure 2). The primary treatment strategies can be divided into the following four main categories: (1) repair or replacement of the SPR (figure 3)[14-21], (2) groove deepening of the retromalleolar groove (figure 4)[22-25], (3) bony procedures[9,26], or (4) rerouting procedures[27-29]. Most studies utilizing these procedures have demonstrated good-to-excellent outcomes and a high rate of return to sports.[22,23,25,28-30]

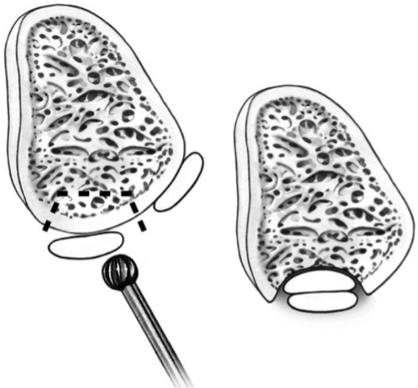
Figure 2
The superior peroneal tunnel: normal anatomy (left) and subluxation of the peroneus longus tendon over the lateral malleolus (right)



Although numerous treatment strategies have been previously described, there is a lack of consensus on how to treat patients diagnosed with peroneal tendon dislocation. To evaluate currently used surgical treatment options and to create a treatment strategy for optimal functional outcomes, a review of available evidence is required. The purpose of this systematic review was to (1) determine the outcome after different surgical treatment techniques of peroneal tendon dislocation and (2) compare the rates of return to sports and clinical outcomes in different surgical techniques. It is hypothesized that operative treatment of peroneal tendon dislocation leads to good functional outcomes and allows for return to sports at the pre-injury level with normal peroneal tendon function.

Figure 3
Anatomy of the lateral ankle after repair of the superior peroneal retinaculum

Figure 4
Groove deepening of the retromalleolar groove



Material and methods

Search strategy
Relevant publications were identified by searching PubMed/MEDLINE and the EMBASE electronic database in March of 2015. Three keywords (peroneal, dislocation and treatment) and related synonyms were used. All synonyms were combined with the Boolean command AND, and were linked by the Boolean command OR.

Eligibility criteria
Original studies were included if (1) diagnosis on peroneal subluxation or dislocation was confirmed during surgery, (2) the AOFAS or return to sports was described, (3) the surgical technique was well described and (4) full texts were available in English. Exclusion criteria were (1) case reports, imaging reviews, surgical technique reports and animal studies, (2) studies with less than ten participants, (3) studies with a primary purpose other than to report the outcomes of a peroneal tendon dislocation treatment and (4) studies with a mean follow-up less than six months.

Study selection
One author performed the literature search (PAD), and two authors independently reviewed the search results (PAD, AG). The titles and abstracts were reviewed by applying the eligibility criteria, and potentially relevant studies were reviewed on full text. The reference lists of included studies were also reviewed and compared with the collected studies to ensure no pertinent studies were omitted.

Data extraction
Pertinent data from the original articles were extracted using a modified extraction form. Whenever an outcome was reported at more than one point in time during follow-up, values of the last recorded follow-up were used.

Quality assessment
Quality assessment of the included studies was performed by two authors independently (PAD, AG) using the modified Macleod scale.[31] Included criteria were: published in a peer-reviewed journal, reported gender of included patients, reported inclusion and exclusion criteria, reported concomitant comorbidities, presence of a control group, random allocation to treatment or control, blinded assessment of outcome, reported follow-up and statement of potential conflict of interests. If no consensus was reached, the independent opinion of a third reviewer (JGK) was established.

Best-evidence synthesis
A modified version of the best-evidence synthesis was used to combine results because of the poor level of evidence and the heterogeneity of outcome measures.[32] The results of the quality of evidence assessments were used to classify the level of evidence.[33] This qualitative analysis was performed with five levels of evidence, based on the quality and results of the included studies:

1. Strong evidence: provided by two or more high-quality studies and by generally consistent findings in all studies (75 % of the studies reported consistent findings).
2. Moderate evidence: provided by one high-quality study and/or three or more low-quality studies and by generally consistent findings in all studies (75 % of the studies reported consistent findings).

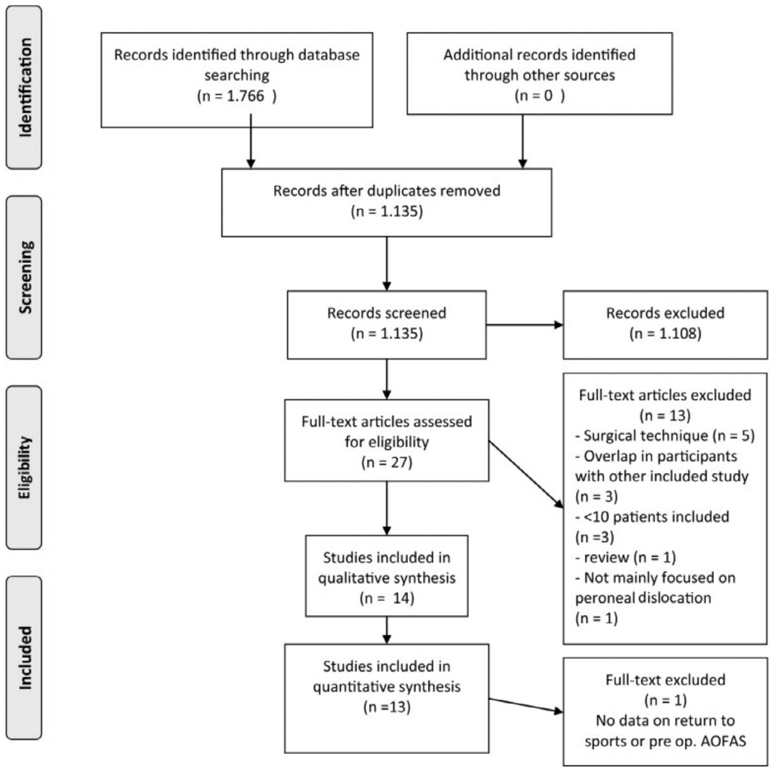
3. Limited evidence: provided by two or less low-quality studies.
4. Conflicting evidence: inconsistent findings in multiple studies (less than 75 % of the studies reported consistent findings).
5. No evidence: when no studies could be found.

Statistical analysis
Independent samples t-tests were used for comparison of group means in return-to-sports rate and time, and a paired-samples t-test was used to compare pre-operative and post-operative AOFAS scores. A p-value of < 0.05 was considered as statistically significant. Statistical analysis was performed using Stata version 13.0 software (STATA Corp., TX, USA).

Results

Search and literature selection
The literature search in PubMed/MEDLINE and EMBASE databases yielded 925 and 841 records, respectively (figure 5).[34] After eligibility criteria were applied, fourteen original studies were included in this study[9,14,18,22,23,30,35-42], whereof thirteen were included in the quantitative analysis.[9,14,18,22,23,30,35-41] Reasons for exclusion of the remaining thirteen articles are listed in figure 5. Citation tracking did not add any additional study.

Figure 5
PRISMA flow diagram



Quality assessment

Quality assessment scores of the included studies are shown in table 1. All studies were published in a peer-reviewed journal and reported on follow-up time. None of the studies included a control group nor randomization or masked assessment. With an average-quality score of 4.2 (range 3 – 6), all included studies were scored as low quality. An article was considered low-quality if at least four of the criteria were missing. Quality of evidence was comparable between the different included studies. Results on the best-evidence synthesis are reported in table 2.

Table 1

Quality assessment scores of the included studies

PRJ Peer-reviewed journal, *C* control group, *R* randomization, *MA* masked assessment, *G* gender, *CC* comorbid conditions, *COI* conflict of interest, *I/E* inclusion/exclusion, *F/U* follow-up

	PRJ	C	R	MA	G	CC	COI	I/E	F/U	Stats	Total
Adachi et al[14]	+				+				+	+	4
Cho et al[35]	+				+		+	+	+	+	6
Hui et al[36]	+				+				+		3
Karlsson et al[18]	+				+				+		3
Kollias et al[22]	+						+		+		3
Maffulli et al[37]	+				+		+		+	+	5
Ogawa et al[42]	+				+	+			+	+	5
Porter et al[23]	+				+		+		+		4
Raikin et al[30]	+				+		+		+	+	4
Saxena et al[38]	+						+		+	+	5
Tomihara et al[39]	+				+				+	+	4
Walther et al[40]	+						+		+		3
Wang et al[41]	+				+	+			+	+	5
Zhenbo et al[9]	+				+		+		+	+	5
Total	14				11	2	8	1	14	9	59
Average											4.2

Table 2

Best-evidence synthesis

BES Best-evidence synthesis

Outcomes	Outcome measure	High-quality studies	Low-quality studies	BES
Group A: SPR repair	RTS rate		14,35,36,39	Moderate
	AOFAS improvement		14,35,37,39	Moderate
	Satisfaction		35,37	Moderate
Group B: Groove deepening and SPR repair	RTS rate		18,22,23,35,38,40	Moderate
	AOFAS improvement		22,30,35,38,40,42	Moderate
	Satisfaction		30,35	Limited
Group C: Bony procedure	RTS rate		9,39	Limited
	AOFAS improvement		9,39	Limited
	Satisfaction		9	Limited
Group D: Rerouting procedure	RTS rate		41	Limited
	AOFAS improvement		41	Limited
	Satisfaction		41	Limited

Evaluation of study characteristics

Of the fourteen studies included, twelve were case series.[9,14,18,22,23,30,36-38,40-42] The other two included comparative case series.[35,39] Baseline characteristics are shown in table 3. Treatment options were divided into four different groups:

1. Group A: SPR repair[14,35-37,39]
2. Group B: groove deepening and SPR repair[18,22,23,30,35,38,40,42]
3. Group C: bony procedure[9,39]
4. Group D: rerouting procedure[41]

Outcomes are shown in table 4. Statistical analysis was performed with group A and B. Analysis could not be performed on group C and D, as numbers of participants were too small. Characteristics and statistical analysis of the groups are shown in table 5.

Table 3

Baseline characteristics

Group A SPR repair, *Group B* groove deepening and SPR repair, *Group C* bony procedure, *Group D* rerouting procedure

Study	Study design	Group	Patient demographics	Concomitant ankle comorbidities	Follow-up
Adachi et al[14]	Retrospective case series	A	*N* = 20 age = 24 year gender M/F = 17/3	Lateral ankle instability (*N* = 2)	Mean = 38 months (24–86 months)
Cho et al[35]	Prospective, comparative case series	A	*N* = 16 (29), age = 21 year gender M/F = 16/0	*N* = 0	Mean = 33 months (22 – 45 months)
Cho et al[35]	Prospective, comparative case series	B	*N* = 13 (29), age = 20 year gender M/F = 13/0	*N* = 0	Mean = 25 months (17 – 38 months)
Hui et al[36]	Retrospective case series	A	*N* = 21 age = 24 year gender M/F = 18/3	Not reported	Mean = 112 months (42 – 180 months)
Karlsson et al[18]	Retrospective case series	B	*N* = 15 age = 23 year gender M/F = 10/5	Not reported	Mean = 42 months (24 – 84 months)
Kollias et al[22]	Retrospective case series	B	*N* = 11 age = 25 year gender M/F = unknown	Intra articular changes (*N* = 10), lateral ankle instability (*N* = 3)	Mean = 72 months (24 – 102 months)
Maffulli et al[37]	Retrospective case series	A	*N* = 14 age = 25 year gender M/F = 14/0	Not reported	Mean = 38 months (22 – 47 months)
Ogawa et al[42]	Retrospective case series	B	*N* = 15 age = 33 year gender M/F = 8/7	*N* = 0	Mean = 13 months (3 – 36 months)
Porter et al[23]	Case series	B	*N* = 13 age = 24 year gender M/F = 9/4	*N* = 0	>12 months

Study	Study design	Group	Patient demographics	Concomitant ankle comorbidities	Follow-up
Raikin et al[30]	Retrospective case series	B	*N* = 14 age = 34 year gender M/F = 14/0	Peroneal brevis rupture (*N* = 5) Peroneal longus rupture (*N* = 1)	Mean = 32 months (26 – 45 months)
Saxena et al[38]	Prospective cohort study	B	*N* = 31 age = 33 year gender M/F = unknown	Peroneal brevis rupture (*N* = 9) Ankle instability (*N* = 6)	>2 years
Tomihara et al[39]	Retrospective, comparative case series	A	*N* = 19 (15 athletes) age = 23 year gender M/F = 15/4	Not reported	Mean = 51 months (18 – 120 months)
Tomihara et al[39]	Retrospective, comparative case series	C	*N* = 15 (11 athletes) age = 17 year gender M/F = 10/5	Not reported	Mean = 66 months (18 – 210 months)
Walther et al[40]	Case series	B	*N* = 23 age = 34 year gender M/F = unknown	*N* = 0	24 months
Wang et al[41]	Retrospective case series	D	*N* = 17 age = 23 year gender M/F = 17/0	*N* = 0	Mean = 28 months (24 – 60 months)
Zhenbo et al[9]	Retrospective, comparative case series	C	*N* = 26 age = 29 year gender M/F = 18/8	*N* = 0	Mean = 57 months (36 – 96 months)

7

Table 4
Outcomes
[a] *Group A* SPR repair, *Group B* groove deepening and SPR repair, *Group C* bony procedure, *Group D* rerouting procedure
[b] *E* excellent, *G* good, *F* fair, *P* poor

Study	Group[a]	Return to sports	AOFAS	Satisfaction[b]	Redislocation
Adachi et al[14]	A	83 %	Pre *m* = 76, post *m* = 93		*N* = 0
Cho et al[35]	A	100 %, mean 3.0 months	Pre *m* = 60, post *m* = 93	*E* = 4, *G* = 10, *p* = 2	*N* = 1
Cho et al[35]	B	100 %, mean 3.1 months	Pre *m* = 59, post *m* = 91	*E* = 3, *G* = 9, *p* = 1	*N* = 0
Hui et al[36]	A	86 %			*N* = 0
Karlsson et al[18]	B	100 %, mean 4.5 months			*N* = 0
Kollias et al[22]	B	91 %, mean 9.1 month	Pre *m* = 53, post *m* = 96		*N* = 0
Maffulli et al[37]	A		Pre *m* = 5, post *m* = 95	*E* = 12, *G* = 2	*N* = 0
Ogawa et al[42]	B		Post *m* = 87		*N* = 0
Porter et al[23]	B	100 %, mean 3.0 months			*N* = 0
Raikin et al[30]	B		Pre *m* = 61, post *m* = 93	*E* = 9, *G* = 4, *F* = 1	*N* = 1
Saxena et al[38]	B	100 %, mean 3.2 months	Pre *m* = 58, post *m* = 97		*N* = 1
Tomihara et al[39]	A	80 %, mean 2.9 month	Pre *m* = 78, post *m* = 93		*N* = 0
Tomihara et al[39]	C	54.40 %, mean 3.9 months	Pre *m* = 77, post *m* = 89		*N* = 2
Walther et al[40]	B	100 %	Pre *m* = 69, post *m* = 95		*N* = 0
Wang et al[41]	D	100 %, mean 2.8 months	Pre *m* = 73, post *m* = 100	*E* = 17	*N* = 0
Zhenbo et al[9]	C	88 %, mean 4.4 months	Pre *m* = 56, post *m* = 88	*E* = 12, *G* = 11, *F* = 3	*N* = 0

Table 5
Characteristics and statistical analysis of the different treatment groups
[a] Studies that reported on the aforementioned outcome

	Group A SPR repair	Group B Groove deepening and SPR repair	*p* value	Group A + B
Number of patients	*N* = 90	*N* = 120		*N* = 210
Gender	M: 76 (88 %), F: 10 (12 %)	M: 61 (71 %), F: 25 (29 %)		M: 137 (80 %), F: 35 (20 %)
a	14,35-37,39	18,23,30,35,42		14,18,23,30,35-37,39,42
Age	Mean 23 ± 1.5 years	Mean 28 ± 5.8 years	$p = 0.099$	Mean 26 ± 5.1 years
a	14,35-37,39	18,22,23,30,35,38,40,42		14,22,23,30,35-40,42
AOFAS	Mean 67 ± 12	Mean 60 ± 5.6	$p = 0.24$	Mean 63 ± 9.2
Pre-operative	Mean 93 ± 0.79	Mean 94 ± 2.3		Mean 94 ± 1.8
Post-operative	Mean 26 ± 13	Mean 35 ± 6.4		Mean 31 ± 3.3
Improvement	$p = 0.0249$	$p = 0.0003$		$p < 0.0001$
p value				
Improvement				
a	14,35,37,39	22,30,35,38,40,42		14,22,30,35,37-40,42
RTS rate	Mean 87 ± 8.9 %	Mean 99 ± 3.7 %	$p = 0.022$	Mean 93 ± 8.4 %
a	14,35,36,39	18,22,23,35,38,40		14,18,22,23,35,36,38-40
RTS time	Mean 3.0 ± 0.070 months	Mean 4.6 ± 2.6 months	$p = 0.44$	Mean 4.1 ± 2.3 months
a	35,39	18,22,23,35,38		18,22,23,35,38,39

Rate of return to sports

Eleven studies reported on RTS rate.[9,14,18,22,23,35,36,38-41] Two of the studies excluded non-athletes from the RTS analysis, leaving a total of 230 evaluated patients.[14,39] Surgical treatment of peroneal tendon dislocation resulted in a RTS rate from 55 % to 100 %. In group A, 83 % to 100 %; group B, 91 % to 100 %; group C, 55 % to 88 %; and group D, 100 % of the patients were able to return to sports. A difference was found between group A and B ($p = 0.022$).

Time to return to sports

Eight studies reported on time to RTS, with a total number of 168 included patients.[9,18,22,23,35,38,39,41] The time to RTS ranged from 1.2 to 12 months (table 4). Mean time to return to sports was 3.0 ± 0.070 months in group A and 4.6 ± 2.6 months in group B. Time to return to sports did not differ between groups A and B ($p = 0.44$).

AOFAS score

Eleven studies used the AOFAS scale as an outcome measure.[9,14,22,30,35,37-42] Mean pre-operative AOFAS score ranged from 53 to 78, and mean post-operative AOFAS score ranged from 87 to 100. All studies reported a significant improvement in the AOFAS score after surgical treatment. There was no significant difference in improvement between group A and B ($p = 0.24$).

Satisfaction

Five studies (100 patients) reported on patient satisfaction.[9,30,35,37,41] Fifty-seven patients stated that the results were 'excellent', and 36 patients evaluated the treatment as 'good'. 'Fair' patient satisfaction was reported in six patients, and one patient evaluated the treatment as 'poor'. In total, over 90 % of the patients reported a 'good' or 'excellent' satisfaction.

Redislocation

All studies reported on redislocation rates.[9,14,18,22,23,30,35-42] In ten studies, there was no recurrence of peroneal dislocation. Cho et al reported redislocation in one patient which was treated with SPR repair re-surgery.[35] In the study by Tomihara et al, two patients treated with a bony procedure had post-operative peroneal tendon redislocation.[39] Management of the redislocation was not reported. Saxena et al and Raikin et al both reported redislocation in one patient after groove deepening and SPR repair.[30,38] Neither study reported on the management of the redislocation.

Discussion

The most important finding of the present study was that both isolated SPR repair and SPR repair combined with a groove-deepening procedure are successful treatment options in the management of peroneal tendon dislocation, with a higher rate of return to sports in patients treated with groove deepening. Since peroneal tendon dislocation is most present in the athletic population, surgical treatment with a combination of groove deepening and SPR repair is recommended.[2,3] However, this finding was based on limited evidence due to a lack of high-quality studies.

In the current study, treatment with SPR repair (group A) and treatment with groove deepening and SPR repair (group B) was compared. Between 1995 and 2015, only three studies reported on bony procedures (group C) and rerouting of the peroneal tendons (group D).[9,39,41] Based on the best-evidence syntheses and the small number of patients, it was concluded that evidence for groups C and D is limited, and therefore, the two groups were excluded from further analysis. A possible explanation for the lack of studies in groups C and D is the relatively high rate of occurrence of complications including non-union and fractures previously reported, which limited their use in current practice.[20,26,27,29,43]

The high return-to-sports rate in both treatment groups A and B (83 – 100 %) and improvement in the AOFAS score after treatment, provides evidence for good surgical outcomes ($p < 0.0001$). The redislocation rate was less than 1.5 % in both groups, and other major complications were uncommon. As far as reported, over 90 % of the patients were satisfied with their treatment. These findings are confirmed in the only published study which compared groups A and B in a prospective comparative case series.[35] In the current study a higher rate of return to sports was found in patients treated with groove deepening and SPR repair, compared with patients treated with SPR repair alone.

To our knowledge, no previous systematic review has been published addressing the surgical treatment of peroneal tendon dislocation. A review from Oliva et al demonstrated that reattachment of the SPR is the most appropriate technique when utilizing an anatomic approach.[4] This study, however, was not based on systematic analysis of collected studies and did not provide sufficient data to substructure their conclusions. In the current study, no difference in the time to return to sports was found in patients treated with SPR repair compared with other treatments. In addition, a higher rate of return to sports was found in patients treated with both SPR repair and groove deepening.

Peroneal tendon subluxation and dislocation has been attributed to forceful ankle dorsiflexion and concomitant reflex peroneal muscle contraction leading to rupture of the SPR and has been associated with anatomic variants including acquired peroneal retinaculum laxity, absence of a groove in the fibula, presence of a convex surface on the posterior aspect of the malleolus, low-lying muscle belly and the presence of a peroneus quartus muscle.[5,6,8-10] Diminished volume within the superior peroneal tunnel may render tendons more prone to dislocation. This volume is determined not only by the fibular shape, but also by the fibrocartilaginous periosteal cushion. In patients with peroneal tendon dislocation, this periosteal cushion is often torn from the fibula, decreasing the volume of the tunnel when only reattaching the SPR. Retromalleolar groove-deepening procedures may provide stabilization of the peroneal tendons behind the lateral malleolus, thereby preventing redislocation.[5] Title et al reported a cadaveric biomechanical study analyzing pressures at different positions of the ankle before and after peroneal groove-deepening procedures.[44] Significant decreases in pressure were noted within the distal and middle groove at all ankle positions after the procedure. Retromalleolar groove deepening with peroneal retinaculum reconstruction resulted in an increased tunnel volume reducing the risk of redislocation, improving both patient rehabilitation and the ability to return to sport.

