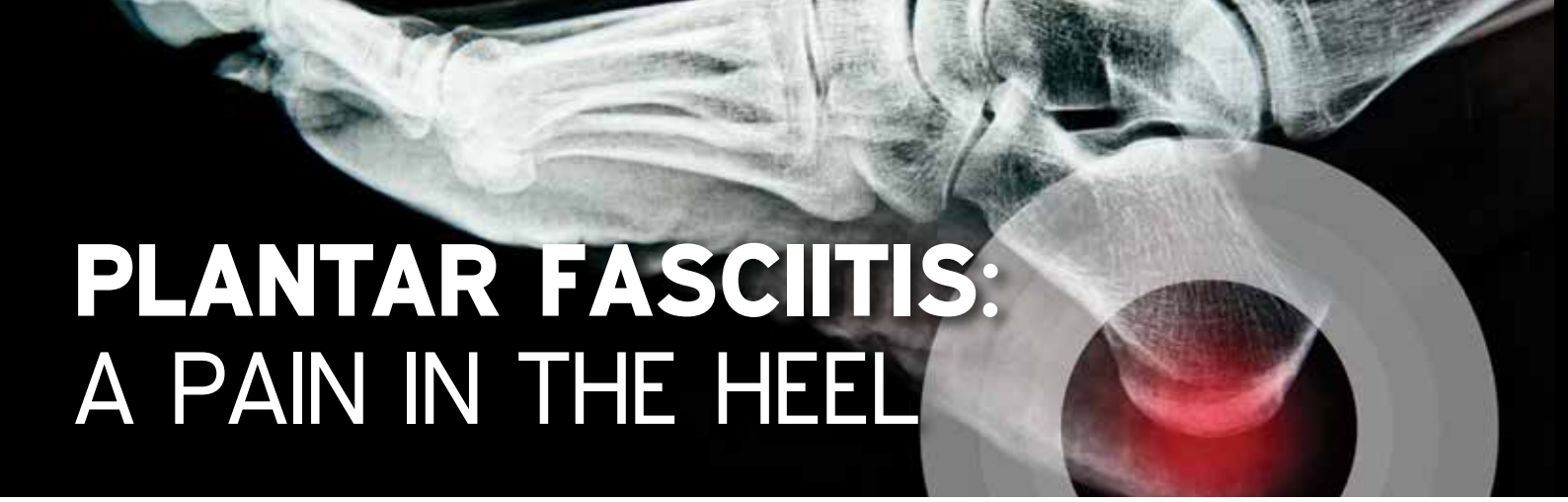


PLANTAR FASCIITIS: A PAIN IN THE HEEL

This article outlines the latest incidence statistics for chronic plantar heel pain, explains how the structure and function of the plantar fascia is affected by pathology, outlines a detailed differential diagnosis and then delves into an evidence-based exploration of passive treatment options, exercise therapy and late stage rehabilitation. We have also created an accompanying Heel Pain Content Marketing Kit (http://spxj.nl/2fnESRn) which contains all the material you need to build awareness about Heel Pain and the how physical therapy can speed up the recovery process. This includes a social media awareness campaign, material for an email and a website article, a postal campaign using leaflets and postcards and a poster campaign for your work area and for the areas of any partners you collaborate with. This Kit is included as part of a full site subscription or can be purchased individually for those without a full site subscription. More information about our campaign kits in general can be found here (http://spxj.nl/2gZkQwP) and to read this article online go to http://spxj.nl/2gy2ZjG.

BY DR CHRISTOPHER NORRIS PHD, MCSP

PLANTAR FASCIITIS: OVERVIEW

Chronic plantar heel pain (CPHP) is pain under the front of the heel bone (calcaneus). It is said to account for about 1% of all orthopaedic referrals, and occurs in up to 7% of the adult population in general. In runners, the incidence is slightly higher with 8–10% affected (1,2).