The current study is not without limitations. First, this systematic review shows that there is a lack of high-quality studies. All studies scored 0 points on the following quality of evidence criteria: control group, randomization, and masked assessment. Therefore, caution should be used when making conclusive statements based on this level of quality. Although peroneal tendon dislocation is a relatively rare condition, there has been many treatment techniques described making it difficult to set up a high-level of evidence study.[1,4]

Second, the AOFAS has been used as an outcome measure in the study. The validity of the AOFAS is undetermined. Nevertheless, a systematic review from Hunt et al showed that the AOFAS score is the most frequently used patient-reported outcome measure in foot and ankle surgery. Given the fact that most of the studies included reported AOFAS outcomes, it was considered that this would be an appropriate measure to compare results of the different studies.[45]

A third limitation is the prevalence of lateral ankle comorbidities among patients in some of the included studies, creating risk of selection bias.[14,22,30,38] However, due to the relatively low prevalence of peroneal tendon dislocation, this bias is hard to avoid. In addition, as it is not uncommon that peroneal tendon dislocation occurs with concomitant lateral ankle comorbidities, including these patients creates a more accurate reflection of this patient population.

Another limitation of the study is combining different surgical techniques in the treatment groups. Although the surgical attempts within each group were relatively similar, the specific techniques used varied within each group. Due to small numbers of patients included per study, it was not possible to analyze different surgical techniques. Therefore, combining different techniques in treatment groups was the best option for comparison.

Future prospects
Future high-level prospective studies are necessary to establish a management algorithm for patients presenting with dislocation of peroneal tendons. Based on the quality of evidence assessment, it is evident that future studies should include control groups, randomization, and masked assessment. Peroneal tendon dislocation is most prevalent in the athletic population; therefore, attention should be directed towards return to sports rates and time to return to sports.[2,3]

Conclusion

Surgical treatment of peroneal tendon dislocation provides good outcomes, high satisfaction, and a quick return to sports. A combination of a groove deepening and SPR repair gives a higher rate in return to sports when compared to a SPR repair by itself.

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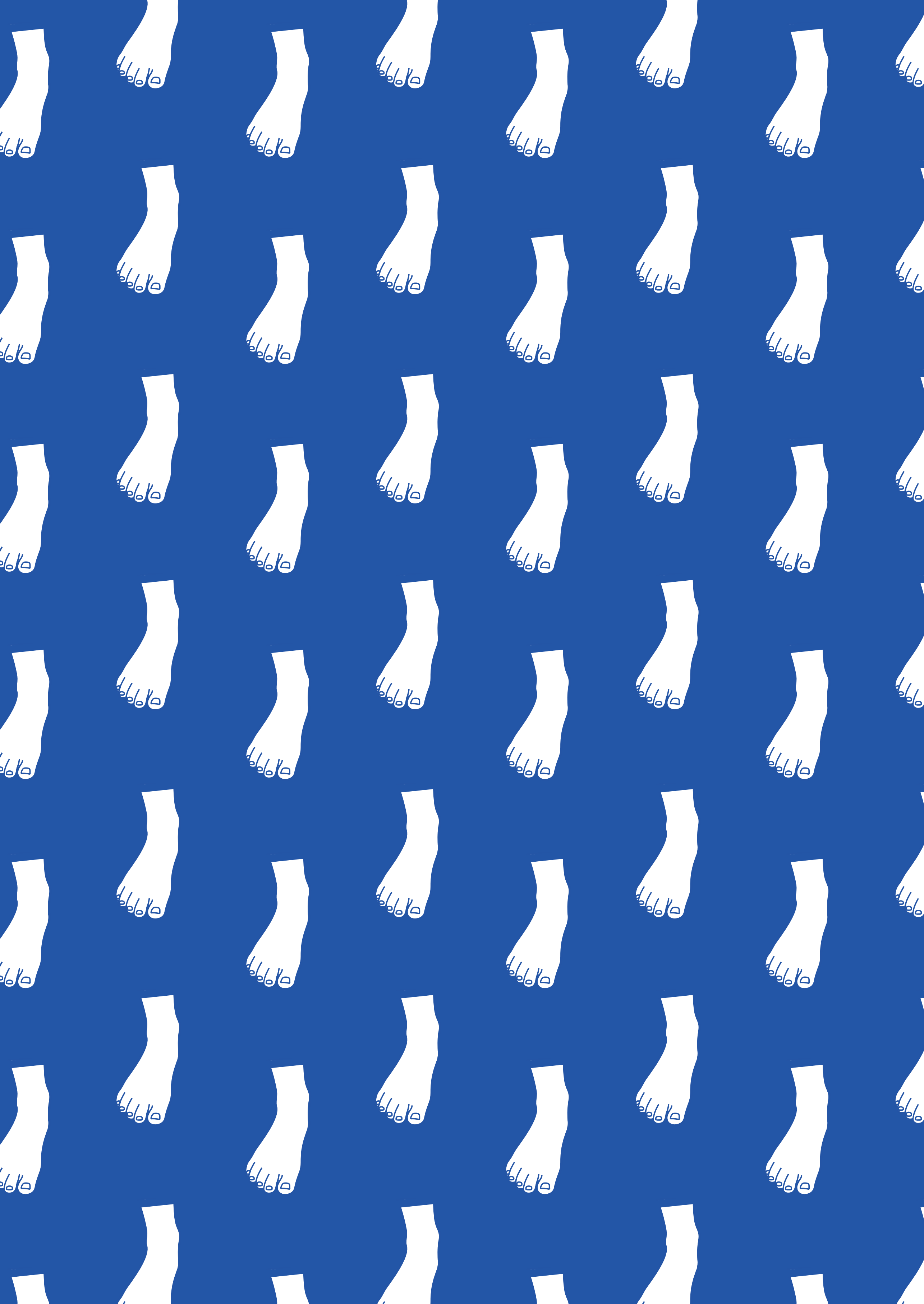

CHAPTER 8

Retromalleolar groove deepening in recurrent peroneal tendon dislocation: technique tip

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Abstract

Peroneal tendon dislocations are most prevalent in the active and athletic population, so accurate diagnosis and management are essential of optimal return of function. Although many nonoperative and surgical management options have been described, the optimal treatment method continues to be debated. In this technique article, a modified retromalleolar groove deepening technique is described for addressing all anatomic variations of the posterior distal fibula and retromalleolar groove without unduly disturbing the important anatomic facets meant for retention in this region. This technique is indicated for chronic dislocated peroneal tendons, recurrent dislocating peroneal tendons, and dislocation of the tendons after acute injury with a shallow fibular peroneal groove. Although it remains unclear what effect a cortically abraded fibular gliding surface or forceful cortical impaction on the fibrocartilage gliding surface might have on peroneal tendon integrity and function long term, it would seem preferable to avoid such techniques if reliable alternatives are available.

Chapter 8. Retromalleolar groove deepening in recurrent peroneal tendon dislocation: technique tip

Introduction

Peroneal tendon dislocations can be subtle and sometimes difficult to diagnose. Accurate diagnosis and management are therefore essential for maximized return of function.[1,2] Although many nonoperative and surgical management options have been described, the optimal treatment method continues to be debated.[3]

Nonoperative treatment with a period of cast immobilization can be successful in patients with acute dislocation, although this form of management has been associated with both poor clinical outcomes and failure rates approximating 50 % to 76 %.[4,5] Therefore, surgical management can reasonably be considered as an appropriate initial treatment alternative, especially in high-demand individuals.[6] Over the past century, more than twenty surgical reconstruction techniques have been described for relocating the peroneal tendons and restoring the integrity of the superior peroneal tunnel. A recent systematic review found a greater rate of return to sports in patients treated with both repair of the superior peroneal retinaculum (SPR) and deepening of the retromalleolar groove as compared with SPR repair alone.[7] By stabilizing the peroneal tendons behind the fibular tip and reducing pressure within the retromalleolar groove, the risk of redislocation has been drastically reduced.[8,9]

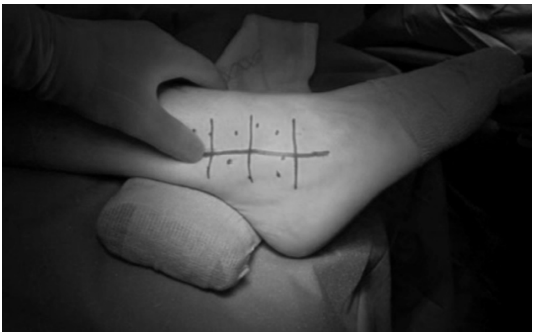
Groove deepening may be performed utilizing a number of different techniques, many of which vary in whether they explicitly preserve the fibrocartilage-gliding surface along the posterior lateral malleolar surface. Some authors describe direct deepening of the groove by burring through the fibrocartilage-gliding surface into the subchondral bone beneath the tip of the fibula.[10-14] Others preserve this natural fibrocartilage by various indirect means, including elevating a flap of periosteal bone followed by cancellous bone removal and bone flap reduction into the newly deepened groove.[15-18] These techniques, however, are also not without technical shortcomings. The senior author (C.W.D.) has modified the indirect groove-deepening approach with an emphasis on (1) preserving the integrity of the fibrocartilage gliding surface, (2) avoiding any requirement for creating a bone flap, and (3) allowing for a simple, reproducible means of groove deepening without significant anatomic disturbance. This technique entails image-guided intramedullary bone removal in the distal fibula using sequentially larger caliber cannulated drills, followed by double “reverse trap door” sagittal plane fibular osteotomies, and finally, gentle compression of the newly created flap to a desired depth as a means of creating the necessary space for stable peroneal relocation. This simplified approach preserves the fibrocartilaginous gliding layer while minimizing any chance of iatrogenic damage to this surface and its surrounding anatomy by avoiding bone flap elevation as well as decreasing the amount of force needed to impact the posterior fibula to physically deepen the groove.

Over the past five years, the two senior authors (C.W.D. and A.Y.) have collectively performed more than 60 surgeries using the currently described technique. This technique is believed to be useful for addressing all anatomic variations of the posterior distal fibula and retromalleolar groove without unduly disturbing the important anatomic facets meant for retention in this region. This technique is indicated for chronic dislocated peroneal tendons, recurrent dislocating peroneal tendons, and dislocation of the tendons after acute injury with a shallow fibular peroneal groove.

Operative technique

This technique can be performed under local, regional, epidural, or general anesthesia. The patient is placed in a lazy lateral position with a support placed under the ipsilateral leg to promote free ankle motion during surgery and easy access to the peroneal tendons and the posterior fibula. A tourniquet is placed around the upper thigh to optimize visualization with the mini C-arm during radiographic assessment if desired. A 4 to 6 cm incision is made along the lateral margin of the fibula and curved distally around the fibular tip in line with the peroneal excursion (figure 1). The dissection carefully isolates the SPR over the peroneal tendons and reflects the sural nerve posteriorly. The SPR is then incised 1 to 2 mm posterior to its fibular attachment to allow easy repair after the procedure. It can also be removed directly off the bone if one elects to utilize a bone tunnel repair technique. Often a "Bankart-type" lesion of the SPR is found on the lateral edge of the distal fibula, having been created or perpetuated by the dislocated peroneal tendons. The remainder of the anatomical SPR is carefully preserved while the donor site of the reflected flap is then roughened to a bleeding cortical surface to maximize healing and provide a healthy bed on which to later re-suture the reflected retinaculum to the fibula at the conclusion of the groove-deepening procedure.

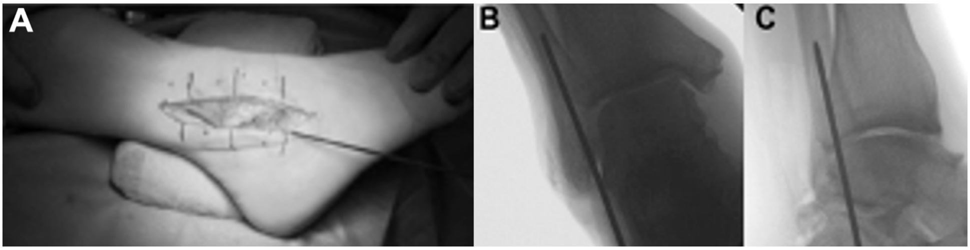
Figure 1
A 4 to 6 cm insertion is made directly posterior to the fibula and curves distally around the fibular tip.



The peroneal tendons are dislocated out of the retromalleolar groove to inspect the tendons, repair any tears, and evaluate the fibular anatomy and fibrocartilage along the posterior aspect of the fibula. The tip of the fibula is thereafter exposed, and a guide wire from the Arthrex biotenodesis set (Arthrex) or other anterior cruciate ligament tunnel reamer set is introduced up the center of the fibular shaft. This position can be verified under fluoroscopy in orthogonal planes (figure 2). Sequentially, the shaft is then reamed 3 cm proximally until "chatter" can be heard. It is recommended to start with a 4 mm acorn reamer and increase by 1 mm increments, but rarely is anything greater than 8 mm necessary, and a 6 mm final reaming has been typical. Fluoroscopy can also be helpful in determining whether an adequately sized reamer has been used.

Next, an approximately 3 × 1 cm sagittal saw blade (9 × 25 mm, 0.51 mm thick; Stryker model 2296-033-111) is used to make two fibular corticotomies approximately 2 mm deep in the sagittal plane, starting from the posterior cortex of the fibula. The first cut is made just inside the lateral-most edge (cortical margin) of the posterior distal fibula and the second is made just inside the

Figure 2
(A) The tip of the fibula is exposed and a guidewire is introduced in the center of the fibular shaft (Arthrex Biotenodesis; Arthrex).
(B) Anteroposterior fluoroscopy of the ankle.
(C) Lateral fluoroscopy of the ankle.



medial-most edge in a similar fashion (figure 3). Both are allowed to exit distally from the fibular tip. Gentle tamping can thereafter be used to carefully recess the posterior fibular fibrocartilaginous cortical flap located between these two cuts from posterior to anterior. With minimal effort, the flap easily impacts into the drilled subcortical bone and rotates on its proximal, intact cortical hinge to create a stable, deepened groove without the requirement of fixation (figure 4).

The newly deepened groove is inspected to ensure that there is no bone spike on the medial aspect of the fibula that could cause tendon impingement or irritation. Bone wax can be applied to the more prominent lateral ledge of the peroneal tunnel to further facilitate a smooth edge over which the peroneal tendons must travel. The peroneal tendons can then be relocated and manually tested to ensure stable reduction. In the rare event that further deepening is required, additional tamping can be performed.

Once the peroneal tendons are deemed stably relocated, attention can be turned back to the avulsed SPR. This margin is repaired back to its previous bed, which is now a roughened cortical edge, using either two G2 suture anchors (Dupuy Synthes Mitek Sports Medicine) or an osseous tunnel technique. The latter can be achieved using a 0.054 K-wire for the repair holes through which no. 1.0 Vicryl suture (Ethicon) can be passed. Interrupted sutures are passed through the fibula and SPR and then tied over the SPR in a horizontal fashion to reattach it back to the fibula without the possibility of further peroneal dissection. The redundant retinaculum can be advanced during repair to ensure that the retinaculum is tight. After SPR reattachment, the remaining retinacular exposure more proximally can be repaired using interrupted 0 Vicryl suture. Typically, the senior author (C.W.D.) recommends that the lowest two or three sutures are passed transosseously through the posterior lateral aspect of the fibula and then through the posterior portion of the retinaculum in a horizontal mattress fashion to reapproximate the retinaculum over the peroneal tendons and minimize any chance for recurrent peroneal subluxation (figure 5).The remainder of the retinaculum can then be closed more proximally with running 0 Vicryl suture via direct soft tissue repair, making sure that the SPR is not overly tightened during closure.

After care is taken to ensure that neither the tendons nor the sural nerve is included in the retinacular reapproximation, the subcutaneous tissues and skin are closed.

Figure 3
Two vertical osteotomies are created in the fibula using a sagittal saw. (A) The first cut is made on the lateral aspect of the fibula and (B) the second cut is made on the medial aspect of the fibula.

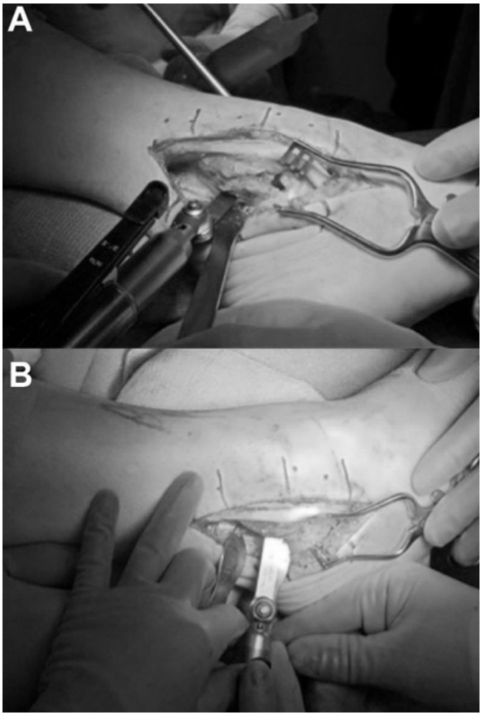


Figure 4
(A) A tamp is used to carefully recess the fibrocartilage layer.
(B) The groove is deepened approximately 1 cm.

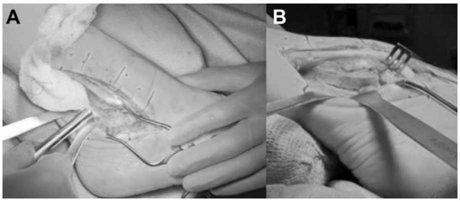


Figure 5
Repair of the superior peroneal retinaculum with at least three horizontal 0 Vicryl sutures. The sutures are passed in a transosseous fashion through the posterior lateral aspect of the fibula and then through the posterior portion of the retinaculum to close it over the peroneal tendons.

Postoperative Care

For the first two weeks postoperatively, the patient is placed in a posterior splint and made non-weightbearing until the incision has healed. The patient is then placed into a short-leg cast and allowed touch-down weightbearing until six weeks after surgery not only to permit interval retinacular and bony healing but also to allow for some early mobilization of the tendons to prevent adhesions. Finally, the patient is transitioned to a controlled ankle movement (CAM) boot with more formal active physical therapy, progressive weightbearing, and weaning out of the boot by roughly ten weeks. Full normal activity can be resumed by twelve weeks, but return to competitive, impact, or pivot sports is not permitted until at least four months postoperatively.

Discussion

The optimal treatment method for peroneal tendon dislocation remains a topic of discussion in the literature. The majority of techniques primarily attempt to restore the superior peroneal tunnel by deepening the retromalleolar groove and repairing the SPR. While most of these have been documented to have good results, a number entail additional and potentially unnecessary steps or violate the natural fibrocartilaginous surface to create a roughened surface that has unknown consequences for peroneal gliding.[13,15,16,18] Although it remains unclear what effect a cortically abraded fibular gliding surface or forceful cortical impaction on the fibrocartilage gliding surface might have on peroneal tendon integrity and function long term, it would seem preferable to avoid such techniques if reliable alternatives are available.

Several authors have described techniques that attempt to preserve the fibrocartilage gliding layer by cortical elevation of bone, followed by removal of the cancellous bone beneath the fibrocartilaginous flap.[15-18] This technique, however, is less predictable and perhaps more technically demanding than the one described. The force needed to create such a bone flap has the capacity to uncontrollably damage the posterior fibula, and the technique has unclear effects on fibrocartilage viability — especially if repeated elevations are necessary to deepen the groove further. More recently, other authors have advocated an indirect groove-deepening technique by burring the cancellous bone from under the cortex, starting at the tip of the fibula, followed by direct impaction of the cortex.[10-14,19] Shawen and Anderson described cannulating the fibula using a biotenodesis system followed by tamping the posterior cortex down without making an osteotomy in the posterior fibula.[19] Without osteotomizing of the fibula, however, additional force is needed to tamp down the posterior cortex. This may also cause increased iatrogenic damage to the fibrocartilage or even fracturing of the bone. When bone quality is good, such as one would expect with a young athlete, this method of impaction can be particularly destructive.

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Walther et al described a technique creating multiple drill holes up the fibula followed by two vertical osteotomies in the fibula using an osteotome.[14] Over the years it seems that portions of this approach are adopted independently, although it feels that the singular cannulated reaming system is more easily reproduced and perhaps quicker given that only one tract needs to be made down the center of the fibula under fluoroscopic visualization.

While both the aforementioned techniques have significant merit, our technique is considered a combination of the strengths of these individual approaches. In recent years, the senior authors (C.W.D. and A.Y) have chosen to deepen the groove using sequential, cannulated reaming of the intramedullary canal as opposed to relying on multiple small drill holes followed by two small subcortical osteotomies. A thin and narrowly curved saw is used instead of an osteotome, since this requires less energy delivery to the distal fibular bone during use. This sequence allows the posterior cortex to be tamped down with almost no force, preserving the integrity of the natural fibrocartilage gliding layer along the peroneal margin, and is easily expandable should additional depth be necessary without fear of compromising the initial construct.

It is acknowledged that the aforementioned groove-deepening techniques offer effective means of providing additional space for the peroneal tendons, but it is believed that our described constellation of modifications offers distinct advantages to these various approaches and does not require any formal fixation. To capitalize on the advantages of this procedure, though, several potential complications must be considered. The sural nerve is always in direct proximity of this exposure and should be identified and then protected, particularly during reaming of the fibula. Care must also be taken to remain cognizant of the nerve's location during retinacular closure to avoid iatrogenic entrapment. A final potential pitfall to be avoided with this and all related techniques is overtightening of the retinaculum, which can result in either retinacular tearing (loss of integrity) or over constraint, which can lead to symptomatic stenosis.

In summary, the modified retromalleolar groove–deepening technique described has been designed to (1) preserve the gliding layer of fibrocartilage within the retromalleolar groove, (2) theoretically prevent iatrogenic damage by reducing the force needed for creating the bony flap and then impacting the posterior fibula, and (3) enable what the senior authors have found to be a reproducible single-step centralized reaming technique to avoid the possibility of eccentric or unpredictable cortical flap creation. Over the past five years, the senior authors (C.W.D. and A.Y.) have seen no complications using this proposed technique and, therefore, it is recommended as an optimized way of respectfully resculpturing the anatomy around the retromalleolar groove when dealing with peroneal dislocation, in situ subluxation, or tenostenosis.

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PART 4

REHABILITATION

CHAPTER 9

Rehabilitation after surgical treatment of peroneal tendon tears and ruptures

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Abstract

Purpose
The purpose of this study was to provide an overview of the available evidence on rehabilitation programs after operatively treated patients with peroneal tendon tears and ruptures.

Methods
A systematic review was performed, and PubMed and EMBASE were searched for relevant studies. Information regarding the rehabilitation program after surgical management of peroneal tendon tears and ruptures was extracted from all included studies.

Results
In total, 49 studies were included. No studies were found with the primary purpose to report on rehabilitation of surgically treated peroneal tendon tears or ruptures. The median duration of the total immobilization period after primary repair was 6.0 weeks (range 0 – 12), 7.0 weeks (range 3.0 – 13) after tenodesis, 6.3 weeks (range 3.0 – 13) after grafting, and 8.0 weeks (range 6.0 – 11) after end-to-end suturing. Forty-one percent of the studies that reported on the start of range of motion exercises, initiated range of motion within four weeks after surgery. No difference was found in duration of immobilization or start of range of motion between different types of surgical treatment options.

Conclusion
Appropriate directed rehabilitation appears to be an important factor in the clinical success of surgically treated peroneal tendon tears and ruptures. There seems to be a trend towards shorter immobilization time and early range of motion, although there is no consensus in the literature on best practice recommendations for optimizing rehabilitation after surgical repair of peroneal tendon tears or ruptures. It is important to adjust the rehabilitation protocol to every specific patient for an optimal rehabilitation.

Chapter 9. Rehabilitation after surgical treatment of peroneal tendon tears and ruptures

Introduction

Lateral ankle sprains are among the most common acute musculoskeletal injuries and can result in peroneal tendon disorders, particularly peroneus brevis tendon tears.[1] The exact prevalence of these tears in general population remains unknown, but cadaveric studies have shown a prevalence of 11 – 38 %.[2,3] Surgical treatment is essential to prevent deterioration of tendon tissue and chronic pain complaints.[4-7] To our knowledge, there is no consensus in the available literature regarding appropriate after-treatment of surgically treated peroneal tendon tears.

Acute ankle inversion injury is a typical trigger for a peroneal tendon tear. Chronic lateral ankle instability with repetitive sprains, repetitive stress or overuse, peroneal tendon subluxation or dislocation, or anatomic abnormalities can also provoke tears.[5,7-12] Patients often present with undefined lateral ankle pain or lateral ankle giving way complaints and typically demonstrate recognizable pain on palpation located over the posterior part of the distal fibula, worsened by activity.[7]

Injury of the peroneal tendons can be debilitating for patients. Prompt diagnosis is the first step in the pathway of treating peroneal tendon tears. Depending on the severity of the pathology, different surgical treatment options are proposed.[5,6] When less than 50 % of the cross-sectional tendon is involved, tears are often treated with debridement and tubularization of the tendon. Involvement of more than 50 % of the cross-sectional tissue may necessitate tenodesis to the adjacent intact peroneal tendon when it remains functional, or grafting when both tendons are found to be non-functional.[5-7] In the case of an acute complete rupture, both ends may be sutured together, although in chronic cases some form of tenodesis or tendon interposition is required to restore peroneal integrity. In symptomatic patients, surgical treatment has been associated with improved return to full activity and improvement in patients-reported outcome scores.[4]

To optimize recovery of surgically treated peroneal tendon tears and ruptures, an appropriate rehabilitation program is necessary. Facilitation of early return to activity is of great importance, since peroneal tendon tears are mostly found in active patients and athletes. Both non-weight-bearing immobilization (NWB) and weight-bearing immobilization (WB) are used in the rehabilitation process to facilitate an optimal recovery while preventing re-injuries. Since flexor tendons tend to form adhesions between the repaired tissue and surrounding scar tissue after surgical repair, early range of motion (ROM) is recommended in several tendon pathologies.[13] No evidence can be found, however, as to specifically when to begin ROM exercises following surgical repair of peroneal tendon tears and ruptures. The aim of this study is to create an overview of available best practice evidence in the current literature with respect to rehabilitation options following surgical treatment of peroneal tendon tears and ruptures.

Materials and methods

Search strategy

Searching PubMed/MEDLINE and EMBASE electronic databases identified relevant literature. Three keywords (peroneal, tendon and tear) and related synonyms were used. All synonyms were combined with the Boolean command AND, and were linked by the Boolean command OR. The last search was performed on 25 June 2015.

Eligibility criteria

Original studies were included if (1) the study reported on peroneal tendon tears or ruptures, (2) the rehabilitation process after surgical treatment was described, (3) duration of immobilization was described, (4) the study was published after December 1994, and (5) full text was available in English.

Study selection

Two authors (PAD, BL) performed the literature search and independently reviewed the search results. Titles and abstracts were reviewed by applying strict inclusion criteria for study characteristics as described above. Consensus for studies to be included was achieved by discussion between the two reviewers based on the predetermined selection criteria. Identified articles were reviewed on full text, and each reference list was screened for additional citation tracking.

Data extraction

All data items were predetermined and specified as shown in table 1. Two authors performed data extraction independently, using a modified extraction form. Duration of immobilization was described and rounded in weeks.

Statistical analysis

Descriptive statistics including means and standard deviations were calculated for each variable. One-way ANOVA was used for the comparison of group means in duration of immobilization and time of start with ROM exercises, and post hoc analyses using Bonferroni correction were employed. A p value of less than 0.083 (0.05 divided by 6) was considered as statistically significant. Statistical analysis was performed using Stata (version 13.0, STATA Corp., TX, USA).

Table 1

Baseline characteristics

**Study design:* I *review or descriptive paper*, II *case series*, III *case report*

^*Treatment:* A *debridement with or without suturing*, B *tenodesis*, C *grafting*, D *end-to-end*

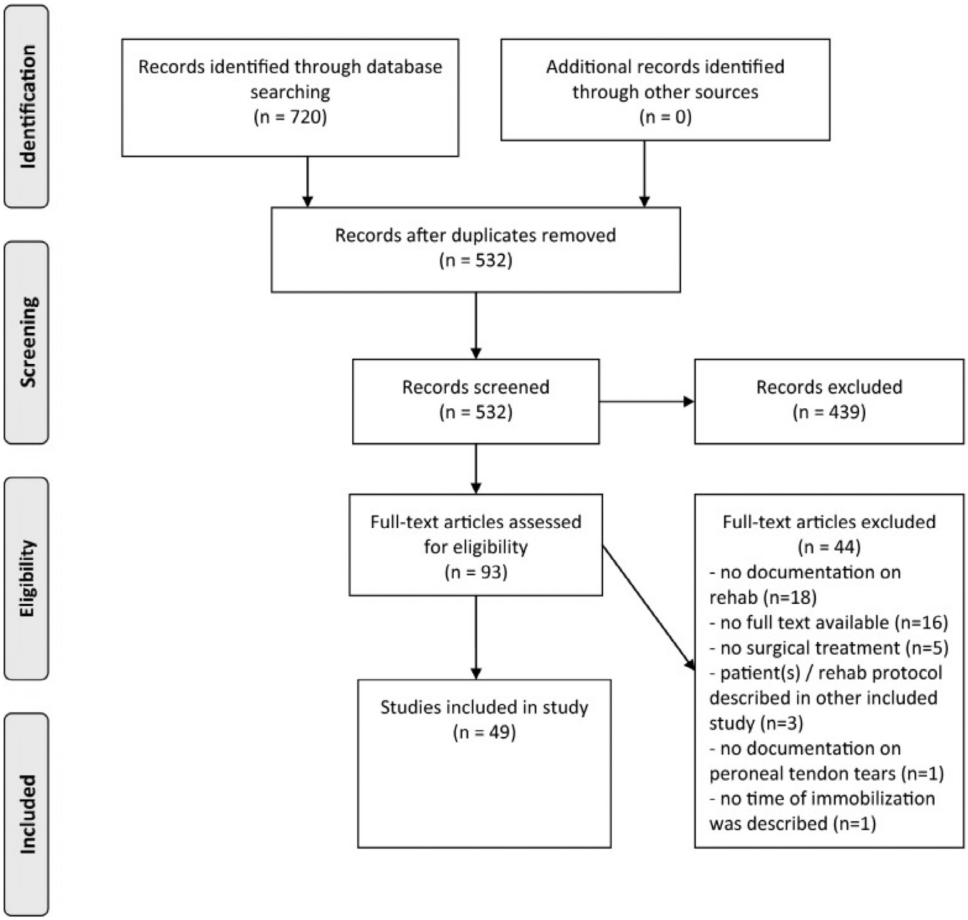
[a]*Study reported on both technique A and B. Since results from technique A were already reported in the study by Saxena and Pham*[14]*, only the results from technique B are included In the table.*

Study	Study design*	Treatment^	NWB in weeks	WB (partial) in weeks	Start ROM (weeks)
Arbab et al[15]	II	A, B, D	2	4	6
Bare et al[16]	II	A, B	4	4	5
Berg et al[17]	III	D	2	6	–
Blitz and Nemes[18]	III	B	8	2	2
Bonnin et al[19]	II	A	0	6.5	–
Borland et al[20]	III	A	6	0	6
Borton et al[21]	III	C	6	0	6
Cerrato et al[22]	I	B, C	2	4 – 6	2
De Yoe et al[23]	III	A	4	2	4
Demetracopoulos et al[4]	II	A	2	2	4
Dombek et al[24]	II	A, B	4 – 5	2 – 3	4
Fujioka et al[25]	III	B	2	2	2
Ho et al[26]	III	A	6	6	6
Jockel et al[27]	II	C	8	4	12
Karlsson et al[28]	II	A	0	6	6
Karlsson and Wiger[29]	I	A	0	6	2
Krause and Brodsky[5]	II	A, B	5	1 – 8	5
Lagoutaris et al[30]	III	A	4	0	4
Lucas et al[31]	III	A	2	4	6
Lui et al[32]	I	A	4	0	–
Maurer and Lehrman[33]	III	B	6	2 – 5	3 – 6
Madsen et al[34]	III	C + D	8	0	–
Minoyama et al[35]	III	A	2	2	–
Mook et al[36]	II	C	4	2	3
Ochoa et al[37]	III	A	4	0	4
Ousema and Nunley[38]	II	C	2	10	6
Ozer et al[39]	III	C	4	0	4
Palmanovich et al[40]	III	A	0	0	3
Patterson et al[41]	III	B	1	5	6
Pelet et al[42]	III	D	6	4	5
Pellegrini et al[43]	III	C	2 + 4	0	5
Philbin et al[44]	I	A, B, C, D	10 days + 4 –6 weeks	4 – 6	8
Radice et al[45]	III	B	5	0	5
Rapley et al[46]	II	C	1	5	1
Redfern and Myerson[6]	II	B,C	6	6 – 8 (max. 3 months)	0
Ritter et al[47]	I	A, B, C, D	2 + 2	2	2 – 4
Ross et al[48]	III	A	2	3	–
Sammarco[49]	I	A, B	2	2	3
		C	4	2 – 3	6 – 7
Sammarco[50]	II	A	3	0	3
		C	4	2	–
Saxena and Pham[14]	II	A	2 – 3	2	2
Saxena and Wolf[51a]	II	B	3	3	6
Shoda et al[52]	III	A	6	0	–
Squires et al[53]	I	A, B, C	6	4	3
Stockton et al[54]	II	A, B	4	4 + 4	12
Vega et al[55]	I	A	2	0	2
Verheyen et al[56]	III	D	2	6	–
Waldecker et al[57]	III	B	6	0	6
Wapner et al[58]	II	A, B, C	0	3	3

Results

The literature search in PubMed/MEDLINE and EMBASE databases yielded, respectively, 421 and 299 records. After duplicates were removed, 532 studies were included for title and abstract review. Careful systematic selection resulted in 49 studies eligible for this review; 24 case reports, 8 reviews, and 17 case series (figure 1). No studies were found with the primary focus on rehabilitation of surgically treated peroneal tendon tears or ruptures. Included studies described their rehabilitation method after one or more of the following surgical treatment methods: group A: primary repair with or without tubularization of the tendon[4,5,14-16,19,20,23,24,26,28-32,35,37,40,44,47-50,52-55,58], group B: tenodesis[5,6,15,16,18,22,24,25,33,41,44,45,47,49,51,53,54,57,58], group C: grafting[6,21,22,27,34,36,38,39,43,44,46,47,49,50,53,58],and group D: end-to-end suturing.[15,16,34,42,44,47,56] Fourteen studies reported two or more surgical treatment methods.[5,6,15,16,22,24,34,44,47,49,50,53,54,58] Study characteristics and rehabilitation protocols are shown in table 1.

Figure 1
PRISMA flow diagram[59]



Rehabilitation after primary repair

Twenty-eight studies reported on the rehabilitation protocol after primary repair of the peroneal tendons. Some of these also included performance of side-to-side suturing or tubularization. [4,5,14-16,19,20,23,24,26,28-32,35,37,40,44,47-50,52-55,58]. The median duration of the immobilization period was 6.0 weeks (range 0 – 12) (table 2). Of the studies (*n* = 23) that reported on the start of ROM exercises, nine studies (39 %) started exercises within four weeks post-operative.[14,29,40,47,49,50,53,55,58]

Table 2
Overview of the non-weight-bearing and weight-bearing immobilization period and the moment of start with Range of Motion per treatment group
NWB non-weight bearing, *WB* weight bearing, *ROM* range of motion
[a]Number of studies that reported on the start of range of motion after surgery

	Group A: primary repair (*n* = 28)	Group B: tenodesis (*n* = 19)	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* = 19[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)

Rehabilitation after tenodesis
Rehabilitation after tenodesis was reported in nineteen studies.[5,6,15,16,18,22,24,25,33,41,44,45,47,49,51,53,54,57,58] The median duration of immobilization was 7.0 weeks (range 3.0–13) (table 2). Of the studies (*n* = 19) that reported on the start of ROM exercises, nine studies (45 %) started exercises within four weeks post-operative.[6,18,22,25,33,47,49,53,58]

Rehabilitation after grafting
Rehabilitation after surgical treatment with grafting was reported in sixteen studies with a median immobilization period of 6.3 (range 3.0–13) weeks (table 2).[6,21,22,27,34,36,38,39,43,44,46,47,49,50,53,58] Of the studies (*n* = 15) that reported on the start of ROM, seven studies (47 %) reported on a start within four weeks post-operative.[6,22,36,46,47,53,58]

Rehabilitation after end-to-end suturing
Seven studies described the rehabilitation method after tendon end-to-end suturing technique.[15,16,34,42,44,47,56] The median immobilization period was 8.0 weeks (range 6.0–11) (table 2). Of the studies (*n* = 4) reporting on the start of ROM, one study (25 %) started exercises within four weeks post-operative.[47]

Comparison of groups
There was no difference with respect to the total duration of immobilization between the different treatment groups (*n.s.*). Furthermore, when NWB and WB duration rates among different treatment groups were compared, no difference was found (*n.s.*).

Discussion

The most important finding of this study was that there exists a wide variation in rehabilitation protocols after surgically treated peroneal tendon tears and ruptures, confirming that there is no consensus among orthopedic surgeons. No difference was found in post-operative protocols between different surgical techniques. In recent years, there seems to be a trend towards early ROM and rehabilitation within four weeks post-operative.[4,28,29] It is difficult, however, to draw conclusions based on these data since literature lacks studies that are primarily designed to study specific rehabilitation methods.

Peroneal tendon injuries are common in active patients. For this population, early return to activity and sports is of great importance. Since peroneal tendon tears and ruptures are protracted injuries, surgical repair merely marks the beginning of a long recovery period. Adequate rehabilitation is purported as an important aspect of the clinical success of any operatively treated tendon injury. Properly directed rehabilitation can facilitate tendon healing, minimize scarring and promote early return to pre-injury activity/sports levels. Great attention should therefore be paid to determining the optimal post-operative treatment protocol.

Many rehabilitation recommendations have been published over the past decade regarding flexor tendons of the hand.[13] Flexor tendons are predisposed to forming adhesions between the repair and surrounding tissue, leading to scar, loss of ROM and limitation of tendon gliding. To prevent adhesion formation, early ROM is recommended.[60-63] Different authors have also advocated early post-operative rehabilitation after Achilles tendon surgery.[64-68] A recent change to early ROM exercises can be found in operatively treated patients with peroneal tendon injuries.[4,29] Demetracouplos et al and Karlsson et al have recently described a change in their post-operative management based on this information.[4,28,29] In contrast to a previous protocol of six weeks cast immobilization followed by physical therapy, Demetracouplos et al implemented a post-operative protocol aiming early ROM after four weeks of WB and NWB immobilization.[4] Karlsson et al immobilized the patient six weeks in a plaster cast, but shortened the period in a study published four years later to two weeks plaster cast followed by a WB air cast brace to provide early ROM training.[28,29]

Among the available studies analyzed, we found wide variation in the total immobilization period. While some authors preferred early ROM without post-operative immobilization[40], others immobilized their patients over twelve weeks.[6] Due to the wide range found for this period of inactivity (0 – 13 weeks) among different studies, it is hard to draw conclusions and propose an evidence-based rehabilitation protocol. Based on our own experience, we recommend that an ideal peroneal rehabilitation protocol should be tailored according to individual patients needs and should be dependent upon the exact nature of tendon injury as well as the functional expectations of each patient.

This study has a few limitations. First, the clinical heterogeneity and small patients numbers among the included studies withholds us from drawing hard conclusions and therefore establishing an evidence-based protocol. Secondary, the results of this study were based on reviews and studies with the primary focus on the operative treatment of these ruptures. These methodological limitations prevented high-quality conclusions based on synthesis of the available evidence. Therefore, our results provide an overview on the daily affairs in clinic and do not provide a sufficiently evidence-based recommendation and thus no statement can be made on the effectiveness of the rehabilitation protocols currently being employed. Our analysis, however, is based on best available evidence suggesting broad variation between different surgeons and lack of any consensus on a post-operative peroneal protocol. Finally, the search we performed yielded a relatively large amount of unavailable manuscripts.

Proposed rehabilitation program

In order to come up with an evidence-based algorithm for the rehabilitation of peroneal disorders in daily clinical practice, a program is proposed based on evaluation of available protocols described in today's literature as well as personal experience of the centers involved in this study. It is emphasized that this protocol will ultimately require validation.

Following surgical treatment of peroneal tendon tears, patients should receive a post-operative lower leg splint for two days, followed by twelve days of a NWB lower leg cast. After removal of the stitches, patients are then permitted to weight bear in a walker boot or lower leg cast for four weeks pending surgeon preference.

Six weeks post-operative, physiotherapy is initiated to restore ROM (figure 2) and strength. Strength exercises include isometric exercises in pain free range and electrical stimulation of the peroneal muscles (figure 3). Simultaneously, proprioception and balance are trained by seated or partial WB exercises and proprioceptive exercises on two legs (figure 4). Proprioceptive exercises are gradually expanded from controlled WB on two legs to full WB on two legs (figure 5). Eccentric, concentric and isotonic exercises are also started with the use of a theraband (figure 6). The strength of the foot and calf muscles is trained (figure 7), and the walking pattern is checked.

Patients start to learn to walk again in a controlled setting either with use of an Alter-G trainer (figure 8) or a swimming pool in order to allow good motion in a partial WB setting to start with. This is helpful in preventing development of reactive peroneal tendinitis. No provocation of the peroneal tendons is allowed until twelve weeks post-operatively, and sports-specific rehabilitation is generally not initiated until at least twelve weeks of physiotherapy have concluded.

Figure 2

Patients can start with active full ROM exercises: dorsiflexion, plantar flexion, inversion, eversion

Figure 3

Strength exercises: using the RSQ1 for electrical stimulation. In the second phase you can use this devices during isometric or isotonic exercises

Figure 4
Proprioseptive training: progress from NWB/controlled WB on two legs to full WB on unstable surfaces

Figure 5
Single leg balance activities (stable to unstable surfaces, without and with distractions)

Figure 6
Strength exercises: eversion against theraband. This is one of the most important exercises

Figure 7
Single leg balance activities (stable to unstable surfaces, without and with distractions)

Figure 8
Walking in an Alter-G trainer

An overview of the proposed rehabilitation protocol is shown in table 3. It is important to emphasize that the number of weeks are a median number of weeks and that each rehabilitation program should be tailored according to individual patient needs, depending on both the exact nature of the peroneal problem as well as on the specific personal demands of the specific patient.

Table 3
Overview of the proposed rehabilitation protocol of surgically treated peroneal tendon disorders, based on the evaluation of available protocols in literature
[a] Number of weeks after operation

	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

Conclusion

Rehabilitation is an important factor in the clinical success of all tendon injuries, and treatment of peroneal tendon tears and ruptures is no exception. There is no consensus in today's literature with regard to an ideal post-operative immobilization time or initiation of range of motion exercises. Prospective, randomized controlled trials are needed to refine optimal rehabilitation methods for patients with peroneal tendon tears or ruptures after operative treatment. Based on currently available data and a combined personal clinical experience exceeding 50 years, a tailored rehabilitation protocol for every specific patient is advised for optimal functional recovery and prevention of re-rupture.

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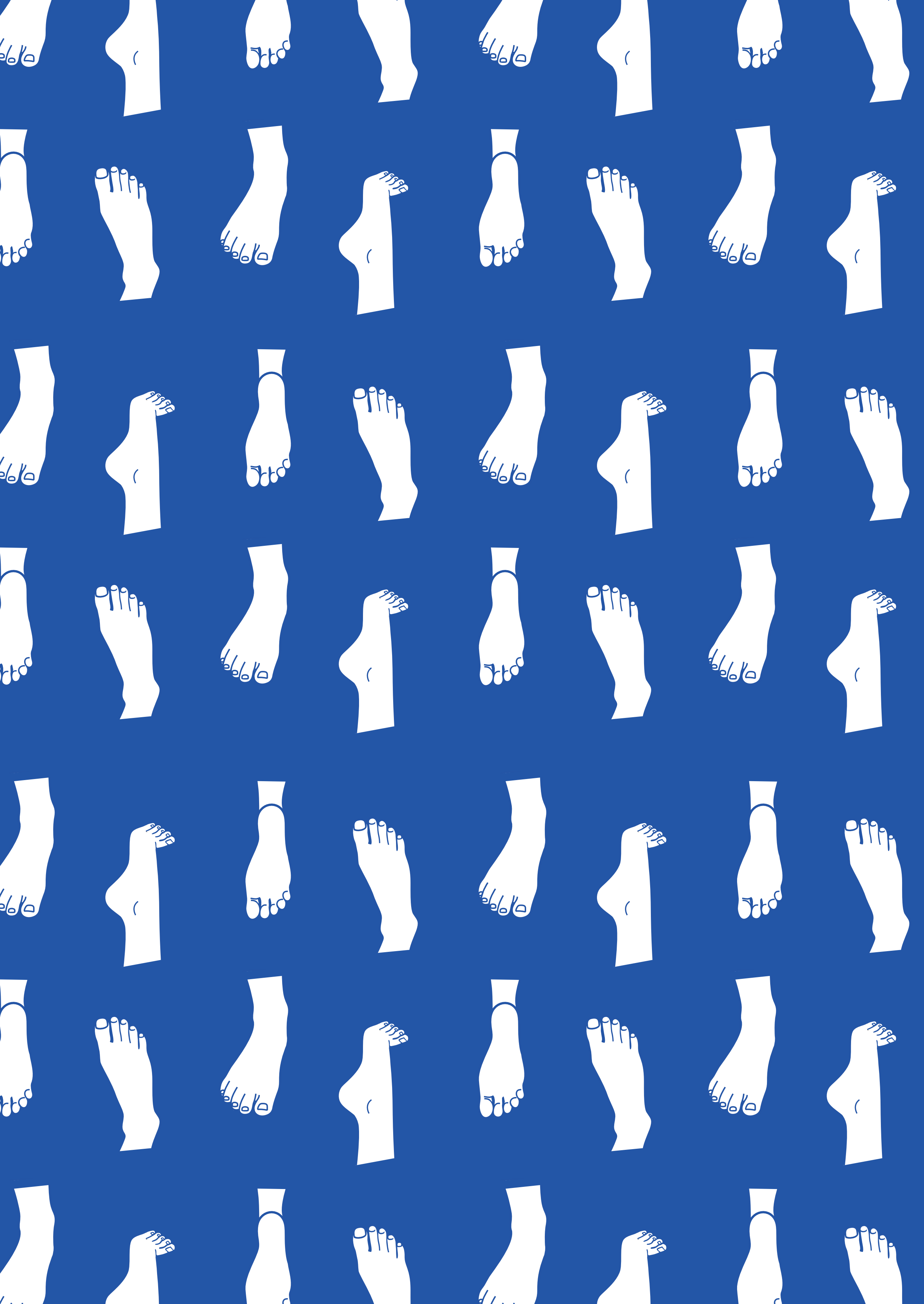
PART 5

INTERNATIONAL CONSENSUS GUIDELINE



CHAPTER 10

The ESSKA-AFAS international consensus statement on peroneal tendon pathologies

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Abstract

Introduction

Peroneal tendon injuries are a significant cause of lateral ankle symptoms in the active population. Accurate diagnosis and prompt treatment is important for minimizing the risk of long-term sequelae associated with chronic peroneal tendinopathy. Although several studies have been published on diagnostic strategies and treatment outcomes, there is no consensus on the optimal management of peroneal tendon pathologies.