Functionally, the plantar fascia (PF) acts as an important mechanical link between the rearfoot and forefoot. At heel contact, the curved surface of the calcaneus acts as a rocker or roll over shape (3) to help facilitate forward body motion. Similarly, the body weight rolls over the curved ankle (talocrural) joint mortise and ball of the foot [1st metatarsophalangeal (MTP) joint], the combined motion of the three body parts being described as the 3-rocker system (4). As the body weight moves forwards, the foot acts as a mobile adaptor flattening both the longitudinal and transverse arches to absorb load through tissue extensibility. Further forward motion of the body sees the foot change to a rigid lever to prepare for the propulsive phase of gait and toe off. The change from tissue lengthening (adaptor) to tissue tension (lever) comes about as a result of the windlass effect where the PF is wound up around the 1st MTP joint as the heel lifts and the foot moves into plantarflexion. Tension is seen in both the PF and Achilles tendon, which effectively transmits the contractile force created by the calf musculature.

As the fascia tightens through the windlass effect, it shortens the foot by raising the longitudinal arch (Fig. 1). The combination of these effects supinates the foot (high arch) making it more rigid to push from the ground. As the foot contacts the ground again at heel strike, the arch lowers and the foot pronates (flat arch) becoming more mobile to adapt to the uneven ground. The plantar fascia is relaxed as the foot lengthens, to accommodate to the surface.

The functional linkage between the PF and posterior leg structures is paralleled by pathology. A positive association between Achilles tendon loading and PF tension has been demonstrated, and chronic stretching and tightness of the Achilles tendon are risk factors for plantar fasciitis (5). Greater tightness in posterior leg muscles is also seen in plantar fasciitis patients (6).

DIFFERENTIAL DIAGNOSIS OF PLANTAR FASCIITIS

Pain in this condition is usually over the calcaneal attachment of the PF or its medial edge. Pain may be localised to the heel as though the athlete is 'stepping on a stone', or may present as a burning sensation over the inner

ANKLE-FOOT | LOWER-LIMB | RUNNING | HANDOUT | 17-01-COKINETIC
FORMATS ▶WEB ▶MOBILE ▶PRINT

MEDIA CONTENTS

- **Video: Low Dye Taping for Plantar Fascia Pain** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG
- **Video: Plantar Fascia-specific Taping** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG
- **Video: Self-massage for Plantar Fascia Pain** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG
- **Video: Heel-raise Exercises for Plantar Fascia Strengthening** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG
- **Video: Supported Lunge for Plantar Fascia Strengthening** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG
- **Video: Quarter Squat Exercise for Plantar Fascia Strengthening** (C. Norris, 2016) - http://spxj.nl/2gy2ZjG

TABLE 1: PLANTAR FASCIITIS NOMENCLATURE AND DIFFERENTIAL DIAGNOSIS (C. Norris, 2016)

Alternative names	Differential diagnosis
■ Chronic plantar heel pain (CPHP)	■ Calcaneal apophysitis (Sever's disease)
■ Painful heel syndrome	■ Calcaneal stress fracture or other bone injury
■ Plantar fasciitis	■ Fat pad syndrome (atrophy, heel bruise)
■ Plantar fasciopathy	■ Inflammatory or reactive arthritis (Reiter syndrome/ankylosing spondylitis/psoriatic arthritis)
■ Plantar tendinopathy	■ Bone pathology (osteomalacia/osteomyelitis/ Paget's disease/bone cyst)
■ Plantar enthesopathy	■ PF rupture/local tissue infection
■ Subcalcaneal bursitis	■ Tumour (sarcoma)
■ Neuritis	■ PF fibromatosis (Ledderhose's disease)
■ Medial arch pain	■ Calcaneal or retrocalcaneal bursitis
■ Stone bruise	■ Neural referral lumbosacral, local neuritis, tarsal tunnel syndrome)
■ Calcaneal periostitis	
■ Heel spur	
■ Subcalcaneal spur	
■ Calcaneodynia	

> "MOVEMENT VARIATION IS LIKELY TO ENHANCE FUNCTION MORE THAN THE REPEATED USE OF THE SAME EXERCISE ACTIONS OVER TIME"