Purpose

The purpose of this ESSKA-AFAS consensus statement was to conduct an international and multidisciplinary agreed guideline on management of patients with peroneal tendon pathologies.

Methods

Using the Nominal Group Technique, a panel comprised of sixteen specialists spanning nine countries was convened by the ESSKA-AFAS board. In preparation for the meeting, relevant questions were identified and supported by a systematic literature search. During the meeting, the panel members gave presentations on each question, and the evidence supporting each subject was then vetted by open discussion. Statements were thereafter adjusted on the basis of the discussion and voted upon to determine consensus using a 0 – 10 range Likert scale. Agreement was confirmed when a mean score of at least 7.5 was reached.

Conclusion

This ESSKA-AFAS consensus statement on the optimal management of peroneal tendon pathologies is the result of international and multidisciplinary agreement combined with a systematic review of the literature.

Chapter 10. The ESSKA-AFAS international consensus statement on peroneal tendon pathologies

Introduction

Improved knowledge based on contemporary studies has ensured that peroneal tendon disorders are a serious cause of posterolateral ankle symptoms following lateral ankle sprains (acute or chronic), despite previously being considered rare entities. Pathology may range from tendinopathy to ruptures, tears, and instability of the tendons.[1-4] Since chronic peroneal tendinopathy is associated with long-term sequelae, accurate diagnosis and prompt treatment in an early stage is important.

Current practice is mainly based on level IV and V evidence. As a consequence, different diagnostic and treatment strategies are advocated in the literature without general consensus. In diagnostics, for example, different authors propose either Magnetic Resonance Imaging (MRI) or (dynamic) Ultrasound (US) as the best modality when diagnosing peroneal tendon instability.[5-7] In the treatment of irreparable peroneal tendon tears, some studies state that both tenodesis and the use of a graft are sufficient[8], while others conclude that grafting is superior to tenodesis.[9]

Considering peroneal tendinopathy is associated with long-term sequelae when addressed inaccurate, adequate diagnosis and prompt treatment in an early stage is important. So far, however, no optimal management algorithm is available for diagnosing and treating different peroneal tendon pathologies. The purpose of this ESSKA-AFAS consensus meeting was to produce experience-based guidelines on the management of patients with peroneal tendon pathology, predicated on international and multidisciplinary agreement, and supported by systematic review of the literature.

Material and Methods

This consensus statement was initiated by the Ankle and Foot Associates (ESSKA-AFAS) of the European Society of Sports traumatology, Knee surgery and Arthroscopy (ESSKA). ESSKA is one of the leading organisations worldwide concerning sports-related pathology. Using the Nominal Group Technique or mini-Delphi method, an international consensus panel (ICP) was selected by the board of the ESSKA-AFAS on the basis of extensive knowledge and experience regarding the management of, and science pertaining to peroneal injury.[10] The panel was specifically compiled to gain a global representation that would cover a spectrum of opinions relevant to peroneal pathology. In total, fourteen orthopaedic surgeons, one PhD-student, and one physiotherapist were invited to join the panel. All participants were required to have at least one published or submitted peer-reviewed paper on the topic. Represented countries included Australia, France, Italy, the Netherlands, Portugal, Singapore, Spain, Sweden, the United Kingdom, and the United States of America.

Preliminary work
After initial proposal of potential discussion topics by the board of ESSKA-AFAS, the ICP agreed upon ten final questions requiring accurate study and consensus assessment:

1. Is there a relation between the anatomy and the development of peroneal tendon pathologies?
2. How should peroneal tendon pathologies be classified?
3. What are the key features to diagnose peroneal tendon pathology?
4. What conservative therapies may be considered and when?
5. What is the optimal treatment for peroneal tendon tears?
6. What is the optimal treatment for peroneal tendon ruptures?
7. What is the optimal treatment for acute peroneal tendon instability/dislocation?
8. What is the optimal treatment for a Painful Os Peroneum Syndrome?
9. When should hindfoot realignment procedures be considered?
10. What is the optimal post-operative protocol and rehabilitation following surgical treatment of a peroneal tendon pathology?

The questions were unanimously considered to represent current controversial and relevant to daily practice topics. Each subject was designated to two independent panel members who individually performed a literature search using the PubMed and Cochrane databases to identify relevant literature published before the panel meeting date of 25th May 2017. In each case, a level of evidence was determined based on available literature, and a summary recommendation grade was then made using guidelines from the University of Oxford, Centre for Evidence-Based Medicine.[11]

Search strategy
Searching PubMed/MEDLINE and EMBASE electronic databases relevant literature was identified. Two keywords (peroneal and tendon) and related synonyms were used. All synonyms were combined with the Boolean command AND, and were linked by the Boolean command OR. The last search was performed on May 25th, 2015.

Consensus meeting
During a two-day meeting, each of the study questions was discussed by the panel. Preceding the discussion on each question, an overview was given on the outcome of the systematic review of the literature. At the conclusion of each subject's discussion, a level of agreement was defined based on provided recommendation. In cases where full agreement could not be reached, panel members were asked to vote using a Likert scale from 0 to 10, where 0 reflected complete disagreement and 10 complete agreement. A mean score of at least 7.5 was thereafter required to confirm consensus. When consensus was not met, the differing opinions and rationale were outlined further, and these are discussed in the "Results" section.

Results

Results of the consensus process are summarized below and are followed by a *rationale* and summary of the panel's consensus discussion and literature review/support. For each consensus statement, the level of agreement and the level of evidence are stated in table 1.

Table 1
Levels of agreement and evidence

Statement	Level of agreement	Level of evidence
1.1 – 1.3	Full agreement	IV
2.1 – 2.3	Full agreement	V
3.1 – 3.3	Full agreement	III
4.1 – 4.4	Full agreement	V
5.1 – 5.4	Full agreement	IV
6.1, 6.2	Full agreement	IV
7.1 – 7.3	Full agreement	II
7.4	6.3	II
7.5	8.0	II
8.1 – 8.3	Full agreement	V
9.1, 9.2	Full agreement	V
10.1-10.3	Full agreement	II

Question 1. Is there a relation between the anatomy and the development of peroneal tendon pathologies?
1.1 Several anatomical variations may predispose a patient to the development of peroneal tendon pathology.
1.2 "Overstuffing" of the peroneal tunnel is an important factor in the development of peroneal tendon pathology, and therefore, assessment of proper volume is more important than characterization of the groove shape.
1.3 Chronic loading of the tendons, as seen in a cavovarus malalignment, may predispose the tendons to pathology and this should be considered before deciding upon a treatment.

Rationale
The Peroneus Longus (PL) and Peroneus Brevis (PB) muscles together form the lateral compartment of the lower leg. In their distal course towards their insertion, they curl around the tip of the fibula within the superior peroneal tunnel. The panel agreed that several anatomical variabilities in the vicinity of this fibro-osseous tunnel could predispose to the development of a peroneal tendon pathology, including:

a. A low-lying muscle belly
The PL muscle becomes completely tendinous around 3 – 4 cm proximal to the distal fibular, whereas the PB muscle extends lower within the retromalleolar groove.[12] If the musculotendinous junction extends distal to the tip, it is considered as a low-lying muscle belly (LLMB).[12,13] In the literature, the relation of a LLMB to the development of peroneal tendon pathologies has been advocated. A study by Freccero et al found that the distance in between the musculotendinous junction and the fibular tip was significant shorter in patients with symptomatic peroneal tendon pathology and, therefore, considered it to be a significant contributing factor.[13] Other studies, however, describe a high prevalence of LLMB also in asymptomatic cases. The panel agreed that the extent of the muscle belly does not necessarily predispose to peroneal tendon pathology, but the effect of overstuffing within the tunnel due is likely to predispose a patient to peroneal tendinopathy.

b. Accessory (peroneal) muscles

Two accessory muscles have been described within the retromalleolar groove: the peroneus quartus muscle and the peroneus quintus muscle with an incidence of 10 – 22 % and 18 – 34 %, respectively.[14] Both muscles can originate from the PB, the PL, the fibula, the peroneus tertius, or a combination of these structures; however, their insertion points differ. The peroneus quartus usually inserts on the extensor digitorum longus slip or along the retro trochlear tubercle of the calcaneus, while the peroneus quintus typically inserts on the dorsal aspect of the fifth metatarsal. Both accessory muscles have been linked to pain and swelling around the lateral malleolus — presumably due to over-filling of the retromalleolar peroneal tunnel as discussed above.[14] Association with other pathologies such as tendon tearing and dislocation has also been proposed in the literature, but this remains controversial and the panel did not reach consensus on this topic.[15]

c. Shape of the retromalleolar groove

At the level of the fibular tip, both tendons course through a fibro-osseous tunnel formed by the superior peroneal retinaculum (SPR) and its fibrocartilaginous ridge on the posterolateral side and the deep posterior compartment fascia and the retromalleolar groove anteromedially. As reported in current literature, the shape of the groove has been associated with peroneal tendon pathologies, with a flat or convex groove being more prone to luxation of the tendons.[12] Nevertheless, a study by Kumai et al found that the shape is predicated more by the fibrocartilaginous ridge of the SPR than by the osseous groove.[16] Purnell et al stated that integrity of the retinaculum is the most critical factor for preventing peroneal tendon subluxation or dislocation.[17] There was consensus among the panel about the influence of retromalleolar morphology on peroneal disorders.

d. Peroneal tubercle

Distal to the fibular tip, the peroneal tendons are separated by the peroneal tubercle. No clinical evidence is available on the relation between the peroneal tubercle and the development of peroneal tendon pathology. In a study by Hyer et al, the tubercle was described as prominent in 29 % of cadaveric specimens and an association with pain was suggested.[18] The panel agreed that a prominent peroneal tubercle may predispose the tendons to (recurrent) tears, and excision should, therefore, be considered during treatment.

e. Os peroneum

The os peroneum (OP) is an accessory ossicle located within the distal part of the PL tendon at the level where it enters the cuboid tunnel, and protects the PL from abrasion as the tendon curls under the cuboid bone. Its incidence is estimated at 4 – 30 %.[19,20] Asymptomatic OPs may consists of both bony and fibrocartilaginous tissue[21,22], whereas calcification of the OP potentially predisposes the PL tendon to tear or dislocation (see section "Painful os peroneum syndrome").[20]

Question 2. How should peroneal tendon pathologies be classified?

2.1 The differentiation between acute and chronic peroneal pathology was not deemed to be clinically relevant, except in the case of peroneal tendon instability. Attempts at classification, therefore, should be based on the type of pathology.

2.2 Differentiation between athletes and non-athletes was determined to be an important factor in relation with treatment and outcomes.

2.3 The term "tear" usually denotes a longitudinal tear or incomplete rupture, whereas "rupture" typically denotes complete tendon discontinuity (separation of the ends).

Rationale
There is no consensus in the literature as to when an acute injury becomes chronic. Conflicting time frames of six weeks, three and six months have been reported. The panel concluded that the differentiation between a potentially acute or chronic injury pattern is generally not clinically relevant, since it does not affect treatment. The panel did agree, however, that this differentiation might influence both outcome and prognosis, since acute injuries have a better healing tendency. Concerning peroneal tendon instability, the panel concluded that it is important to differentiate between acute and chronic, since management does differ between the two groups (see section "What is the optimal treatment for acute peroneal tendon instability/dislocation?"). Treatment and outcome may also be determined by whether the injury is sustained in an athlete rather than a non-athlete.

The panel agreed that peroneal tendon pathology is best classified by type of pathology, as divided into three categories: (1) tendinopathy, (2) tear/rupture, and (3) instability/dislocation. Tears are classified as either a partial (simple or complex) longitudinal tendon tear, that does not result in complete discontinuity of the muscle tendon unit, or a rupture including a transverse discontinuity and resulting in complete dissociation between muscle and tendon at that level.

Question 3. What are the key features to diagnose peroneal tendon pathology?
3. 1 Initial assessment of a patient presenting with an acute ankle injury should follow the Ottawa ankle guidelines.
3.2 Based on imaging and physical examination, a specialist should be consulted for further examination. Both US and MRI are appropriate imaging modalities for the evaluation of peroneal tendons.
3.3 Peroneal tendoscopy should be reserved for patients with high clinical suspicion of peroneal tendon pathology based on history and clinical exam, but with the absence of any positive findings on imaging. See figure 1 for a schematic algorithm on diagnostic management of peroneal tendon pathology.

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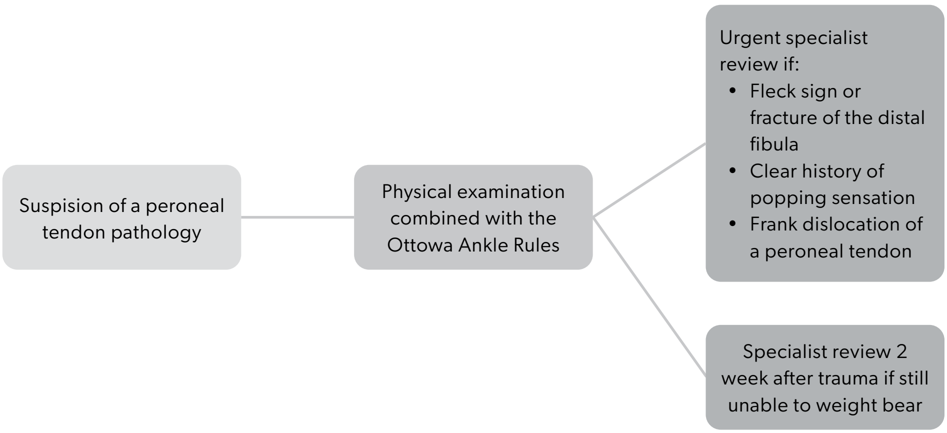
Figure 1
Flowchart on diagnostic management of peroneal tendon injuries



Rationale

Pathology of the peroneal tendons may present with a broad variety of symptoms. Acute dislocations typically present following an identifiable injury in a previously asymptomatic ankle.[23] On investigation, there is posterolateral swelling and tenderness specifically over the SPR.[24] Dislocation can frequently be reproduced on resisted eversion of the ankle.

Acute tears are likely to present with a sudden onset of pain and swelling, which also might be caused by the additional pathology such as a lateral ligament rupture often accompanying the acute pathology. Acute injuries present with bogginess and tenderness to palpation around the distal fibula.[25] PB tears usually present with pain around the distal fibula, whereas PL tears typically present with pain near the peroneal tubercle and cuboid tunnel. Examination may also reveal respective weakness during ankle eversion and first ray plantarflexion.[26]

When assessing a patient presenting with an acute ankle injury, the panel agreed that initial assessment should follow the Ottawa ankle guidelines proposed by Stiell et al, including anteroposterior and lateral weight-bearing radiographs of the affected ankle and, if foot pathology is suspected, an oblique view.[27] Review by a specialist is reserved for cases where imaging reveals a "fleck sign" or fracture of the distal fibula, or in case of a clear history of a "popping" sensation or frank dislocation of the tendons(s). In addition, if the patient is unable to weight bear by one to two weeks postinjury, referral to the specialist is warranted. The panel agreed that specialist evaluation should also consider and evaluate for other causes for lateral ankle pain.

Both MRI and US are appropriate investigations and the choice is dependent on the clinician's preference, user expertise, and the availability of the imaging modality. Tendoscopy may be beneficial when there is a high clinical suspicion of peroneal tendon pathology in the absence positive findings on imaging.[28]

Question 4. What conservative therapies may be considered and in case of which pathology?

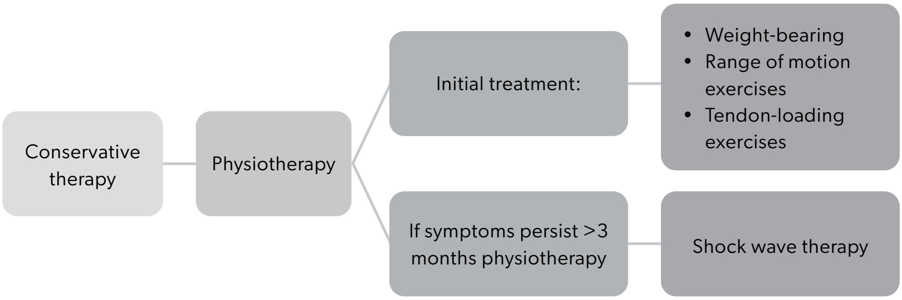
4.1 Conservative management should be considered in all patients with a peroneal tendon pathology.

4.2 In the acute situation, conservative treatment should concentrate on additional pathology such as a lateral ligament rupture. Treatment includes ice, compression, and elevation. Range of motion and exercises should be started when clinically relevant.

4.3 Shockwave therapy should be considered when initial measures fail.

4.4 The use of platelet-rich plasma is not supported by the literature to approve its use. Figure 2 presents a schematic algorithm on conservative treatment of acute peroneal tendon pathologies.

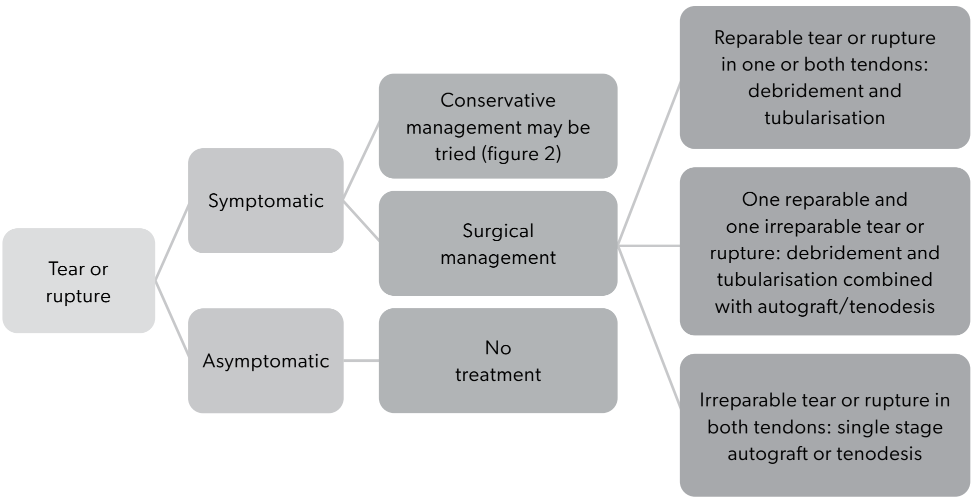
Figure 2
Flow chart on conservative treatment of peroneal tendon injuries



Rationale
There is broad agreement among the panel and in the literature that under the vast majority of circumstances, conservative management of acute peroneal tendon pathology is treatment of choice. Nonetheless, there is limited and varied evidence on the outcomes of conservative treatment in acute peroneal tendinopathy.[29-31] Initial treatment is directed towards additional pathology and consists of rest, ice, compression, and elevation. When painless, the patient may start weight bearing followed by range of motion and tendon-loading exercises. The panel agreed that immobilization should be avoided.

When symptoms persist beyond three months, there is some suggestion for the use of shockwave therapy in tendinopathy of the lower extremity.[32,33] The panel supported this application under those circumstances. With regard to the use of platelet-rich plasma, the panel agreed that at this time, there is insufficient evidence to support its use in the treatment of peroneal tendinopathy.[29]

Figure 3
Flow chart on treatment of peroneal tendon tears and ruptures



Question 5. What is the optimal treatment for peroneal tendon tears?
5.1 Treatment should be reserved for symptomatic patients only.
5.2 Initial management consists of conservative treatment.
5.3 Concerning operative management, the first choice of treatment includes debridement and repair/tubularization of one or both tendons as indicated. When such treatment is not feasible, single-stage autograft with the hamstrings, or side-to-side tenodesis are recommended. When one of the two tendons is deemed irreparable, perform debridement and tubularization on the reparable tendon and use autograft or tenodesis to treat the irreparable tendon. In cases when neither tendon can be repaired nor the proximal muscle tissue is healthy, single-stage autograft is recommended. Whenever possible, grafting is preferred over tenodesis.
5.4 In tenodesis, there is no preference of PB to PL or PL to PB. In figure 3, a schematic algorithm for the treatment of peroneal tendon tears is presented.

Rationale
The prevalence of peroneal tendon tears in general population remains unknown, but cadaveric studies found tears in 11 – 38 % of the studied ankles.[34,35] It is assumed that only a percentage of all peroneal tendon tears becomes symptomatic and the panel, therefore, agreed that surgical treatment should only be performed in symptomatic patients. Different treatment algorithms have been proposed in the literature, suggesting that if less than 50 % of the cross-sectional area of the tendon is involved in the tear, then any affected tissue can be debrided and tubularized.[2,3,8] This 50 % threshold, however, remains quite arbitrary and is not based on any substantiated data. The panel decided that it is always preferable to attempt to preserve the tendon(s) and, therefore, agreed that primary debridement and tubularization should always be tried when there can be at least some reasonable native tendon left behind in the repair (resistant to surgeon's manual pull stress), even if less than 50 %. In the literature, treatment of peroneal tendon tears with primary debridement and repair has been associated with excellent return to full activity and patient-reported outcome scores.[3,36,37]

In cases where repair of one or both tears is not possible, the panel recommends single-stage grafting. Autograft is preferred over allograft because of both its mechanical and biological characteristics. Concerns associated with the use of an allograft include tissue availability, delayed graft incorporation, strength, disease transmission, and fatigue (creep).[38]

The panel favours grafting over a tenodesis procedure, mainly because tenodesis directly affects biomechanical balance of the foot. A cadaveric study by Pellegrini et al found insufficient tension on the peroneal tendons after tenodesis of the PB to the PL, while an allograft was associated with substantial restoration of the tension.[9] In cases where performing tenodesis is indicated, therefore, it seems that PL to PB transfer would be the better option and transfer of the PB to the PL should be avoided. The panel does not recommend a tendon transfer using the flexor digitorum longus or flexor hallucis longus, because the procedure has several biomechanical limitations and is associated with significant deficits in strength and balance on the longer term.[4]

The panel agreed that predisposing abnormalities possible contributing to the development of peroneal tendon tears should be treated simultaneously with the tear. Examples include a hypertrophic peroneal tubercle, a LLMB or bulky PB muscle belly, peroneal subluxation or dislocation, or an accessory tendon. When left untreated, any of these may lead to recurrent tearing, persistent pain, and dysfunction.[26,39]

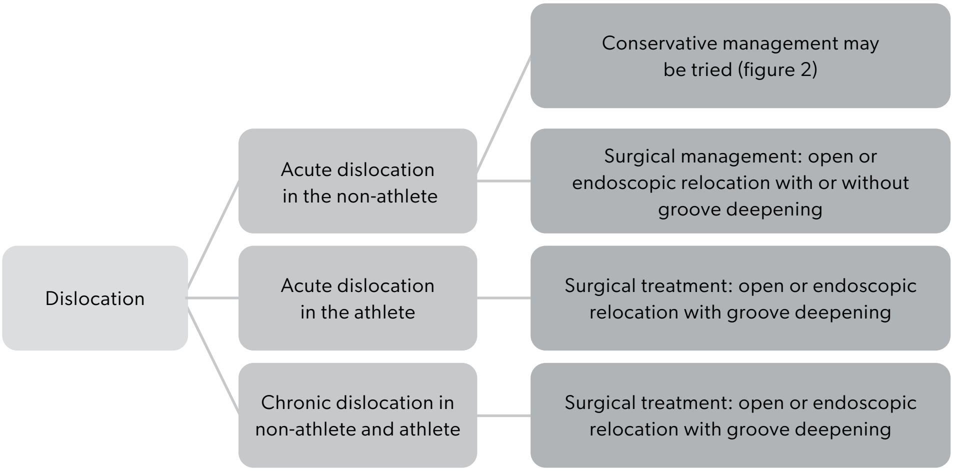
Question 6. What is the optimal treatment for peroneal tendon ruptures?
6.1 Complete rupture of one tendon can be treated conservatively in the inactive and asymptomatic patient.
6.2 In active patients, symptomatic complete rupture of one of the two peroneal tendons should usually be treated with repair. If repair is not possible, a single-stage hamstring autograft or tenodesis may be performed. In tenodesis, there is no preference of PB to PL or PL to PB. When these options are not feasible, FHL or FDL tendon transfer is a final option. In figure 3, a schematic algorithm for the treatment of peroneal tendon ruptures is presented.

Rationale
Complete rupture of one of the tendons can be treated conservatively in the event that the patient remains low demand and asymptomatic. In the symptomatic or highly active patient, however, surgical management is often required to support return to sports. Patients with rupture of both tendons benefit from surgical management to treat their symptoms. The panel agrees that, if possible, the tendon tissue should be preserved and, therefore, recommends end-to-end repair of the rupture(s).

In cases when this is not possible, the panel recommended the same treatment algorithm agreed for peroneal tendon tears. If grafting or tenodesis remains insufficient, a tendon transfer may be considered.[4] It should be recognised that elite athletes may not return to their pre-operative level of sports after surgical treatment for peroneal tendon rupture.

Question 7. What is the optimal treatment for acute peroneal tendon dislocation?
7.1 Treatment of peroneal tendon dislocation should be based on whether it is an acute or chronic injury and whether or not the patient is an athlete.
7.2 The non-athlete with an acute dislocation may be offered conservative management but should be warned that there is a 50 % chance of recurrent dislocation. In case of unsuccessful conservative management or chronic instability, surgical intervention is advised.
7.3 Surgery is recommended for elite athletes having sustained either acute or chronic dislocation.
7.4 Surgery in non-athletes with acute peroneal instability consists of reduction of the tendons into the retrofibular groove and repair of the SPR. There was no agreement as to whether to perform an additional groove deepening in non-athletes.
7.5 There was agreement that surgical treatment in athletes should routinely include groove deepening, regardless of other possible treatment gestures. Figure 4 shows a schematic algorithm on treatment of peroneal tendon dislocation.

Figure 4
Flow chart on treatment of peroneal tendon dislocation



Rationale
Acute peroneal tendon dislocation typically occurs after a forced eccentric contraction of the peroneal muscles combined with dorsiflexion and eversion of the ankle.[40] Multiple management options have been proposed for the treatment of peroneal dislocations, generally aiming to repair or reconstruct the SPR, correct predisposing factors and increase the volume of the peroneal tunnel. While the benefits of surgery have been shown in the literature, the value of conservative management remains unclear.[41] The current evidence is limited to a number of case reports and small retrospective series suggesting that the risk of recurrent peroneal instability is approximately 50 %[30]. As discussed in the section "Classification and Terminology", the panel determined that choosing optimal treatment necessitates differentiation between acute and chronic injury and between the athlete and non-athlete population.

For acute instability in non-athletes, the panel agreed that both conservative and surgical management are indicated. Although conservative management carries a 50 % risk of failure, secondary surgical treatment does not lead to a worse prognosis or alter the surgical options available if it fails. Conservative management should include immobilization in a cast in slight plantarflexion or in a boot with a 2 cm heel wedge for six weeks. If, however, the patient has a suspected or confirmed anterior talofibular ligament injury, they should be immobilized in a neutral position to not compromise the lateral ligament healing. Physical therapy is commenced after six weeks with peroneal strengthening and ankle proprioception exercise.

Surgery in non-athletes with acute peroneal instability consists of reduction of the tendons into the retrofibular groove and repair of the SPR. There was no consensus as to whether an additional groove deepening procedure was required in open repairs. In addition, no agreement was reached as to whether endoscopic or open treatment was favoured, but it was agreed that either was acceptable with the acknowledgement that endoscopic treatment may have less potential complications and allows for earlier functional rehabilitation. If endoscopic stabilization is performed, the panel agreed that the most appropriate technique is to debride the lateral edge of the fibula, where the retinaculum has been lifted away, followed by groove deepening. The SPR does not require formal repair; however, this option is valid.

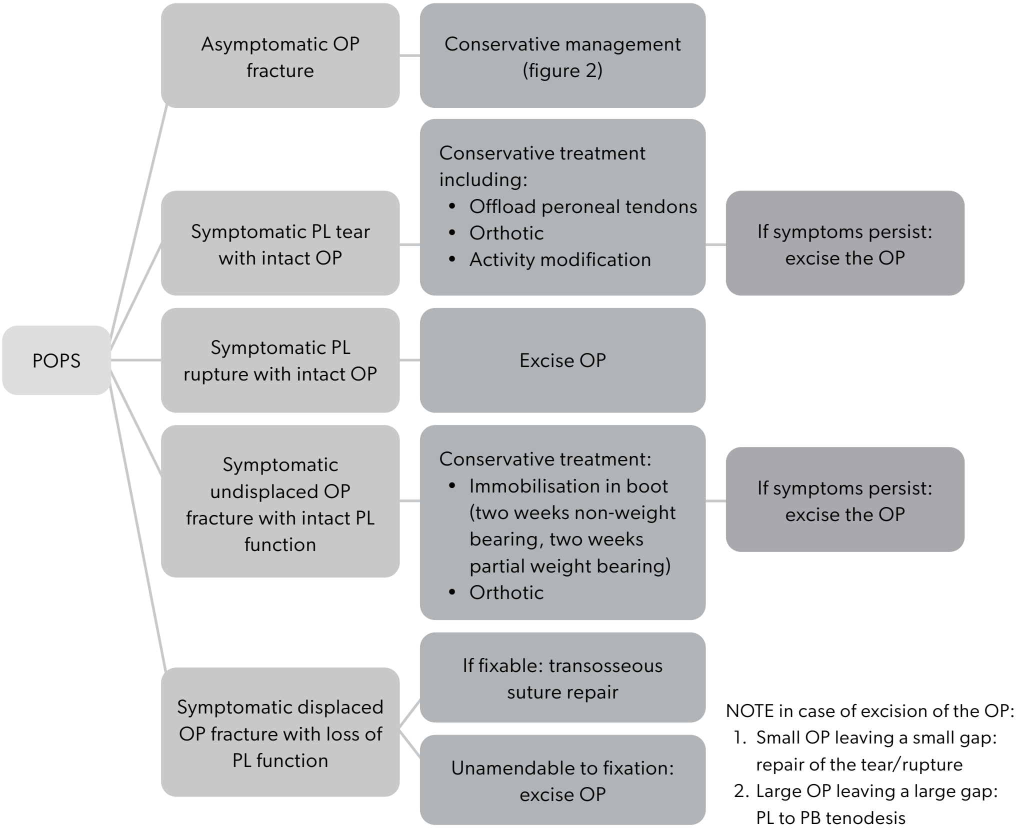
In the athlete with acute instability, conservative management is not advised and early surgical stabilization is the treatment of choice. Opposing to the non-athlete population, the panel agreed that, for this group, surgery should include deepening of the retromalleolar groove. There was agreement that both endoscopic and open treatment are accurate surgical modalities. As stated above, however, endoscopic treatment may allow earlier functional rehabilitation, which may allow earlier return to play.

In chronic injuries, the panel recommended surgical stabilization as the first line treatment with deepening of the retromalleolar groove. In chronic injuries, shortening of the tendons is often seen and groove deepening allows for accommodation of this and greater stability. There was no favour as to the choice of endoscopic or open treatment.

In all types of peroneal instability, there was agreement that in open stabilization, the SPR should always be repaired, but extra care should be taken not to over tighten the SPR, which could result in stenosis of the retromalleolar space. It was also recommended to treat potential tunnel overcrowding factors such as a LLMB or an accessory muscle.

Question 8. What is the optimal treatment for a painful OP syndrome?
8.1 Patients with tears of the PL, associated with an OP and in the absence of frank rupture, should be initially treated conservatively.
8.2 Symptomatic rupture of the PL tendon or symptomatic OP syndrome that fails conservative management should be treated surgically. If the PL cannot be directly repaired, then it can either be tenodesed to the PB tendon or an allograft interposition graft can be used.
8.3 Fractures of the OP can either be repaired or excised and treated as per a PL rupture. A schematic algorithm on optimal management is shown in figure 5.

Figure 5
Flowchart on treatment of the painful OP syndrome.
POPS Painful Os Peroneum syndrome, *OP* Os peroneum, *PL* peroneus longus tendon



Rationale

The painful OP syndrome (POPS) is a relatively uncommon condition that covers a broad spectrum of pathology, including acute and chronic fracture or diastasis of the OP, a tear of the PL, a frank avulsion rupture, an enlarged peroneal tubercle which entraps the OP and PL, or a tenosynovitis without rupture or tear.[20] Currently, there is only level IV and V evidence on the treatment of POPS.[42]

The panel agreed that the treatment regime should be based on the presenting symptoms and the diagnosed pathology. Symptomatic tears without frank rupture of the PL with intact power should be treated conservatively with measures to offload the tendons and provide symptomatic relief, for example, with orthotics and activity modification. There was no consensus on the use of corticosteroids injections as a therapeutic or diagnostic tool and the benefits need to be balanced with the risk of a tendon rupture, because there is currently insufficient evidence available to draw any meaningful conclusions. It was acknowledged by the panel that the reported risk of complete rupture following US-guided injection of corticosteroid into the peroneal tendon sheath is actually low.

The panel agreed that in symptomatic ruptures of the PL with loss of function, the decision for operative intervention should be based on the patient demands. In addition, the group remarked that the consequences of a loss in PL function have not been clearly defined in the literature. In addition, the panel agreed based on anatomical studies that it is important to consider the presence of a fibrocartilaginous OP even if there is a rupture of the PL without X-ray evidence of an OP.

If surgery is indicated, a direct repair is recommended combined with excision of any OP present. If a direct repair cannot be obtained, either a PL to PB tenodesis or repair with the use an interposition graft can be performed. If there is a displaced fracture of the OP leading to loss of PL function, there is mixed evidence for either repair of the osseous OP or excision and direct repair of the tendon.[20,42-44] Express concern with osseous repair is being able to obtain adequate stability and delayed union if the etiology is a stress fracture. Controversially, excision of the OP may leave a large defect affecting the ability to perform a direct repair of the rupture. The panel agreed that it is the surgeon's preference to either perform a PL to PB tenodesis or interposition graft. It was acknowledged that after complete PL rupture near the cuboid, direct repair (e.g., osseous tunnel, suture anchors) or interposition graft is technically very difficult and tenodesis of PL to PB may be the most practical option. In rare cases of an undisplaced fracture of the OP with intact PL function, then, the panel agreed that this can be treated conservatively with boot immobilization, non-weight bearing for two weeks, partial weight bearing for two weeks, and on-going orthotics to offload the PL.

Question 9. When should hindfoot realignment procedures be considered?
9.1 Hindfoot realignment procedures are recommended only for patients with hindfoot deformity, such as varus or valgus, associated with joint degeneration or instability.
9.2 Care should be taken when performing these procedures in elite athletes, once they might be less likely to return to their pre-operative level of sports after surgical realignment of the hindfoot.

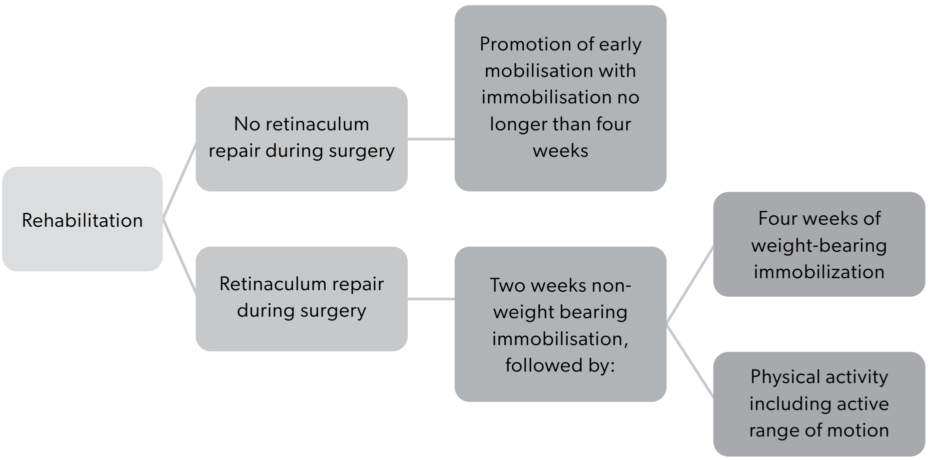
Rationale
Peroneal tendon pathology is often seen with both cavovarus and planovalgus deformity, predisposing these tendons to compression or overuse injuries within the sub-fibular region.[25] The etiology of cavovarus deformity is multifactorial, but is most commonly due to a muscle imbalance in the lower leg and foot. The PL insertion on the plantar aspect of the first metatarsal has been postulated as a cause of deformity in the cavovarus foot.[19,45] Indeed, Helliwel et al demonstrated that in 75 % of cavovarus feet, the PL is enlarged on MRI.[46] In addition, Redfern et al found that in patients presenting with a peroneal tendon tear, 32 % had a concomitant isolated hindfoot varus or cavovarus foot deformity.[3]

Currently, there is no evidence on the isolated effect of a calcaneal osteotomy in peroneal tendon injury. Some case studies support the role of a calcaneal osteotomy for peroneal tendon pathology with a cavovarus deformity.[3,45] The panel agreed that hindfoot realignment procedures should be reserved for symptomatic varus or valgus associated joint degeneration and/or ankle instability and not in the case of an isolated peroneal pathology.

The panel agreed that in athletes with hindfoot malalignment and peroneal tendon pathology, correction of the hindfoot malalignment is probably best avoided. The panel's experience is that it is not uncommon for athletes to have asymptomatic idiopathic hindfoot varus and in case when this is corrected, the biomechanical change in the lower limb alignment may have a detrimental effect on their level of elite performance.

Question 10. What is the optimal post-operative protocol and rehabilitation following surgical treatment of peroneal tendon pathology?
10.1 For optimal rehabilitation, one must distinguish whether or not the SPR was repaired during the surgical procedure.
10.2 When the SPR is not repaired, rehabilitation should be goal- and not time-based with the promotion of early mobilization.
10.3 When surgery included repair of the SPR, rehabilitation should consist of two-week non-weight bearing in a lower leg cast, followed by four weeks of weight bearing in a cast or a walker boot. At two weeks post-operatively, active range of motion and physical therapy should be encouraged. The tendons should not be loaded until six weeks post-operatively. In addition, several pre-operative sessions are recommended for best achievement of rehabilitation objectives, although these may not be feasible. Figure 6 shows a schematic algorithm on post-operative management.

Figure 6
Flowchart on post-treatment rehabilitation on peroneal tendon injuries



Rationale
A broad range of rehabilitation protocols has been described without enough scientific support to enable proposing any evidence-based post-operative protocol.[47] Based on a recent review by van Dijk et al, presenting an overview of all different protocols being used, the panel agreed that it is mandatory to distinguish whether or not the SPR was repaired during the surgical procedure.[47] In cases where the SPR was not repaired, but the stabilization of the tendons relied on the groove deepening alone, the immobilization time should be minimalized to prevent tethering of the tendon(s). It is, therefore, recommended to aim for an immobilization period no longer then four weeks. The panel agreed that in the future, this period of protection might be shortened.

When the SPR is formally repaired, a minimum immobilization time of six weeks is important for sufficient healing of the retinaculum. The initial two-weeks non-weight bearing is advised. After these two weeks, the patient is allowed weight-bearing immobilization combined with physiotherapy and supervised range of motion to allow peroneal movement while protecting the repaired SPR. For optimal healing, pain free loading of the peroneal tendons should not be performed until six-weeks post-operative. The panel agreed that commencement of running activities should not be based on time criteria, but rather be dependent upon the patient's pre-operative condition, the ability to perform a single heel rise, and the patient's overall strength, neuromuscular control, and proprioceptive ability.

Conclusion
Considering the scarce published knowledge, this consensus statement on peroneal tendon pathology summarizes the most practical and scientifically supported diagnostic and treatment algorithms for enabling optimized management of peroneal tendon pathology. The guidelines are based on international and multidisciplinary expert agreement following the Nominal Group Technique, combined with a systematic review of available literature.

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PART 6

CONCLUSIONS AND FUTURE PERSPECTIVES

CHAPTER 11

General discussion and future perspectives

Chapter 11: General discussion and future perspectives

"There is no simple peroneal tendon disorder"[1]

Once being considered the underdog of the ankle, nowadays it is hard to underestimate the importance of the peroneal tendons. Whether standing on bare feet or wearing high heels, when it comes to our mobility, the peroneal tendons do their utmost to keep us upright.[2] This thesis highlights the peroneal tendons throughout the whole spectrum - from epidemiology and anatomy to diagnostics, treatment and rehabilitation – with its primary aim to optimize the management of peroneal tendon disorders.

Epidemiology

Comprehending the breadth of peroneal tendon disorders has rapidly evolved in recent years, especially in the active population. Many studies on peroneal tendon disorders start with statements such as 'Peroneal tendon pathology is becoming an increasingly recognized source of lateral-sided ankle pain…'[3], 'Although once thought to be rare…'[4], and 'Peroneal tendon injuries are common…'[5,6]. On the other hand, recent epidemiological studies in professional athletes reported a relatively low injury incidence.[7,8] In our study among professional football players in **Chapter 2**, the peroneal tendons were affected in only 2.4 % of the injuries related to the ankle.[7] Since active individuals who perform repetitive ankle movements – such as professional football players – are generally at higher risk for ankle injuries, this incidence seems fairly low.[7]

Earlier studies indeed showed higher rates of peroneal tendon disorders. For example, cadaveric studies found a peroneus brevis tear in 11 – 37 % of all cadavers.[9,10] In clinical studies among patient with chronic ankle instability, a peroneal tendon disorder was found in 23 – 77 % of the patients.[11-14] More in line with our current study, a cohort study among professional American football players reported a peroneal tendon disorder in only 4.0 % of all injuries related to an ankle sprain.[8] This low incidence among professional athletes compared to cadaveric and clinical studies might be explained by the fact that peroneal tendon disorders tend to get misdiagnosed and reported as an ankle sprain.[15] Moreover, peroneal tendon disorders are often classified as mild.[12,16,17] As professional athletes have less incentive to report mild injuries, it might be that not all peroneal tendon disorders were reported to the medical staff. This can be extended to the general population where not all patients with mild lateral ankle complaints find their way to an orthopedic surgeon, resulting in a higher incidence of peroneal tendon disorders in cadavers compared to clinical practice. In this way, our reported incidence in professional athletes could well be underestimated and the real incidence could be higher than observed.

11

Anatomy

The peroneal muscles and tendons jointly form the lateral compartment of the lower leg and act as the primary plantarflexion evertors of the foot. Moreover, they play an important role in the active stabilization of the ankle. Throughout history, with only limited evidence available, the vascularization of the peroneal tendons remained controversial.[18-20] In 2000, Petersen et al postulated that the peroneal tendons exhibited critical avascular zones that possible contribute to the development of pathology.[19] In contrast, Sobel et al found no proof for any avascular zones within the tendons.[20]

Our study on the arterial anatomy of the peroneal tendons in **Chapter 3** found that both peroneal tendons are well vascularized by distal branches of the peroneal artery, the anterior lateral malleolar branch of the anterior tibial artery or a communicating branch between the peroneal artery and the posterior tibial artery.[21] These branches enter the tendons through a common vincula which originates from the dorsolateral aspect of the fibula and runs down to the insertion of both tendons, just as described by van Dijk and Kort in 1998.[18] Such vincula were earlier found to play a crucial role in vascularization of tendons in general, as they provide intratendinous nutrient diffusion and oxygenation through longitudinal vessels .[22,23]

Studying the vincula and the intratendinous vascularization in the peroneal tendons, no avascular zones were found in the peroneus brevis, while 20 % of the cadavers showed avascular zones within the peroneus longus tendon. Interestingly, a more recent cadaveric study by Gomes et al found this same vincula without any avascular zones in the peroneus longus tendon, while 23 % of the studies cadavers had avascular zones within the peroneus brevis tendon.[24] As both studies concluded, it is fair to say that the common vincula plays an important role in the vascularization of the peroneal tendons and care should be taken to leave this vincula intact during surgical treatment in order to keep the tendons well vascularized and improve its healing tendency. Moreover, in case of other ankle injuries such as calcaneofibular ligament ruptures or talar fractures, the peroneal vincula should be kept in mind. As the calcaneofibular ligament is closely related to the peroneus brevis tendon and covered by the sheath of the peroneal tendons, concomitant damage to the peroneal might occur in case of ligamentous injuries.[25] During surgical repair of the calcaneofibular ligament, damage to the common vincula of the peroneal tendons should therefore actively be avoided.