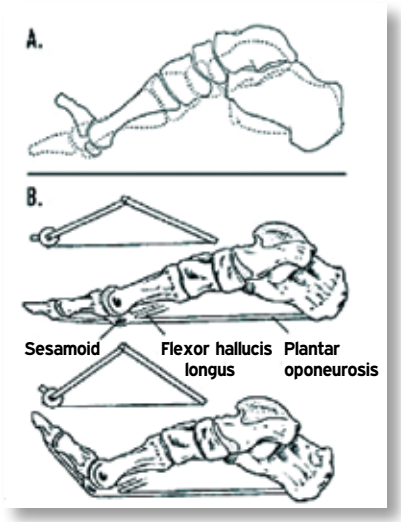
foot arch. Imaging may be used to assess the condition and to rule out other pathologies. Plain radiograph (X-ray) is non-specific, but will often show a calcaneal bone spur which may be asymptomatic. Bone scan will show increased uptake at the medial calcaneal tubercle and may be used to rule out stress fracture. Ultrasound (US) has the convenience of immediate application, but is far more reliant on the skill of the operator. Typically, it shows fascial thickening and fascial regions which appear darker as they reflect less ultrasound (hypoechoic). Magnetic resonance imaging (MRI) can be used to show swelling (oedema) of the fascia and adjacent fat pad, fascial thickening (usually in the proximal PF), bone marrow oedema to the medial calcaneal tuberosity, and altered tissue signal. MRI has an important use in ruling out co-morbidities such as infection or tumour. US scanning has been shown to be reliable in assessing the progress of a treatment, to indicate tissue changes over a time period (7).

Bilateral or atypical heel pain may require laboratory tests such as rheumatoid factor, uric acid, blood count or erythrocyte sedimentation rate (ESR) to assess systemic causes. Table 1 shows alternative names for the condition and differential diagnoses.

STRUCTURE AND FUNCTION OF THE PLANTAR FASCIA

The PF is a thick tissue layer stretching from the calcaneus to the toes. It averages 12cm in length and 2–6cm in width. Attaching from a point just behind the inner (medial) tubercle of the calcaneus it runs anteriorly as medial, lateral, and central portions. The PF is divided into a thicker central portion and thinner medial and lateral bands. The medial band is continuous with the abductor hallucis muscle (big toe abductor), the lateral band with the abductor digiti minimi (little toe abductor) (Fig. 1). As it approaches the metatarsal heads the fascia divides into superficial and deep layers, with the superficial layer attaching beneath the skin, and the deep layer dividing into two portions to surround each of the five flexor tendons. Each of these five portions attaches to the base of a proximal phalanx and to the deep transverse ligament, which runs across the centre of the forefoot.

On dissection, the PF has been found to extend backwards over the calcaneus as a 1–2mm think band (continuous with the periosteum) to merge with the paratenon of the Achilles tendon (1). Through this linkage, forces within the fascia may be transmitted to and from the myofascia stretching along the length of the posterior leg.



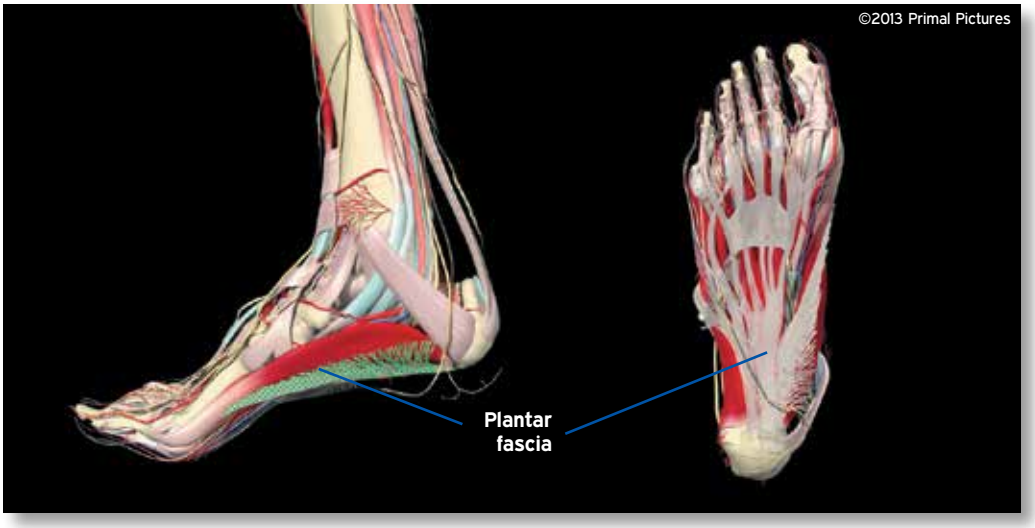


Figure 1: Anatomy of the plantar fascia (PF) and the windlass mechanism (Moseley C. sportEX medicine 2013;55:15)

Gross attachment of the PF to the calcaneus is via an enthesis (connective tissue junction) formed of fibrocartilage. The fibrocartilaginous layer represents a zone of transition from soft to hard tissue and this region can calcify, a change visible on X-radiography.

The PF has structural similarities to ligaments and tendons. Like these structures, it consists of a ground matrix with cells (fibrocytes and fibroblasts) embedded in it. These cells produce collagen (connective tissue), which in the case of the plantar fascia is crimped producing a highly adaptive matrix that may also have a sensory function. The combination of these two features makes it possible that the PF may transmit force passively (like an elastic band) and be able to change its response depending on the stresses imposed upon it.

Type I collagen is found arranged longitudinally throughout the PF, with type III in the loose connective tissue and within areas where the PF bundles are arranged haphazardly. Type II collagen is found close to the heel, and very few elastic fibres are present. Hyaluronan (HA) is found between fibres, and fibroblast like cells arranged in the direction of the collagen fibres. The HA may facilitate gliding between the PF fibrous bundles and have an anti-inflammatory nature. It is most likely secreted by fasciacytes. Nerve endings and Ruffini and Pacini corpuscles are found within the PF, more concentrated in the medial, lateral, and distal portions where the PF joins onto muscle. The inner surface, where the muscles of the sole of the foot attach, is more innervated than the outer surface which is continuous with the skin. The PF innervations have been proposed to give it a proprioceptive role (1). The PF is said to be capable of perceiving both foot position and intrinsic foot muscle contraction.

TABLE 2: FACTORS ASSOCIATED WITH THE DEVELOPMENT OF CHRONIC PLANTAR HEEL PAIN (C. Norris, 2016: sourced Irving et al. J Sci Med Sport 2006;9(1):11–22)

Strength of association	Factor considered
Strong	Body mass index (BMI) in sedentary individuals
	Presence of calcaneal spur on X-radiography
Weak	Increased body weight in sedentary individuals
	Increased age
	Reduced ankle dorsiflexion
	Reduced 1st MTP joint extension
	Prolonged standing in daily living
Inconclusive	Static foot posture
	Dynamic foot motion

TABLE 3: PATHOLOGICAL CHANGES SEEN IN PLANTAR FASCIITIS (C. Norris, 2016: sourced Rathleff et al. Scand J Med Sci Sports 2015;25(3):e292–300)

- Degenerative changes at the plantar fascia enthesis
- Deterioration of collagen fibres
- Increased secretion of ground substance proteins
- Focal areas of fibroblast proliferation
- Increased vascularity

Video 1: Low Dye taping for plantar fascia pain (C. Norris, 2016)

PATHOLOGY OF PLANTAR FASCIITIS

A systematic review of factors associated with CPHP concluded that only body mass index (BMI) and calcaneal spur in a non-athletic population had been shown to have a strong association (8). Increased age, decreased ankle dorsiflexion, decreased 1st MTP joint extension and prolonged standing showed a weak association (Table 2).

Calcification of the PF enthesis increases tissue stiffness, a process increased in elderly individuals perhaps explaining the greater incidence of PF in the elderly. Traction (tensile loading) at the enthesis is often considered a causal factor in PF, but shearing and compression stress is likely equally important. Compressive forces are associated with similar conditions, such as tendinopathy (9).

The term 'plantar fasciitis' itself implies an inflammatory reaction to the fascia (itis being a suffix meaning inflamed in medicine) but there is a question as to whether this is appropriate. Studies have shown degeneration and fragmentation of the fascia with bone marrow vascular ectasia (expansion) at its insertion but, generally, no inflammatory markers are present. Changes have been summarised by Rathleff et al. (2) (Table 3).

Such changes imply that the condition may be more accurately termed a fasciosis (-osis, an abnormal state) rather than a fasciitis. This fact is important when treating the condition, as the steroid injections (anti-inflammatory) that are often used to treat plantar pain have a strong association with plantar ruptures (10). In a study of 765 patients with plantar fascia pain, Acevedo and Beskin (11) found 51 patients who had received corticosteroid injection. Of this subgroup 44 suffered plantar rupture, with 68% showing sudden onset tearing and 32% gradual onset tearing. At follow-up, 26 subjects still showed symptoms 1 year after rupture. Rupture as a result of corticosteroid injection can be seen in up to 10% of patients in general (12).