Another pathology closely related to the peroneal tendons includes Jones fractures. Suggested in earlier studies and confirmed in our study in **Chapter 4**, the peroneus brevis tendon inserts on the base of the fifth metatarsal and lays proximal or overlaps the Jones fracture line in all cases.[26] In this way, the tendon possibly contributes to the fracture mechanism and/or delayed fracture healing by its pulling effect that might potentiate displacement of the fracture fragment or unrealized tissue interposition in the fracture site.[27-32] Farrow et al demonstrated that fractures distal to the peroneus brevis insertion are more unstable than proximal fractures and stated that the insertions' mechanical component may contribute to the poor healing potential of Jones fractures. Other studies showed that impaired post-operative stability and early mobilization of the fracture may lead to treatment failure.[33-35] Immobilization of the peroneus brevis tendon, whether conservative or by surgical fixation of the fracture, likely subjects a healing Jones fracture to less deforming force from pull the peroneus brevis tendon.[36]

In line with earlier studies, our study in **Chapter 4** found that intramedullary screws used for the treatment of Jones fractures compromised the insertion of the peroneus brevis tendon to some degree.[37] The effect to which even minimal damage of the insertion has on outcome, however, remains unclear and has to be further investigated. In order to prevent (further) displacement of the fracture and to minimize iatrogenic damage of the tendon, care should nonetheless be taken to consider the peroneus brevis tendon carefully during treatment of Jones fractures.

Diagnostics

Based on a thorough review of the literature in **Chapter 5**, early identification and proper management of peroneal tendon disorders seem essential to prevent tendon deterioration.[38] Patient history and physical examination form the first, and perhaps most important, step to diagnose peroneal tendon disorders.[38-40] During the ESSKA-AFAS consensus meeting on peroneal tendon disorders in **Chapter 10**, it was generally agreed that when a patient is clinically suspected of a peroneal tendon disorder, both magnetic resonance imaging and ultrasound are appropriate diagnostic tools to further specify the location and severity of the disorder and to evaluate surrounding structures.[39] To date, while dynamic ultrasonography is gaining popularity due to its in-office availability, low cost, speed of use, and dynamic capabilities[41,42], magnetic resonance imaging remains the golden standard in diagnosing peroneal tendon disorders.[15,43,44]

Over the recent years, the quality and technique of magnetic resonance imaging in evaluating tendons has increased. Earlier studies report fairly poor reliability of magnetic resonance imaging due to diagnostic challenges such as the difficulty to differentiate between different peroneal tendon pathologies and the magic angle effect.[45-48] In a retrospective review by O'Neill et al in 2010, assessing different ankle lesions in patient with ankle instability, only 56 % of peroneal tendon tears diagnosed at the time of surgery were seen on pre-surgical MRI.[45] Moreover, a study by Giza et al found a positive predictive value of only 48 %.[47] With the use of high(er) resolution 1.5 and 3.0-Tesla scanners, better scanning protocols and techniques such as the oblique view, and increased awareness for peroneal tendon disorders, better correlation between magnetic resonance imaging- and perioperative findings was found.[49,50] Our prospective review on peroneal tendon disorders in **Chapter 6**, using a 3.0 Tesla scanner, found an overall magnetic resonance imaging sensitivity of 0.90 (95 % CI 0.82 – 0.95) and specificity of 0.72 (95 % CI 0.62 – 0.80), with a positive predictive value of 0.76 (95 % CI 0.68 – 0.83).[51]

Despite radiological innovations, in some cases diagnosing peroneal tendon disorders remains challenging. In patients with a high clinical suspicion for a peroneal tendon disorder but a lack of positive findings on diagnostic modalities, peroneal tendoscopy can offer a good remedy.[39,51] Some authors, however, still consider this tendoscopic technique relatively invasive with risks such as neurovascular and cartilage damage.[52] Recent attention has been drawn to even less-invasive techniques using smaller portals and instruments, also known as 'needle- or nanoscope arthroscopy.[52,53] Earlier studies found this techniques to be save and effective in the visualization of the peroneal tendon, but further research is needed to divine possible indications for the use of this technique in peroneal tendon disorders.[54,55]

Treatment

As agreed upon during the ESSKA-AFAS consensus meeting in **Chapter 10**, although based on limited available evidence[56,57], conservative treatment should be considered first when treating patients with a (symptomatic) peroneal tendon disorder.[39] In case conservative treatment fails, numerous surgical interventions have been proposed in the treatment of peroneal tendon disorders, mostly with promising outcomes.[38]

As described in the paragraph 'Diagnostics', peroneal tendoscopy is useful as a diagnostic tool but also offers treatment opportunities without the inherent risk of complications associated with open surgical techniques.[7-49] In line with earlier studies, our prospective case series in Chapter 6 recommended tendoscopic debridement and fibular groove deepening when treating different peroneal tendon disorders.[51,58-60] Prospectively studying 23 patients with a peroneal tendon disorder, peroneal tendoscopy performed by a senior foot and ankle specialist was found to be an effective minimally invasive treatment tool. Both tendoscopic debridement of inflamed or damaged tissue and a fibular groove deepening in case of tendon tears, stenosis and subluxation resulted in significant improvement of post-operative outcomes. In contrast to other studies, no superior peroneal retinaculum ruptures were found in the study, neither on MRI nor during peroneal tendoscopy. In this way, tendoscopic retinaculum repair could not be evaluated. Other studies, however, found promising results following tendoscopic repair of the superior peroneal retinaculum.[61-63] Both as a diagnostic and a treatment tool, therefore, peroneal tendoscopy seems an effective and save technique with the caveat that the surgeon should be well trained in performing the procedure.

In the treatment of peroneal tendon dislocation, over twenty operative techniques have been described in literature without general consensus on best management strategy. Chapter 7 included a systematic review comparing functional outcomes of all surgical techniques used in peroneal tendon dislocation.[64] It was found that all proposed techniques, while being widely divergent, attempted to restore the superior peroneal tunnel. The most common treatment strategies could be generally divided in two categories: (i) repair or reconstruction of the superior peroneal retinaculum, and (ii) retromalleolar groove deepening. Both techniques were found successful surgical options in treating peroneal tendon dislocation. Groove deepening procedures, however, were associated with a higher rate of return to sports. As athletes require sufficient repetitive ankle movements and strong active ankle stability, adequate stability of the tendons within the peroneal groove is demanded. As diminished volume of the superior peroneal tunnel may render tendons more prone to dislocation, it could well be that repair of the retinaculum alone does not solve the underlying cause of the pathology.[39] In fact, the volume of this tunnel may even decrease by repair of the retinaculum alone. On the other hand, groove deepening provides a higher tunnel-volume and better stabilization of the peroneal tendons behind the malleolus.[65] In a cadaveric biomechanical study, Title et al found significant decreased pressure within the superior peroneal tunnel after a groove deepening procedure, reducing the risk of redislocation.[66] Based on these results, the ESSKA-AFAS consensus statement in Chapter 10 concluded that there is insufficient evidence to recommend performing a groove deepening procedure in all non-athletic patients. For elite athletes, on the other hand, surgical treatment including both repair of the superior peroneal retinaculum and deepening of the retromalleolar groove was recommended.

In Chapter 8, a groove deepening and superior peroneal tendon retinaculum repair technique was proposed combining the strengths of earlier proposed techniques, while being less technical demanding.[67-73] The procedure aimed to (i) avoid the creation of an eccentric or unpredictable cortical flap by using a reproducible single-step centralized reaming technique, (ii) preserve the protective fibrocartilage layer within the retromalleolar groove in order to prevent possible damage to the tendons, and (iii) prevent iatrogenic damage to the fibula for better stability. While two foot and ankle specialist have performed this technique over 9 years with good results, true evidence is needed to validate this technique.

Rehabilitation

Surgically treated flexor tendons such as the peroneal tendons tend to form adhesions between the repaired tendon and surrounding scar tissue.[74-77] For optimal rehabilitation of any flexor tendon, a balance between adequate healing and early range of motion seems therefore essential. Based on systematic review of the poorly available literature on this topic, Chapter 9 provided an evidence- and personal experience-based rehabilitation program following surgical treatment of peroneal tendon disorders.

A wide variation in rehabilitation protocols after surgically treated peroneal tendon tears was found in literature without strong consensus. While most studies immobilized their patients at least six weeks, two authors were found to have changed their post-operative management throughout the years towards shorter immobilization time and early range of motion practice.[78-80] Within one study, Demetracouplos et al changed their earlier post-operative protocol from six weeks of immobilization to a protocol aiming for range of motion after four weeks of immobilization.[80] Karlsson et al used to immobilize patients for six weeks[78], but shortened this immobilization period in a study published four years later.[79] Based on the best available evidence, our proposed rehabilitation program suggested six weeks of immobilization in general, after which range of motion may be slowly started. In specific patients, however, earlier range of motion may be pursued. In case of repair of the superior peroneal retinaculum, on the other hand, it was suggested that provocation of the tendons should generally wait until twelve weeks after surgery.

Years after publication of the protocol, when discussed with foot and ankle experts from all over the world during the ESSKA-AFAS consensus meeting, this protocol seemed a bit defensive.[39] The consensus statement dared to be more progressive, stating that rehabilitation should be goal- and not time-based with the promotion of early mobilization. After surgical repair of the retinaculum, however, a minimal immobilisation of six weeks was still recommended with active range of motion and physical therapy be encouraged at two weeks postoperative.

Both publications concluded that tailoring rehabilitation to the pathology's nature and demands of each specific patient is essential to optimize recovery. Expounding on this further, I strongly believe that individualizing management of patients with peroneal tendon disorders will optimize their outcomes and most predictably return them to being actively on their feet!

Future perspectives

As with most research, the content of this thesis probably raised more questions than it has answered. In this manner, it lays a foundation for further studies towards better management of peroneal tendon disorders.

Derived from the famous words of Benjamin Franklin in 1736, the old Dutch saying goes: 'prevention is better than cure'. There is indeed considerable potential in the area of prevention of peroneal tendon disorders. Chapter 2, for instance, suggested that prevention of chronic overload of the ankle might help in reduction of peroneal tendon disorders, but further epidemiological and clinical studies are needed to better determine what strategies would be most effective and which patients would benefit most from preventive strategies.[7]

Diagnosing peroneal tendon tears remains challenging. **Chapter 6** has shown that magnetic resonance imaging is a reliable tool for diagnosing peroneal tendon tears.[51] Moreover, a recent pilot study suggested that preoperative magnetic resonance imaging can be useful to analyse the quality of peroneal muscle tissue using the Goutallier classification.[81] This Goutallier classification was earlier found to be reliable in patients with rotator cuff tears showing correlation between the severity of the pathology and clinical outcome following cuff repair.[82] The pilot study found that patients with a peroneus brevis tear demonstrated significantly more fatty degeneration than patients without a tear, suggesting future potential for preoperative magnetic resonance imaging to guide the choice of surgical treatment technique and predict surgery outcome.[81] A randomized study is currently being carried out to validate and better understand the clinical utility and reliability of the Goutallier classification in patients with a peroneal tendon tear, including its implications with respect to severity of the pathology and clinical outcome after treatment.

Peroneal tendoscopy is recommended as diagnostic tool in patients with a high clinical suspicion for peroneal tendon pathology but a lack of positive findings on imaging.[39,51] Moreover, this minimally invasive technique allows for treatment opportunities without the inherent risk of complications associated with open surgery.[59,83,84] Nevertheless, some authors still consider this tendoscopic technique relatively invasive with risk of neurovascular and cartilage damage[52,85]. Interestingly, in the early days of arthroscopy the use of rather small instruments with a diameter of only 16 – 30 mm was described.[85,86] Due to disadvantages such as easily broken instruments and lack of treatment opportunities, however, bigger instruments were invented that are currently still being used. With our current improvements in knowledge and technique, recent attention has again been drawn to the use of smaller instruments such as 'needle- or nanoscope arthroscopy.[53,55] The technique was found to be safe and effective in the visualization of the peroneal tendon, but further research is needed to define possible indications for the use of this technique in peroneal tendon disorders.[52-55]

With only little available evidence on outcomes after both conservative and surgical treatment of several peroneal tendon disorders including tendinopathy, tendon tears and painful os peroneum syndrome, further research should focus on analyzing long-term outcomes after treatment. Patient reported outcome measures are found to be a reliable research tool in relatively rare foot and ankle disorders and therefore could be helpful in evaluating our current peroneal tendon practice.[87] Furthermore, it may be a valuable tool in predicting treatment outcomes.

As it comes to rehabilitation after surgical management of peroneal tendon pathology, this thesis proposed a recovery program based on level IV and V evidence which was later revised based on expert opinion.[39,64] With rehabilitation after surgery being as important as the surgical procedure itself, better evidence is necessary in order to optimize treatment outcomes. A randomized controlled trial could determine the possible benefits of shorter immobilization time and earlier range of motion.

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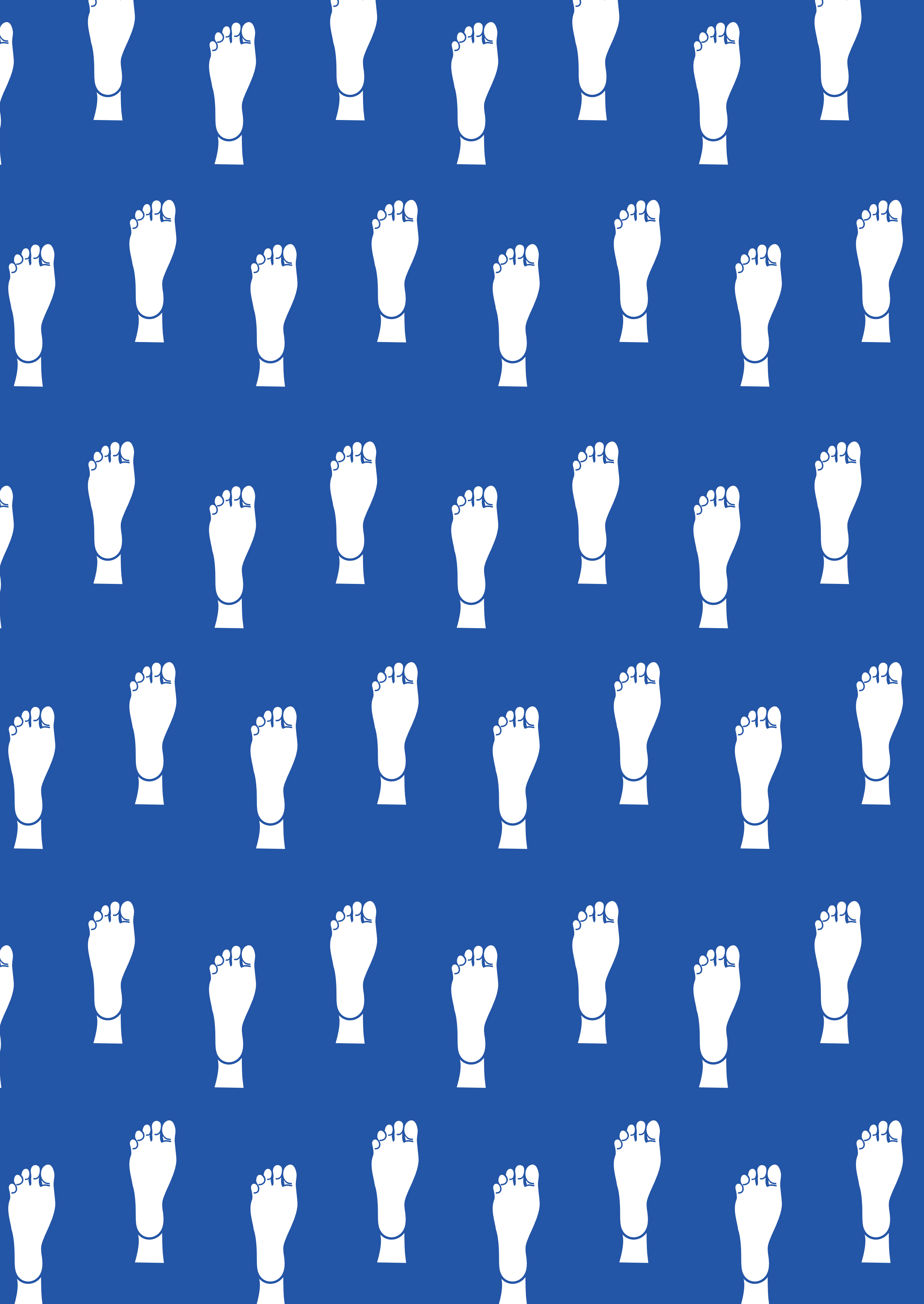

CHAPTER 12

Summary

including take away messages for management of peroneal tendon disorders in daily practice

Chapter 12. Summary, including take away messages for management of peroneal tendon disorders in daily practice

"There is no simple peroneal tendon disorder"[1]

Introduction

Chapter 1 provided a general introduction on peroneal tendon disorders: a potentially serious cause of posterolateral ankle problems that can be debilitating when left un- or incompletely addressed. This thesis aimed to review and advance management of peroneal tendon disorders by studying various issues throughout the whole spectrum - from epidemiology and anatomy to diagnostics, treatment and rehabilitation.

Part 1 Epidemiology

Peroneal tendon disorders are assumed to be most frequent in the young and active population. **Chapter 2** therefore evaluated the incidence and epidemiological characteristics of peroneal tendon disorders in professional football players, using the UEFA Champions League and the English Premier League database.

Within this large prospective database, including 69 football teams with a total of 18,631 disorders during 424,441 hours of match exposure and 2.331.768 hours of training, the peroneal tendons were affected in only 2.4 % of the disorders related to the ankle. Most of these peroneal tendon disorders resulted from overuse, but patients with a traumatic injury required a longer recovery period and players with a reinjury reported a higher injury burden. Results of the study suggested that prevention of chronic ankle overload might help in prevention of peroneal tendon disorders. Moreover, especially after traumatic- or re-injuries, caution should be exercised in the management of football players with a peroneal tendon disorder to prevent a prolonged rehabilitation or reinjury.

Part 2 Anatomy

The second part of the thesis focused on the peroneal tendon's anatomy in relation to pathophysiology of both the tendons itself as well as the surrounding structures.

Vascularization of the peroneal tendons
Chapter 3 analyzed the macroscopic arterial anatomy of the peroneal tendons in ten cadavers, using intravascular natural colored latex. Moreover, the Spätleholz technique - providing transparent three-dimensional structures - was used to visualize the intra-tendinous vascularization.

Both peroneal tendons were found to be well vascularized by distal branches of the peroneal artery, the anterior lateral malleolar branch of the anterior tibial artery or a communicating branch between the peroneal artery and the posterior tibial artery. These branches entered the tendons through a common vincula, originating from the dorsolateral aspect of the fibula and running down all the way to the insertion of both tendons. No avascular zones were distinguished in the peroneus brevis, while 20 % of the cadavers showed avascular zones within the peroneus longus tendon.

As the common vincula played an important role in the vascularization of the peroneal tendons, the study concluded that care should be taken to leave this vincula intact during surgical treatment of any peroneal tendon disorder in order to keep the tendons well vascularized and improve healing tendency.

Insertion of the peroneus brevis tendon in relation to Jones fractures
Chapter 4 studied the relation between the peroneus brevis insertion and Jones fractures. In the 21 cadaveric bones that were included, the peroneus brevis inserted proximal from the Jones fracture line in 71 % and overlapped the Jones fracture line in the other 29 %. Due to (i) the peroneus brevis tendon's force vector whose pull potentiates displacement of basilar type fifth metatarsal fractures and (ii) unrealized tissue interposition at the fracture site, it is believed this tendon can contributes to both fracture mechanism as well as delayed fracture healing. Immobilization of the peroneus brevis tendon, whether conservative or by surgical fixation of the fracture, may therefore prove to be beneficial to proper healing of basilar type fifth metatarsal and Jones fractures. In case of surgical treatment, intramedullary screws used for the treatment of Jones fractures damaged the insertion of the peroneus brevis tendon in 33 % of the cadavers with a median surface loss of 1.6 % (range 0.2 – 3.2 %). The effect to which even minimal damage of the insertion has on outcome, however, remains unclear and has to be further investigated. Care should nonetheless be taken to consider the peroneus brevis tendon carefully during treatment of Jones fractures, both in order to prevent (further) displacement of the fracture and to minimize iatrogenic damage of the tendon.

Part 3 Diagnostics and treatment

The third part of this thesis focused on the advancement of diagnostics methods and treatment of peroneal tendon disorders.

Chronic peroneal tendon pathology
Chapter 5 included a current concept review on the management of chronic peroneal tendon disorders. Review of the literature yielded that early identification and proper management of peroneal tendon disorders are essential to prevent further deterioration of the tendons. Patient history and physical examination were identified as key to diagnosing peroneal tendon disorders. To further specify the location and severity of the disorder, and to evaluate surrounding structures, both MRI and ultrasound were found useful. In treatment, different surgical interventions were associated with promising outcomes in case conservative measures failed. Extra attention should be paid to address predisposing factors such as pes cavus, hindfoot varus, accessory tendons, or stability of the ankle, since these factors were associated with poorer treatment outcomes.

Magnetic resonance imaging and tendoscopy in diagnosing and treating peroneal tendon disorders
In Chapter 6, a retrospective case series evaluated tesla 3.0 MRI as a diagnostic tool and peroneal tendoscopy as a treatment technique in the management of peroneal tendon disorders. In 23 patients, the correlation of MRI and perioperative peroneal tendoscopic findings was analyzed. After tendoscopy, long-term clinical outcomes were evaluated

using the Foot and Ankle Outcome Score and the Short Form-12 outcome questionnaires. MRI showed an overall sensitivity of 0.90 (95 % CI 0.82 – 0.95) and specificity of 0.72 (95 % CI 0.62 – 0.80) with a positive predictive value of 0.76 (95 % CI 0.68 – 0.83), suggesting that tesla 3.0 MRI is useful in diagnosing clinically suspected peroneal tendon disorders. At a mean follow-up of 33 ± 7.3 months both outcome scores improved significantly after treatment with peroneal tendoscopy, with only one out of 23 patients complaining of persistent lateral ankle pain. For a variety of peroneal tendon pathologies, therefore, tendoscopy was found to be an effective and safe treatment.