As indicated above, normally during mid-stance the foot is flattened,

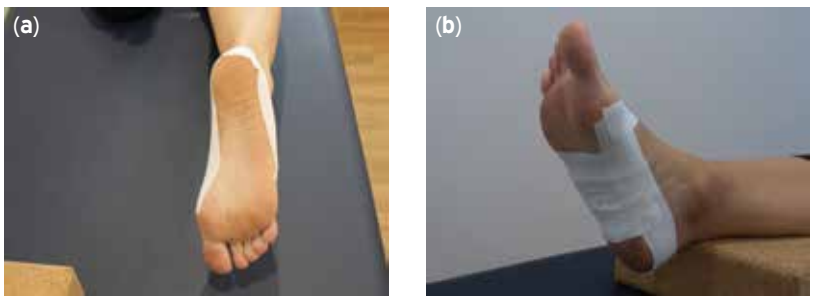


Figure 2: Low Dye taping (C. Norris, 2016)

Figure 3: Plantar fascia-specific taping (C. Norris, 2016)

stretching the plantar fascia and enabling it to store elastic energy to be released at toe off. However, a variety of sub-optimal foot postures (malalignment) may increase stress on the fascia. Excessive rearfoot pronation will lower the arch and overstretch the fascia, and a reduction in mobility of the first metatarsal may also contribute to the condition (13). In addition, weak peronei, often the result of incomplete rehabilitation following ankle sprains, may reduce the support on the arch, thus stressing the plantar fascia. Congenital problems such as pes cavus (high arch) may also leave an athlete more susceptible to plantar fasciitis. PF tension through a prolonged windlass effect may exacerbate the condition, and tightness in the Achilles tendon or a plantarflexed foot position (high-heeled shoes) can produce this.

Sports shoes and general footwear may exacerbate symptoms. Inadequate rearfoot control may fail to eliminate hyperpronation, and a poorly fitting heel counter will allow the calcaneal fat pad to spread more at heel strike, transmitting extra impact force to the calcaneus and PF. Degeneration of the fat pad with ageing has been suggested as a risk factor for the condition.

Both static and dynamic foot posture have been examined using navicular height, calcaneal angle (pitch) using radiographs, and medial longitudinal arch contour using a footprint test. Looking for an association with the development of CPHP the evidence produced was inconclusive (8). Modification of foot position using orthotics or shoe types should be considered if they modify a patient's symptoms, but used with caution as they may build dependence and distract from one of the primary aims of rehabilitation, which should be to build increased tissue capacity.

PASSIVE TREATMENTS

Taping (low Dye taping) may give temporary pain relief and allow continuation of daily living activities or low-level sport. A systematic review of six trials (14) showed an immediate increase in navicular height (mean 5.9mm) post-application. This was not maintained during exercise, and the authors questioned whether the change was clinically useful. Low Dye taping has also been shown to reduce mid PF strain in a cadaveric study (15).

For the classic low Dye method, a strip of zinc oxide tape is placed along the medial edge of the foot proximal to the 1st MTP joint around the back of the calcaneus (heel lock) to finish proximal to the base of the 5th metatarsal (Fig. 2a), a second strip may be used to reinforce if required. Reins are then placed between the longitudinal strips across the sole of the foot, and tension altered to suit requirements (Fig. 2b; Video 1). Metatarsal or longitudinal arch padding may be placed on the sole of the foot prior to tape application to give extra support.

PF-specific tape may be applied in a similar fashion. With the foot in its neutral position, one anchor surrounds the heel and the other is placed just behind the metatarsal heads (Fig. 3a). Three strips of tape (medial, lateral and central) are then passed from the anchor over the heel to stop on the posterior aspect of the calcaneum, and tension in each may be varied (Fig. 3b, c; Video 2). A horseshoe-shaped fixing strip secures the tape behind the heel. Additional strips may be placed transversely across the foot from the metatarsal heads to the calcaneal tubercle.

Manual treatments such as deep tissue massage, and trigger point therapy for the plantar muscles (quadratus plantae and flexor hallucis) may give some short-term benefit, although the results are likely to non-specific. Patients can be taught self-pressure techniques using a roller (foam or hard) or ball (tennis or golf ball) placed on the floor with the sole of the foot resting on the object. Self-massage may be applied

Figure 4: Self-massage to plantar tissues (C. Norris, 2016)

Video 2: Plantar fascia-specific taping (C. Norris, 2016)

Video 3: Self-massage for plantar fascia pain (C. Norris, 2016)

Figure 5: Plantar fascia-specific stretching (C. Norris, 2016)

Figure 6: Passive mobilisation of 1st MTP joint and plantar tissues (C. Norris, 2016)

Figure 7: High-load training of the plantar fascia (C. Norris, 2016)

Video 4: Heel-raise exercises for plantar fascia strengthening (C. Norris, 2016)

with the legs crossed to expose the plantar surface of the foot (Fig. 4; Video 3). It is unlikely that passive techniques of this type will structurally affect the PF long term, but they may produce neuro-modulation to relieve pain and reduce the requirement for medication.

Dry needling to the foot and calf musculature has shown some benefit in a randomised controlled trial (16), although the statistically significant difference between groups (Dry Needling versus Sham) was less than the clinically important difference. The authors argued that the small benefit obtained may be offset by pain caused by the needling technique itself (32% dry needling compared to 1% sham).

Foot supports including gel heel inserts, longitudinal arch supports, and/or orthotics may be used to modify weight-bearing forces imposed upon the PF or control excessive pronation. Both custom fit orthotics (CFO) and prefabricated orthotics (PFO) have been shown to produce similar effects in the treatment of PF pain and provide short-term relief as well as improvement of the foot function index (FFI) (17), PFO being of lower cost and giving immediate access. Gel inserts may be used to provide temporary relief in the short to mid-term (2–52 weeks) [(strong evidence (18)].

EXERCISE THERAPY

Exercise approaches to plantar fasciitis fall broadly into two categories, stretching and strengthening. Specific stretching is aimed at the PF in isolation. The gastrocnemius–soleus complex is assessed and stretched using a generalised programme if the muscles are found to be tighter than the non-injured side or judged to be below what is considered optimal for a patient's daily requirement or sport. Specific PF stretching has been shown to be superior to general calf stretching when measured for worse pain, and first-step morning pain on the foot function index (19).

Plantar-specific stretching (20) can be performed by having the patient sit and cross the affected leg over the non-affected. Placing their fingers distal to the MTP joints they flex the toes to draw the foot down into ankle plantarflexion, to mimic the windlass effect (Fig. 5). The stretch is held for 10s and 10 reps are performed 3 times per day. The PF-specific stretch aims to reduce patient symptoms and may be performed prior to taking the first steps in the morning and following prolonged sitting. Where this protocol interferes with daily living, longer stretches of up to 30–60s may also be used and performed for 5 reps twice each day. The patient palpates the PF with the opposite hand to ensure that tension is placed on the structure, and foot/toe angle may be varied to increase tension.

Where the 1st MTP joint motion is very limited, joint mobilisation may be used as a passive therapy, and exercise therapy used to maintain the effect between treatment sessions. A combination of 1st MTP extension and ankle dorsiflexion (Fig. 6) may be performed with the toes extended against a wall, knee pressing over the foot to place the foot into dorsiflexion. Where this relieves symptoms stretching may be of benefit, as limited motion range at the ankle and MTP joint have been shown to have an association with the condition (8). However, prolonged or repeated tensile stress to the PF over the longer term may not be useful, as it can produce compression within the tissue, a factor shown to be associated with tendinopathy-like pain (9).

Strengthening may be to the limb in general, or to the plantar foot musculature. High load strength training has also been shown to be effective when targeting the PF in a similar fashion to that used when treating tendinopathy (2). High-load training uses the windlass effect and combines flexion of the MTP joints with a heel-raise action (Fig. 7; Video 4). The connection between the PF and Achilles paratenon found at dissection (1) implies that load will be transferred between the two structures.