Peroneal tendon dislocation

Chapter 7 included a systematic review comparing functional outcomes of the varied surgical techniques described in the treatment of peroneal tendon dislocation. A total of fourteen studies was included. The most common treatment strategies could be generally divided in two categories: (i) repair or reconstruction of the superior peroneal retinaculum, and (ii) retromalleolar groove deepening. Both techniques showed significant better functional outcomes after surgery. A combination of both strategies, however, was associated with a higher return-to-sports rate. With peroneal tendon dislocation being most present in the athletic population, the study recommended a combination of groove deepening and repair of the superior peroneal retinaculum in active patients with a peroneal tendon dislocation. In Chapter 8, such groove deepening and superior peroneal tendon retinaculum repair technique was proposed. This technique aimed to (i) avoid the creation of an eccentric or unpredictable cortical flap, (ii) preserve the protective fibrocartilage layer within the retromalleolar groove, and (iii) prevent iatrogenic damage to the fibula.

Part 4 Rehabilitation

Based on systematic review of the literature, Chapter 9 provided an evidence- and personal experience-based rehabilitation program following surgical treatment of peroneal tendon disorders. A total of 49 studies was included and information on the applied rehabilitation program was extracted from each study. There was no general consensus in literature on optimal rehabilitation, ranging from zero to twelve weeks, but a trend was found towards shorter immobilization time and earlier range of motion practice.

The proposed rehabilitation program suggested six weeks of immobilization after which range of motion can be slowly started. It was suggested that provocation of the tendons should generally wait until twelve weeks postoperative. For optimal recovery, however, the rehabilitation program should be tailored to the nature of the pathology and demands of each specific patient. For example, in cases where the superior peroneal retinaculum remained intact during treatment, range of motion might be started earlier.

Part 5 International consensus guideline

Chapter 10 included the ESSKA-AFAS consensus statement based on international and multidisciplinary expert agreement following the Nominal Group Technique, combined with a systematic review of available literature including the content of this thesis. Statements were made on anatomy, classification, diagnostic modalities, treatment and rehabilitation. The most important recommendations are summarized in the key takeaways below.

Key takeaways for management of peroneal tendon disorders in daily practice

This thesis proposed the following eight key takeaways for management of peroneal tendon disorders in daily clinical practice, based on practical and scientifically supported considerations:

1. Important anatomical considerations: overstuffing of the retromalleolar peroneal tunnel and the peroneal vincula
Multiple anatomical variations predispose peroneal tendon disorders, with 'overstuffing' of the retromalleolar peroneal tunnel and chronic overloading of the tendons being of paramount importance. Moreover, the peroneal vincula plays an essential role in the vascularisation of the tendons and care should be taken to leave the vincula intact during treatment.

2. Classification is based on pathology and differentiation between athletes and non-athletes
Peroneal tendon disorders are best classified based on type of the pathology: (1) tendinopathy, (2) tears or ruptures and (3) instability or dislocation of the tendons. Moreover, differentiation between athletes and non-athletes is important for optimal management of peroneal tendon disorders.

3. Evolving diagnostic tools include ultrasound, MRI and peroneal tendoscopy
Patient presenting with an acute ankle injury should be evaluated using the Ottawa ankle guidelines. When a patient is clinically suspected of a peroneal tendon disorder, both magnetic resonance imaging and ultrasound are appropriate diagnostic tools. Peroneal tendoscopy is useful in patients with a high clinical suspicion of a peroneal tendon disorder after patient history and examination, but with negative imaging findings.

4. In general, conservative strategies should be considered first
Conservative treatment should be considered in all symptomatic patients with a peroneal tendon disorder. Treatment in the acute phase includes rest, ice, compression and elevation after which range of motion and tendon loading exercises can be started.

5. Only treat symptomatic peroneal tendon tears
Only symptomatic peroneal tendon tears should be treated, with conservative management being the first step. In case surgical treatment is required, debridement and repair of the tendon(s) should be attempted first. In cases this is not clinically feasible, single-stage autograft with the hamstrings, or side-to-side tenodesis is recommended with grafting being preferred over tenodesis if possible. If both tendons are irreparable and their muscles unhealthy, single-stage autograft transfer is recommended.

6. Treatment of peroneal tendon ruptures primarily includes direct repair
Symptomatic ruptures of one or both tendons generally require surgical repair. If repair is clinically impossible, single-stage hamstring autograft or side-to-side tenodesis are recommended. Tendon transfer, using either the tendon of the flexor hallucis longus or the flexor digitorum longus, should be considered as a last resort treatment.

7. Surgical treatment of peroneal tendon instability/dislocation is generally recommended
Conservative treatment of peroneal tendon dislocation may be considered in non-athletic patients, taking into account that the risk of recurrent dislocation is high. In non-athletic patients, both surgical repair of the superior peroneal retinaculum alone or in combination with retromalleolar groove deepening can be considered. In athletic patients, surgical treatment including both repair of the superior peroneal retinaculum and deepening of the retromalleolar groove should be favoured.

8. Tailor rehabilitation to the specific patient
Peroneal rehabilitation depends on whether or not the superior peroneal retinaculum is repaired during surgical treatment. If not, rehabilitation should be goal based with early range of motion and mobilization. After repair of the retinaculum, six weeks of immobilization is recommended with active range of motion and physical therapy being encouraged at two weeks postoperative. Loading of the tendons should be avoided until six weeks after the surgery.

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CHAPTER 13

Dutch summary / Nederlandse samenvatting

inclusief aanbevelingen voor behandeling van peroneus pees pathologie in de dagelijkse praktijk

Chapter 13. Dutch summary / Nederlandse samenvatting, inclusief aanbevelingen voor behandeling van peroneus pees pathologie in de dagelijkse praktijk

"Er zijn geen simpele peroneuspees aandoeningen"[1]

Inleiding

Hoofdstuk 1 bevat een algemene inleiding over peroneuspees aandoeningen: een oorzaak van posterolaterale enkelklachten die invaliderend kunnen zijn wanneer deze inadequaat worden behandeld. Het doel van dit proefschrift was om de behandeling van peroneuspees aandoeningen te verbeteren, door verschillende aspecten van deze aandoeningen te bestuderen - van epidemiologie en anatomie tot diagnostiek, behandeling en revalidatie.

Deel 1 Epidemiologie

In de literatuur wordt aangenomen dat peroneuspees aandoeningen het meest voorkomen bij de jonge en actieve bevolking. **Hoofdstuk 2** evalueerde daarom de incidentie en epidemiologische karakteristieken van peroneuspees aandoeningen bij professionele voetbalspelers, door gebruik te maken van data uit de UEFA Champions League en de Engelse Premier League.

Binnen deze grote prospectieve databases, met 69 voetbalteams en een totaal van 18.631 blessures gedurende 424,441 wedstrijduren en 18,631 trainingsuren, waren de peroneuspezen in slechts 2,4 % van de enkelblessures aangedaan. Het overgrote deel van deze peroneuspees aandoeningen waren het gevolg van overbelasting, terwijl patiënten met een traumatische blessure een langer herstel nodig hadden en spelers met een recidief een hogere blessurebelasting rapporteerden.

De resultaten van de studie suggereerden dat preventie van chronische overbelasting van de enkel zou kunnen helpen bij het voorkomen van peroneuspees aandoeningen. Bovendien moet, vooral na traumatische- or herblessures, voorzichtigheid worden betracht bij de behandeling van voetbalspelers met een peroneuspees aandoening om een langdurige revalidatie of recidief te voorkomen.

Deel 2 Anatomie

Het tweede deel van het proefschrift richtte zich op de anatomie van de peroneuspezen in relatie tot de pathofysiologie van zowel de pezen zelf als de omliggende structuren.

Vascularisatie van de peroneuspezen
Hoofdstuk 3 analyseerde de macroscopische arteriële anatomie van de peroneuspezen in tien kadavers door de arteriën op te spuiten met natuurlijk gekleurd latex. Daarnaast werd de Spätleholz techniek – een techniek om driedimensionale structuren transparant te maken – gebruikt om de intratendineuze vascularisatie in beeld te brengen.

Beide peroneuspezen bleken goed gevasculariseerd te zijn door distale takken van de a. peroneus, de anterolaterale tak van de a. tibialis anterior of een communicerende tak tussen de a. peroneus en de a. tibialis posterior. Deze takken kwamen de pezen binnen via een gemeenschappelijke vincula, die zijn oorsprong vond aan het dorsolaterale aspect van de fibula en doorliep tot aan de insertie van beide pezen. Er werden geen avasculaire zones onderscheiden in de peroneus brevis. In 20 % van de kadavers werden avasculaire zones gevonden in de peroneus longus.

Aangezien de gemeenschappelijke vincula een belangrijke rol speelde in de vascularisatie van de peroneuspezen, concludeerde de studie dat deze vincula zoveel mogelijk intact moet worden gelaten tijdens een chirurgische behandeling, om de pezen goed gevasculariseerd te houden en de genezing te bevorderen.

Aanhechting van de peroneus brevis pees in relatie tot Jones fracturen
Hoofdstuk 4 bestudeerde de relatie tussen de peroneus brevis insertie op de basis van os metatarsi V en Jones fracturen. In de 21 kadavers die werden geïncludeerd, insereerde de peroneus brevis in 71 % proximaal van de Jones fractuurlijn, en overlapte de insertie de Jones fractuurlijn in de overige 29 %. De peroneus pees lijkt op deze manier bij te dragen aan zowel het fractuurmechanisme als vertraagde fractuurgenezing van de Jones fractuur door (i) (verdere) dislocatie van het fractuurfragment door de trekkracht van de peroneuspees, en (ii) mogelijke weefselinterpositie in de fractuur. Immobilisatie van de peroneus brevis pees, hetzij conservatief hetzij door chirurgische fixatie van de fractuur, zou daarom gunstig zijn voor een genezende Jones fractuur.

In geval van chirurgische behandeling van Jones fracturen, beschadigden intramedullaire schroeven de insertie van de peroneus brevis pees in 33 % van de kadavers met een mediaan oppervlakteverlies van 1.6 % (range 0.2 – 3.2 %). Het effect van zelfs minimale beschadiging van de aanhechting op het behandelresultaat blijft echter onduidelijk en moet verder worden onderzocht. Niettemin dient bij de behandeling van Jones fracturen zorgvuldig met de peroneus brevis pees te worden omgegaan om zowel (verdere) verplaatsing van de fractuur te voorkomen als om iatrogene beschadiging van de pees tot een minimum te beperken.

Deel 3 Diagnostiek en behandeling

Het derde deel van dit proefschrift was gericht op diagnostische methoden en behandeling van peroneuspees aandoeningen.

Chronische peroneuspees pathologie
Hoofdstuk 5 bevat een overzicht van de huidige inzichten in de behandeling van chronische peroneuspees aandoeningen. Literatuuronderzoek wees uit dat vroege herkenning en adequate behandeling van peroneuspees aandoeningen essentieel zijn om verdere verslechtering van de pezen te voorkomen. Anamnese en lichamelijk onderzoek van de patiënt werden geïdentificeerd als sleutel tot de juiste diagnose van peroneuspees aandoeningen. Om de lokalisatie en de ernst van de aandoening verder te specificeren, en om de omliggende structuren te evalueren, werden zowel MRI als echografie nuttig bevonden. Bij de behandeling werden verschillende chirurgische ingrepen geassocieerd met goede resultaten mocht conservatieve behandeling zijn gefaald. Extra aandacht moet worden besteed aan predisponerende factoren zoals een pes

cavus, varus van de achtervoet, accessoire pezen of instabiliteit van de enkel, aangezien deze factoren geassocieerd waren met slechtere behandelingsresultaten.

MRI en tendoscopie bij de diagnose en behandeling van peroneuspees aandoeningen
In **Hoofdstuk 6** wordt in een retrospectieve case serie (i) de tesla 3.0 MRI als diagnostisch instrument en (ii) peroneus tendoscopie als behandelingstechniek geëvalueerd. Bij 23 patiënten werd de correlatie van MRI en perioperatieve peroneale tendoscopische bevindingen geanalyseerd. Na tendoscopie werden de klinische resultaten op lange termijn geëvalueerd met behulp van de Foot and Ankle Outcome Score en de Short Form-12 uitkomstvragenlijsten.

MRI toonde een sensitiviteit van 0.90 (95 % betrouwbaarheidsinterval 0.82 – 0.95) en specificiteit van 0.72 (95 % betrouwbaarheidsinterval 0.62 – 0.80) met een positief voorspellende waarde van 0.76 (95 % betrouwbaarheidsinterval 0.68 – 0.83), wat suggereert dat tesla 3.0 MRI nuttig is bij de diagnose van klinisch verdachte peroneuspees aandoeningen. Bij een gemiddelde follow-up van 33 ± 7.3 maanden verbeterden beide uitkomstscores significant na behandeling met peroneus tendoscopie, waarbij één van de 23 patiënten klaagde over persisterende pijn in de laterale enkel. Voor een verscheidenheid van peroneuspees aandoeningen werd tendoscopie daarom als een effectieve en veilige behandeling bevonden.

Peroneuspees dislocatie
Hoofdstuk 7 omvatte een systematisch literatuuronderzoek waarin de functionele uitkomsten van alle beschreven operatietechnieken bij de behandeling van peroneuspees dislocatie werden vergeleken. In totaal werden veertien studies geïncludeerd. De meest voorkomende behandelingsstrategieën konden worden verdeeld in twee categorieën: (i) reparatie of reconstructie van het retinaculum musculorum fibularum, en (ii) uitdiepen van de retromalleolaire groeve. Beide technieken lieten significant betere functionele resultaten zien na chirurgie, waarbij een combinatie van de technieken resulteerde in een hoger percentage terugkeer naar de sport.

Aangezien peroneuspees dislocatie het meest lijkt voor te komen bij de atletische populatie, werd in de studie aanbevolen om bij actieve patiënten met een peroneuspees dislocatie te behandelen met een combinatie van het uitdiepen van de groeve en herstel van het retinaculum musculorum fibularum.

In **Hoofdstuk 8** werd een dergelijke techniek voor het uitdiepen van de groeve en herstel van het retinaculum musculorum fibularum voorgesteld. Deze techniek had tot doel (i) het creëren van een eccentrische of incorrecte corticale vlap te vermijden, (ii) de beschermende fibrocartilagineuze laag aan de binnenkant van de retromalleolaire groeve te behouden, en (iii) iatrogene schade aan de fibula te voorkomen.

Deel 4 Revalidatie

Op basis van systematisch literatuuronderzoek gecombineerd met persoonlijke ervaring werd in **Hoofdstuk 9** een revalidatieprogramma voorgesteld na chirurgische behandeling van peroneuspees aandoeningen. In totaal werden 49 studies geïncludeerd en informatie over het toegepaste revalidatieprogramma werd uit elke studie geëxtraheerd. Er werd geen algemene consensus in de literatuur gevonden over de optimale revalidatie, variërend van nul tot twaalf weken. Wel werd er een trend gevonden in de richting van een kortere immobilisatietijd en vroeger starten met mobiliteit.

Het voorgestelde revalidatieprogramma raadde zes weken immobilisatie aan, waarna langzaam met de bewegen kan worden gestart. Er werd gesuggereerd dat met provocatie van de pezen in het algemeen moet worden gewacht tot twaalf weken postoperatief. Voor een optimaal herstel moet het revalidatieprogramma echter worden afgestemd op de aard van de pathologie en de eisen van elke specifieke patiënt. Bijvoorbeeld, in gevallen waar het retinaculum musculorum fibularum intact is gebleven tijdens de behandeling, zou eerder kunnen worden begonnen met bewegen.

Deel 5 Internationale consensus richtlijn

Hoofdstuk 10 bevatte de ESSKA-AFAS consensus richtlijn gebaseerd op internationale en multidisciplinaire overeenstemming volgens de Nominal Group Technique, gecombineerd met een systematisch overzicht van beschikbare literatuur. Er werden uitspraken gedaan over anatomie, classificatie, diagnostische modaliteiten, behandeling en revalidatie. De belangrijkste aanbevelingen zijn samengevat in de belangrijkste "take aways" hieronder.

Belangrijkste inzichten voor de behandeling van peroneuspees aandoeningen in de dagelijkse praktijk

In dit proefschrift worden de volgende acht belangrijke uitgangspunten voorgesteld voor de behandeling van peroneuspees aandoeningen in de dagelijkse klinische praktijk, gebaseerd op praktische en wetenschappelijk onderbouwde overwegingen:

1. Belangrijke anatomische overwegingen: 'overstuffing' van de laterale retromalleolaire tunnel en de peroneus' vincula
Meerdere anatomische variaties verhogen het risico op peroneuspees aandoeningen, waarbij 'overstuffing' van de laterale retromalleolaire tunnel en chronische overbelasting van de pezen als belangrijkste factoren worden geacht. Bovendien speelt de peroneus' vincula een essentiële rol in de vascularisatie van de pezen en moet er zorg voor worden gedragen dat deze vincula tijdens de behandeling zoveel mogelijk intact blijft.

2. Classificatie is gebaseerd op type pathologie en het onderscheid tussen atleten en niet-atleten
Peroneuspees aandoeningen worden het best geclassificeerd op basis van het type pathologie: (1) tendinopathie, (2) scheuren of rupturen en (3) instabiliteit of dislocatie van de pezen. Bovendien is differentiatie tussen atleten en niet-atleten belangrijk voor een optimale behandeling van peroneuspees aandoeningen.

3. Diagnostiek middels echografie, MRI en/of peroneus tendoscopie
Patiënten die zich presenteren met een acuut enkelletsel moeten worden geëvalueerd aan de hand van de Ottawa-richtlijnen voor de enkel. Wanneer een patiënt klinisch verdacht wordt van een peroneuspees aandoening, zijn zowel MRI als echografie geschikte diagnostische hulpmiddelen. Een peroneus tendoscopie is nuttig bij patiënten met een hoge klinische verdenking op een

peroneuspees aandoening na anamnese en onderzoek van de patiënt, maar met negatieve beeldvormingsbevindingen.

4. Overweeg eerst conservatieve strategieën
Conservatieve behandeling moeten worden overwogen bij alle symptomatische patiënten met een peroneuspees aandoening. De behandeling in de acute fase omvat rust, ijs, compressie en elevatie, waarna kan worden begonnen met bewegingsoefeningen en belasting van de pezen.

5. Behandel alleen symptomatische peroneuspees scheuren
Alleen symptomatische peroneuspees scheuren dienen behandeld te worden, waarbij conservatieve behandeling over het algemeen de eerste stap vormt. Indien chirurgische behandeling nodig is, moet eerst worden geprobeerd om de pees/pezen te debrideren en herstellen. Indien dit klinisch niet haalbaar is, wordt een hamstrings-autograft, of side-to-side tenodesis aanbevolen, waarbij grafting indien mogelijk de voorkeur heeft boven tenodesis. Indien beide pezen onherstelbaar zijn en het spierweefsel gezond is, wordt het gebruik van een autograft aanbevolen.

6. Behandeling van peroneuspees rupturen bestaat voornamelijk uit direct herstel
Symptomatische rupturen van één of beide pezen vereisen in principe chirurgische reparatie. Indien herstel klinisch onmogelijk is, wordt een hamstrings autograft of side-to-side tenodesis aanbevolen. Een peesverplaatsing, waarbij de pees van de flexor hallucis longus of de flexor digitorum longus wordt gebruikt, moet als laatste redmiddel worden overwogen.

7. Chirurgische behandeling van peroneuspees instabiliteit/dislocatie wordt over het algemeen aanbevolen
Conservatieve behandeling van peroneuspees dislocatie kan worden overwogen bij niet-atletische patiënten, rekening houdend met het feit dat het risico van recidiverende dislocatie groot is. Bij niet-atletische patiënten kan chirurgisch herstel van het retinaculum musculorum fibularum alleen of in combinatie met uitdiepen van de retromalleolaire groeve worden overwogen. Bij atletische patiënten moet de voorkeur worden gegeven aan een chirurgische behandeling die zowel herstel van het retinaculum als uitdiepen van de laterale retromalleolaire groeve omvat.

8. Revalidatie afstemmen op de patiënt
Peroneus revalidatie hangt af van de vraag of het retinaculum musculorum fibularum tijdens de chirurgische behandeling al dan niet is hersteld. Indien dit niet het geval is, moet de revalidatie voornamelijk op het halen van doelstellingen worden gebaseerd, met een vroege start van mobilisatie. Na herstel van het retinaculum wordt zes weken immobilisatie aanbevolen, waarbij actieve beweging en fysiotherapie wordt aangemoedigd na twee weken postoperatief. Belasten van de pezen moet worden vermeden tot zes weken na de operatie.