A slim lift (folded towel or slim plank) is placed under the toes to obtain maximal extension. A heel-raise action is then performed from this starting position using a slow 3–2–3 count of concentric/isometric/eccentric muscle action. The training volume is increased using 12 reps at maximal load to failure, and then 14 days later this is progressed to 10 reps at maximum load, and again after 14 days to 8 reps at maximum load (2). Where patients are not strong enough to perform single-leg heel-raises

TABLE 4: LATE-STAGE REHABILITATION OF PLANTAR HEEL PAIN
(C. Norris, 2016)

Exercise aim	Action
■ Balance training	■ Rocker board, balance board, balance cushion ■ Line/beam walk
■ Foot–ankle stability	■ Single-leg standing: - eyes open/closed - arm/trunk movements
■ Force generation through posterior chain	■ Squat/deadlift/press actions ■ Double-/single-leg vertical jump (free and weighted) ■ In place hop: - forward/back - side/side - hop and twisting - As above using line/beam/low hurdle - Wall/object push (box/prowler)
■ Force acceptance through lower limb	■ Barefoot landing straight/lateral/rotation
■ Foot as mobile adaptor	■ Uneven surface walk/run

or pain limits activity, the exercise is regressed to bilateral heel-raises until the necessary strength is obtained. High-load strength training of this type has been shown to be superior to specific stretching using the FFI (a 0–230 point scale: 0 indicating no pain, disability or limitation of activity). High-load training was superior to specific stretching by 29 points on FFI at 3 months post-intervention and 22 points after 12 months (2), showing quicker pain reduction and improvement in function.

Once pain has reduced and daily function returned to pre-injury levels, reconditioning is used to build physical resilience and prepare for competitive sport and daily life challenges. The tissue specific rehabilitation described above is augmented and progressed using weight-bearing barefoot actions to work the intrinsic foot musculature. This can include single-leg standing, multidirectional walking and running (forward/back/side-side/rotation) progressing to bilateral and unilateral jumps of varying breadth (standing broad jump) and height (vertical jump). Varying surface (mats, sand, grass), movement complexity (single-leg standing barefoot with/without upper limb or trunk movement), timing (slow, fast) and load (body weight, external). Movement variation of this type is likely to enhance function more than the repeated use of the same exercise actions over time (Table 4). Videos 5 and 6 demonstrate examples of weight-bearing exercises for strengthening plantar foot musculature.

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Video 5: Supported lunge for plantar fascia strengthening (C. Norris, 2016)

Video 6: Quarter squat for plantar fascia strengthening (C. Norris, 2016)

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KEY POINTS

- **The plantar fascia (PF) is an important link between the rearfoot, the forefoot and the musculature of the calf.**
- **The combined motion of the heel, the ankle and the ball of the foot are involved in the three-rocker system for forward movement.**
- **The windlass effect is a mechanical model that describes the lengthening and tensioning of the foot by the PF to allow pronation (and adaption to the ground surface on contact) and supination (and force transfer at toe-off), respectively.**
- **In plantar fasciitis, pain is usually over the calcaneal attachment of the PF or its medial edge.**
- **High body mass index in sedentary individuals and the presence of a calcaneal spur on X-radiography are factors strongly associated with the development of plantar fasciitis.**
- **The changes involved in the PF in plantar fasciitis suggest that the condition should more accurately be termed plantar fasciosis.**
- **Passive treatments for chronic heel pain include taping, manual treatments (such as deep tissue massage, trigger point therapy and self-massage) and foot supports.**
- **Exercise therapy involves stretching the PF and strengthening the surrounding musculature.**

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DISCUSSIONS

- **What is the role of the plantar fascia (PF) in the gait cycle?**
- **What pathological changes are commonly seen in plantar fasciitis and which term do you think is a more accurate reflection of the condition: plantar fasciitis or plantar fasciosis? Why is this important when treating the condition?**
- **What biomechanical or congenital problems can increase stress on the PF?**
- **What can you do to treat patients with chronic plantar heel pain and what differential diagnoses should you bear in mind?**

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- Spontaneous Rupture of the Plantar Fascia in a Professional Football Player [Video] - http://spxj.nl/2fEUMJW
- Patient Information Leaflet: Chronic Plantar Heel Pain [Printable Leaflet] - http://spxj.nl/2fEiWjB
- Heel Pain Appointment Prompt [Marketing Campaign Kit]: Posters for your workspace, a leaflet and postcard for local promotions, text for a blog post and email newsletter, artwork for an email header banner and 7 tweets, each with its own social media image - http://spxj.nl/2fnESRn