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PART 7

APPENDICES

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United States of America

Xavier Madirolas
Spain

David Miller
Australia

Christopher D. Murawski
United States of America

Hunter Newman
United States of America

Xavier M. Oliva
Spain

Chris J. Pearce
Singapore

Helder Pereira
Portugal

Francisco Reina
Spain

Pietro Spennacchio
Luxembourg

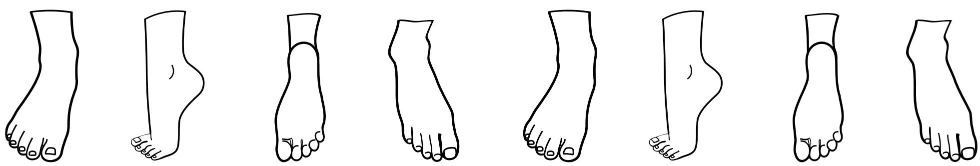
Joanna M. Stephen
United Kingdom

Claire Verheul
The Netherlands

Bryan G. Vopat
United states of America

Youichi Yasui
Japan

Alastair Younger
Canada



B. PhD portfolio

1. Scientific courses (total 45.1 ECT)

- *2021 – 2022: Courses master Epidemiology at the Harvard T.H. Chan School of Public Health*
    1. Public health meta-leadership skills through crisis and change (4 ECT)
    2. Foundations for public health (0.2 ECT)
    3. Introduction to methods and applications in health services research (4 ECT)
    4. Improvement in quality of healthcare (4 ECT)
    5. Introduction to clinical epidemiology (8 ECT)
    6. Statistics for medical research I (4 ECT)
    7. Statistics for medical research II (4 ECT)

- *2017: Course 'Ethische dilemma's in de praktijk' at het Institute for interdisciplinary studies, University of Amsterdam (3 ECT)*

- *2015: Courses as a non-degree summer student at the Harvard T.H. Chan School of Public Health*
    1. Principles of biostatistics I (4 ECT)
    2. Principles of biostatistics II (4 ECT)
    3. Fundamentals of epidemiology (4 ECT)

- *2014 – 2015: Courses at the Graduate school, AMC, UvA*
    1. Endnote (0.1 ECT)
    2. Practical Biostatistics (1.1 ECT)
    3. Clinical epidemiology: systematic reviews (0.7 ECT)

2. Relevant workshops / masterclasses (total 1.5 ECT)

- *2018: The Lisbon Foot and Ankle Clinical Biomechanics Course (1 ECT)*
  Lisbon, Portugal

- *2016: Ankle arthroscopy cadaveric course (0.5 ECT)*
  Boston, USA

3. Relevant visited (inter)national conferences

- *2022: 19th congress ESSKA*
  Paris, France

- *2021: Autumn congress Dutch Orthopedic Society*
  Den Bosch, Netherlands

- *2019: 41th congress SEMCPT*
  Bilbao, Spain

- *2018: 18th congress ESSKA*
  Glasgow, England

- *2017: International consensus meeting 'Talar osteochondral defects'*
  Pittsburgh, USA

- *2017: International consensus meeting 'Peroneal Tendon Pathology'*
  London, England

- *2016: 17th congress ESSKA*
  Barcelona, Spain

- *2016: Several symposia during the 1th Cycle for Science*
  Amsterdam to Barcelona

- *2016: 35th congress AANA*
  Boston, USA

- *2015: 28th Richard J. Smith 'Hand Surgery' day*
  Boston, USA

- *2015: Autumn congress Dutch Orthopedic Society*
  Roosendaal, Netherlands

- *2014: 16th congress ESSKA*
  Amsterdam, Netherlands

4. Teaching activities

- *2021: Basic University Teaching Qualification (BKO): leergang activerend onderwijs*
  Medical Faculty, University of Amsterdam

- *2018 – 2022: Mentor honours program master in medicine:*
  1. Susanne Doeleman
  2. Niels Aarnoudse
  3. Anne Hoekman
  4. Sofie Breuking

- *2015 – 2016: Tutor research internship master in medicine:*
  1. Sofie Breuking
  2. Reinout Heijboer
  3. Lana Kluit

- *2014: Tutor research internship bachelor in medicine*
  1. Maurits Oostenbroek

5. Parameters of Esteem: Grands / Awards

- *2018: AMC Internationaal Fonds*
- *2015: Harvard Orthopaedic Research Stipend*
- *2014: AMC Jong Talenten Fonds*
- *2014: Marti Keuning Eckhart Stichting*
- *2014: Pau Golano Fellowship – ESSKA AFAS*
- *2014: Stichting FARFA*
- *2014: A.S.C. Academy Beurs*

7. Board- / coordinating activities during PhD traject

- *2022 – now: PR board member ESSKA – AFAS*
- *2020 – now: Co-coordinator honours program in medicine*
- *2018 – now: Supervisory board 'Time-Out foundation' on promotion of mental health in students*
- *2020 – now: Editorial board KSSTA journal*
- *2020 – 2021: Board member 'Young OLVG'*
- *2019 – 2021: Coordinator internship general surgery OLVG west*
- *2019 – 2021: Chairman race officials and board member European tall ship race 'Race of the Classics'*
- *2017 – 2018: Student advisor examination council medical faculty at the UvA*

8. Research fellowships

- *2015 – 2016: Research fellow Massachusetts General Hospital*
  Harvard Medical School, Boston, USA

- *2015: ESSKA – AFAS 'Pau Golano research fellow' Hospital for Special Surgery*
  Weil Cornell University, New York, USA

- *2014 – 2015: Research fellow Academic University Medical Center*
  University of Amsterdam, Amsterdam, the Netherlands

- *2014: Research fellow Universidad de Girona*
  Girona, Spain

C. List of publications and presentations

Peer-reviewed publications

1. Mercer NP, Gianakos AL, van Dijk PA, Mercurio A, Kerkhofs GM, Kennedy JG: Return to play and clinical outcomes in the surgical treatment of peroneal tendon dislocation and subluxation. Foot Ankle Orthop, 2022 jan 21; 7(1): 2473011421S00366. doi 10.1177/2473011421S00366
2. Van Dijk PA, Breuking S, Guss D, Johnson H, DiGiovanni CW, Vopat B: Optimizing surgery of metaphyseal-diaphyseal fractures of the fifth metatarsal: a cadaveric study on implications of intramedullary screw position, screw parameters and surrounding anatomic structures Injury, 2020 sept 16:S0020-1383(20)30759-2. doi: 10.1016/j.injury.2020.09.020.
3. Vopat BG, Vopat ML, van Dijk PA, Hazzard S, McKinnon K, Asnis PD, Theodore GH: Return to Sport after Surgical Treatment of Lisfranc Injuries in Athletes: A Retrospective Case Series. Kans J Med. 2019 Nov 25;12(4):141-145. eCollection 2019 Nov.
4. Van Dijk PA, Kerkhoffs GM, Choido C, DiGiovanni CW: Chronic Disorders of the Peroneal Tendons: Current Concepts Review of the Literature J Am Acad Orthop Surg, 2019 Aug. Epub ahead of print. doi: 10.5435/JAAOS-D-18-00623
5. Res LC, Dixon T, Lubberts B, Vincentini JR, Van Dijk PA, Hosseini A, Guss D, DiGiovanni CW: Peroneal tendon tears: should we be looking at the muscle Instead? A pilot study. J Am Acad Orthop Surg, 2018 Nov;26(22):809-815. doi: 10.5435/JAAOS-D-17-00302
6. Van Dijk PA, Murawski CD, et al (the international consensus group): Post-treatment follow-up, imaging, and outcome scores: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):68S-73S. doi: 10.1177/1071100718781861
7. Van Bergen CJ, Baur OL et al: Diagnostics: history, physical examination, imaging and arthroscopy: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):3S-8S. doi: 10.1177/1071100718779393
8. Dombrowksi ME, Yasui Y et al: Conservative management and biological treatment strategies: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):9S-15S. doi: 10.1177/1071100718779390
9. Hannon CP, Bayer S et al: Debridement, curretage and bone marrow stimulation: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):16S-22S. doi: 10.1177/1071100718779392
10. Reilingh ML, Murawski CD et al: Fixation techniques: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):23S-27S. doi: 10.1177/1071100718781096
11. Hurley ET, Murawski CW et al: Osteochondral autograft: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):28S-34S. doi: 10.1177/1071100718781098
12. Smyth NA, Murawski CD et al: Osteochondral allograft: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):35S-40S. doi: 10.1177/1071100718781097
13. Rothrauff BB, Murawski CD et al: Scaffold-based therapies: proceedings of the international consensus meeting on cartilage repair of the ankle Foot Ank Int, 2018 Jul;39(supplement):41S-47S. doi: 10.1177/1071100718781864

14. Shimozono Y, Brown AJ et al: Subchondral pathology: proceedings of the international consensus meeting on cartilage repair of the ankle
Foot Ank Int, 2018 Jul;39(supplement):48S-53S. doi: 10.1177/1071100718781866
15. Mittwede PT, Murawski CD et al: Revision and salvage management: proceedings of the international consensus meeting on cartilage repair of the ankle
Foot Ank Int, 2018 Jul;39(supplement):54S-60S. doi: 10.1177/1071100718781863
16. D'Hooghe P, Murawski CD et al: Rehabilitation and return to sports: proceedings of the international consensus meeting on cartilage repair of the ankle
Foot Ank Int, 2018 Jul;39(supplement):61S-67S. doi: 10.1177/1071100718781862
17. Van Dijk PA, Miller D, Calder J, DiGiovanni CW, Kennedy JG, Kerkhoffs GM, Kynsburg A, Haverkamp D, Guillo S, Oliva XM, Pearce CJ, Pereira H, Spennacchio P, Stephen JM, Van Dijk CN: The ESSKA-AFAS international consensus statement on peroneal tendon pathologies
Knee Surg Sports Traumatol Arthrosc, 2018 Oct;26(10):3096-3107. doi: 10.1007/s00167-018-4971-x
18. Van Dijk PA, Vopat B, Guss D, Younger A, DiGiovanni CW: Retromalleolar groove deepening in recurrent peroneal tendon dislocation: technique tip
Orthop J Sports Med, 2017 May;5(5):2325967117706673. doi: 10.1177/2325967117706673
19. King JD, Van Dijk PA, Overbeek CL, Hageman MG, Ring D: Patient complaints emphasize non-technical aspects of care at a tertiary referral hospital
Arch Bone Jt Surg, 2017 Mar;5(2):74-81. pmid: 28497096
20. Opdam K, Van Dijk PA, Stufkens SA, Van Dijk CN: The peroneus quartus in a locking phenomenon of the ankle: a case report
J Foot Ankle Surg 2017 Jan-Feb;56(1):108-111. doi: 10.1053/j.jfas.2016.07.016
21. Lubberts B, Van Dijk PA, DiGiovanni CW, Van Dijk CN, Calder J: There is no best surgical treatment for chronic isolated syndesmotic instability: A systematic review
Journal of ISAKOS, 2016 Sept;1(5):250-256. doi: 10.1136/jisakos-2016-000058
22. Lubberts B, Van Dijk PA, Donovan N, Van Dijk CN, Calder J: Stable and unstable grade II syndesmotic injuries require different treatment strategies and vary in functional outcomes: a systematic review
Journal of ISAKOS, 2016 Jul;1(4):192-197. doi: 10.1136/jisakos-2015-000026
23. Lubberts B, Heijboer RRO, Van Dijk PA, Vopat BG, Johnson AH, Guss D, DiGiovanni CW: The validity of using ICD-9 codes for identifying venous thromboembolism following below knee surgery
Orth J Harvard Medical School, 2016 Jun;17(1):18-23. www.orthojournalhms.org/17/article18_23.html
24. Kennedy JG, Van Dijk PA, Yasui Y, Duke G, Fraser EJ, Murawski CW: Functional outcomes after peroneal tendoscopy in the treatment of peroneal tendon disorders
Knee Surg Sports Traumatol Arthrosc 2016 Apr. 24(4):1148-54. doi: 10.1007/s00167-016-4012-6
25. Van Dijk PA, Lubberts BA, Verheul C, DiGiovanni CMW, Kerkhoffs GM: Rehabilitation after surgical treatment of peroneal tendon tears and ruptures
Knee Surg Sports Traumatol Arthrosc, 2016 Apr;24(4):1165-74. doi: 10.1007/s00167-015-3944-6
26. Van Dijk PA, Madirolas FX, Carrera Burgaya A, Kerkhoffs GM, Reina de la Torre F: Peroneal tendons well vascularized: results from a cadaveric study
Knee Surg Sports Traumatol Arthrosc, 2016 Apr;24(4):1140-7. doi: 10.1007/s00167-015-3946-4
27. Van Dijk PA, Ganaikos AL, Kerkhoffs GM, Kennedy JG: Return to sports and clinical outcomes in patients treated for peroneal tendon subluxation: a systematic review
Knee Surg Sports Traumatol Arthrosc, 2016 Apr;24(4):1155-64. doi: 10.1007/s00167-015-3833-z

28. Van Dijk PA, Bot AG, Neuheus V, Menendez ME, Vrahas MS, Ring D: Admission from nursing home residence increases acute mortality after hip fractures.
Geriatr Orthop Surg Rehabil, 2015 Sept;6(3):123-9. doi: 10.1177/2151458515570477
29. Van Dijk PA, Bot AG, Neuheus V, Mudgal CS, Ring D: The correlation of phrases and feelings about patient's upper extremity illness with disability.
Hand (NY), 2014 Mar;9(1):67-74. doi: 10.1007/s11552-013-9546-1

Bookchapters

30. Van Dijk PA, Dahmen J, Kerkhoffs GM, d'Hooghe P, Karlsson J: The Achilles tendon, calf and peroneal tendons in Track and Field.
In: Track and field injuries, Gian L. Canata et al, ISAKOS, Springer, 2020
31. van Dijk PA, van Dijk CN: Physical examination of the musculoskeletal system
In: clinical guide for medical interns ('handboek van de coassistent'), W.J. Wiersinga, S. Schimmer and M. Levi, Bohn Stafleu van Loghum, 2020
32. van Dijk PA, Tanriover A, Kvarda P, Waryasz G, DiGiovanni CW: Immobilisation and rehabilitation after surgical treatment of peroneal tendon pathology
In: The peroneal tendons – a clinical guide to evaluation and management, Mark Sobel, Springer, 2020
33. Kvarda P, van Dijk PA, Waryasz G, DiGiovanni CW: Peroneal brevis tears
In: The peroneal tendons – a clinical guide to evaluation and management, Mark Sobel, Springer, 2020
34. Van Dijk PA, van Dijk CN: Peroneal tendons tendinopathy
In: Ankle Joint Arthroscopy, Francesco Allegra et al, Springer, 2020, doi: 10.1007/978-3-030-29231-7_28
35. Van Dijk PA, van Dijk CN: Tibialis posterior tendinopathy
In: Ankle Joint Arthroscopy, Francesco Allegra et al, Springer, 2020, doi: 10.1007/978-3-030-29231-7_29
36. Van Dijk PA, van Dijk CN: Osteochondral lesions of the talus
In: Sports injuries of the foot and ankle, Gian Canata, Springer, 2019, doi: 10.1007/978-3-662-58704-1_12
37. Van Dijk PA, Kerkhoffs GM, van Dijk CN: Peroneal tendon injuries
In: Sports injuries of the foot and ankle, Gian Canata, Springer, 2019, doi: 10.1007/978-3-662-58704-1_28
38. Van Dijk PA, van Dijk CN: Peroneal tendons
In: Muscle and tendon injuries, Gian L. Canata, Springer, 2017, doi: 10.1007/978-3-662-54184-5_35
39. Van Dijk PA, De Leeuw PA, Kerkhoffs GM: Peroneal tendoscopy
In: Arthroscopy: basic to advanced, Jordi Vega, ESSKA, 2016, doi: 10.1007/978-3-662-49376-2_93
40. van Dijk PA, De Leeuw PA, van Dijk CN: Tendoscopy
In: Minimally invasive surgery in orthopedics, Giles Scuderi and Alfred Tria, Springer, 2016, doi: 10.1007/978-3-319-34109-5_101

41. Van Dijk PA, Yasui Y, Murawski CW, DiGiovanni CW, D'Hooghe P, O'Malley M, Madirolas FX, Drakos M, Kennedy JG, Kerkhoffs GM: Peroneal tendon disorders.
    In: ESSKA instructional course lecture book, Roland Becker et al, Springer, 2016. doi: 10.1007/978-3-662-49114-0_13
42. Van Dijk PA, De Leeuw PA, Kerkhoffs GM: Peroneal tendon disorders.
    In: Athletic injuries of the ankle, ESSKA DVD, 2014

Oral presentations

1. Van Dijk PA: The peroneal tendons in relation to lateral ankle instability.
   41e congress Sociedad Española Medicina y Cirugía Pie y Tobillo (SEMTC), 2018 Jun - Bilbao, Spain
2. Van Dijk PA: Biomechanics of the peroneal tendons and related pathologies.
   Lisbon Foot and Ankle Clinical Biomechanics Course, 2018 Sept, Lisbon, Portugal
3. Van Dijk PA: Peroneal tendon tears
   Instructional course lecture: peroneal tendon disorders. 18th Biannual ESSKA congress, 2018 May, Glasgow, England
4. Van Dijk PA, Breuking SH, Vopat BG, Guss D, Johnsson H, DiGiovanni CW, presented by Vuurberg G: The peroneus brevis and plantar fascia insertions are related to proximal fifth metatarsal fractures.
   Free paper session. 11th biannual ISAKOS meeting, 2017 Jun, Shanghai, China
5. Van Dijk PA, Stephen J: Rehabilitation after surgically treated peroneal tendon tears.
   Consensus meeting ESSKA-AFAS, 2017 May, London, England
6. Van Dijk PA, Kerkhoffs GM: Treatment of acute peroneal tendon tears.
   Consensus meeting ESSKA-AFAS, 2017 May, London, England
7. Van Dijk PA, Miller D: Preparation of a consensus statement on peroneal tendon tears.
   Consensus meeting ESSKA-AFAS, 2017 May, London, England
8. Van Dijk PA: My experiences as the first ESSKA-AFAS Pau Golano research fellow.
   ESSKA-AFAS meeting, 17th Biannual ESSKA congress, 2016 May, Barcelona, Spain
9. Van Dijk PA, Gianakos AL, Kerkhoffs GM, Kennedy JG: Treatment of peroneal tendon subluxation and dislocation.
   Instructional course lecture: peroneal tendon disorders, 17th Biannual ESSKA congress, 2016 May, Barcelona, Spain
10. Van Dijk PA, Madirolas FX, Carrera Burgaya A, Kerkhoffs GM, Reina de la Torre F: Peroneal tendons well vascularized: results from a cadaveric study.
    Free paper session. 35th annual Arthroscopy Association of North America meeting, 2016 Apr, Boston, USA
11. Van Dijk PA, Kennedy JG, Yasui Y, Duke G, Fraser EJ, Murawski CW: Peroneal tendoscopy association with magnetic resonance imaging findings and functional outcomes.
    Free paper session. 35th annual Arthroscopy Association of North America meeting, 2016 Apr, Boston, USA
12. Kortlever JT, Janssen SJ, Molleman J, Hageman MG, Ring D, presented by Van Dijk PA: Discrete pathophysiology is uncommon in patients with non-specific arm pain.
    Free Paper Session. 28th annual Richard J. Smithday, 2015 May, Boston, USA
13. Van Dijk PA, Kerkhoffs GM: The self-Induced cracking finger: serious condition or bad habit?
    Amsterdam – Russia Orthopedic Symposium, 2015 Sept, ORCA – AMC Amsterdam

Poster presentations

14. Van Dijk PA, Breuking SH, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: The peroneus brevis and plantar fascia insertions are related to proximal fifth metatarsal fractures
Clinical research day MGH, 2016 Oct, Boston, USA
15. Van Dijk PA, Breuking SH, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: The peroneus brevis and plantar fascia insertions are related to proximal fifth metatarsal fractures
62th ORS annual meeting, 2017 Mar, San Diego, USA
16. Van Dijk PA, Breuking SH, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: The peroneus brevis and plantar fascia insertions are related to proximal fifth metatarsal fractures
AOSSM annual meeting, 2017 Jul, Toronto, Canada
17. Breuking SH, Van Dijk PA, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: Optimal screw fixation in treatment of Jones fractures
Clinical research day MGH, 2016 Oct, Boston, USA
18. Breuking SH, Van Dijk PA, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: Optimal screw fixation in treatment of Jones fractures
62th ORS annual meeting, 2017 Mar, San Diego, USA
19. Breuking SH, Van Dijk PA, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: Optimal screw fixation in treatment of Jones fractures
AANA Annual Meeting, 2017 May, Denver, UVA
20. Breuking SH, Van Dijk PA, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: Optimal screw fixation in treatment of Jones fractures
17th biannual ISAKOS meeting, 2016 Jun, Shanghai, China
21. Breuking SH, Van Dijk PA, Vopat BG, Guss D, Johnsson H, Li G, Hosseini A, DiGiovanni CW: Optimal screw fixation in treatment of Jones fractures
AOSSM annual meeting, 2017 Jul, Toronto, Canada
22. Van Dijk PA, Vopat BG, Hazzard S, Vopat ML, McKinnon K, Asnis P, Theodore G: Return to sport after surgical treatment of ligamentous lisfranc injuries in athletes: retrospective case series
17th Biannual ESSKA congress, 2016 May, Barcelona, Spain
23. Van Dijk PA, Wong J, Vopat ML, Vopat BG, Palmer WE, Reinart S, Sanchez G, Provencher MT: Anchor arthropathy of the glenohumeral joint after arthroscopic labral repair
17th biannual ESSKA congress, 2016 May, Barcelona, Spain

D. Acknowledgements

Collaboration results in better outcomes and this PhD is no exception in that respect. In fact, research is teamwork and without the support, encouragement and challenges of many people, this thesis would have not been possible. Therefore, I would like to thank all of you who have contributed to this thesis and my academic and personal journey so far, including my promotor and co-promotor, mentors, co-researchers, colleagues, patients, secretarial support, friends and family.

E. Curriculum Vitae

Pim Adriana Dirkje van Dijk was born on June 7th 1991 in Amsterdam, the Netherlands. In 2009, she received her gymnasium (pre-university) diploma from the Sint Ignatiusgymnasium in Amsterdam and went on to study medicine at the University of Amsterdam that same year.

During her bachelors, she enjoyed the Amsterdam student life by combining her studies with board- and research activities amongst which an internship at the orthopedic department of the Massachusetts General Hospital, Harvard Medical School in Boston, USA with prof. David Ring. Boston's academic culture further kindled her interest in research, and before finishing her bachelor degree she started a PhD at the orthopedic department of the University of Amsterdam under supervision of prof. Gino Kerkhoffs.

Within the framework of her PhD, Pim got the opportunity to participate in international research fellowships. She spent time at the anatomic lab of the University of Girona in Spain with prof. Francisco Reina de la Torre and worked with prof. John Kennedy at the foot and ankle department of the Hospital for Special Surgery, Weil Cornell Medical School in New York. In 2015, she returned to Boston for a year to work under supervision of prof. Christopher DiGiovanni at the foot and ankle department of Massachusetts General Hospital, Harvard Medical School where she cofounded the Harvard Foot and Ankle Research and Innovation Lab. During her time in Boston, she enrolled in several epidemiology and biostatistics courses at the Harvard T.H. Chan School of Public Health.

In 2016, she returned to Amsterdam to start her master degree in medicine at the University of Amsterdam. While graduating medical school and its honors program *cum laude*, she enjoyed combining her course work with internships in the Netherlands and India while continuing her PhD. To date, her research has resulted in > 40 publications and > 20 presentations on international meetings, including two international consensus guideline meetings.

After graduation, Pim started working at the general surgery department of the Onze Lieve Vrouwe Gasthuis in Amsterdam. In 2020, she commenced her residency in orthopaedic surgery at the Amsterdam University Medical Centers under supervision of dr. Matthias Schafroth and dr. Sjoerd Stufkens. Her general surgery training was completed at the Onze Lieve Vrouwe Gasthuis under supervision of prof. Carel Goslings and she is currently working at the orthopaedic department of TergooiMC under supervision of dr. Ton Vervest.

Pim continues to combine her passion for clinical work with research-, education and management activities such as a position as a supervisory board member of the 'Time-Out Foundation' promoting mental health among students, co-coordinator of the medical honors program at the University of Amterdam, member of the editorial board of the KSSTA and board member of ESSKA-AFAS. She is currently enrolled in the Master in Epidemiology at the Harvard T.H. Chan School of public health including education in epidemiology, biostatistics, medical decision making and public health leadership. She aims to graduate the master's program in 2023 and her orthopaedic residency in 2026.

Once being considered the underdog of the ankle, nowadays it is hard to underestimate the importance of the peroneal tendons as part of the musculoskeletal system. Whether we stand on bare feet or wear high heels, when it comes to our mobility, the peroneal tendons are crucial for keeping us upright.

This thesis discusses the peroneal tendons from various theoretical and practical angles – ranging from epidemiology and anatomy to diagnostics, treatment and rehabilitation – and is fully dedicated to optimizing the management of peroneal tendon disorders.

MANAGEMENT OF PERONEAL TENDON DISORDERS

Amsterdam Movement Sciences

VU Vrije Universiteit Amsterdam

Amsterdam UMC University Medical Centers

Amsterdam Movement Sciences conducts scientific research to optimize physical performance in health and disease based on a fundamental understanding of human movement in order to contribute to the fulfillment of a meaningful life.