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Are models of plantar heel pain suitable for competitive runners? A narrative review

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ABSTRACT

Background: Plantar heel pain (PHP), or plantar fasciopathy, is a common condition in active and sedentary populations, contributing to short- and long-term reductions in quality of life. The condition's aetiology and pathophysiology are the subjects of a significant body of research. However, much of this research has been conducted with sedentary participants, and comparatively little research exists in a population of highly-trained athletes focused on performance outcomes. Models for PHP and proposed mechanisms, such as high body mass index or systemic disease, are mostly absent from an athletic population. Even less is known about the origins of pain in PHP. Pain is believed to be a complex multifactorial process and may be experienced differently by sedentary and highly active populations, particularly endurance athletes. Consequently, conservative through to surgical treatment for athletes is informed by literature for a different population, potentially hindering treatment outcomes.

Aims: The aim of this review, therefore, is to summarise what is known about PHP in athletic populations and propose potential directions for future research.

Methods: Embase, PubMed, and Scopus using MeSH search terms for PHP and competitive sport and common synonyms.

Discussion: Two explanatory models for PHP were found. These primarily propose mechanical factors for PHP. It remains unclear how gait, body composition, and psychological factors may differ in an athletic population with and without PHP. Therefore, research in these three areas is needed to inform clinical and training interventions for this population.

1. Introduction

Plantar heel pain (PHP), often called plantar fasciopathy, is a common condition in active and sedentary populations that contributes to short- and long-term reductions in quality of life.[1] The clinical presentation of pain at the enthesis of the plantar fascia has remained consistent since it was first described in 1812[2] and is similar among both active and sedentary populations. PHP can progress from an acute to a chronic condition and given its frequent manifestation, its aetiology, pathophysiology and treatment are the subjects of a significant body of research. The majority of research to date, however, is focused on older and non-athletic populations, and proposed aetiological mechanisms for the development of PHP, such as high body mass index (BMI) or systemic disease, may have limited generalisability to the athletic population. The utilisation of measurements from plantar soft tissues for diagnostic purposes in sedentary people is encouraged, but could be limited in athletes, who are known to possess thicker plantar soft tissues.[3] Moreover, treatments designed for sedentary people, including the use of weight-loss, orthoses, or improving the strength of intrinsic foot muscles, may have a limited role in typically lean and strong athletic populations. To further complicate matters, pain thresholds and pain tolerance, key clinical measures for PHP, are known to differ between athletes and non-athletes, which may result in poor agreement between pain and tissue morphology within athletic populations.[4] At present, clinicians may be applying diagnostic criteria and management strategies to athletes which are informed by studies consisting of a

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markedly different population. The aim of this review, therefore, is to summarise what is known about PHP in athletic populations and propose directions for future research. Articles were sourced via searches of Embase, PubMed, and Scopus databases using MeSH search terms for PHP, competitive sport and common synonyms, article reference lists, and the authors' collections.

1.1. What defines an athlete?

Running is one of the most popular sports globally,[5] with millions engaged in competition.[6] This recent boom in competitive runners must be considered alongside running-related injury (RRI) rates reported as high as 79%,[7] including a PHP incidence of up to 31%.[8] Consequently, the injury burden among the competitive to elite runners is of significant interest. However, active and athletic populations are variously described in the literature, encompassing infrequent or weekly exercisers to elite professionals, potentially drawing too heavily from casual exercisers. A consensus is yet to be formed based upon intent and focus, where athletes separate themselves from exercisers by training to improve performance for competitive advantage.[9] For this paper, an athlete differs from those undertaking regular physical activity based on their intent to improve competitive performance.

1.2. Aetiology of PHP

The aetiology of PHP is poorly understood but is considered multifactorial.[10] PHP was initially considered an inflammatory condition; more recent research suggests it is a degenerative process, though it is unclear whether these are mutually exclusive, as PHP may exist across a continuum.[11] For this reason, the term PHP has been proposed as more appropriate nomenclature in place of plantar fasciitis/fasciosis/fasciopathy.[12] Mechanical overload of the plantar fascia continues to be considered a primary factor associated with the development of the condition, often associated with extrinsic elements.[13] In the non-athletic population, this mechanical overload is thought to be related to a high BMI.[12,13] In running-related athletic populations, however, high plantar loading is thought to be related to the loading impulse associated with activity. Why some athletes are affected and not others, however, remains unclear. Mechanical overload, secondary to inappropriate training load, appears to be the most logical mechanistic pathway in the athletic population, as described in standard mechanistic models. Additionally, pain is a complex multifactorial process that may be experienced differently by sedentary and highly active populations, particularly endurance athletes.[4] Mechanical overload for which explanatory models have been proposed, due to training load, appears to be the most logical mechanistic pathway in the athletic population. Advances in gait, body composition and psychology research (and possibly the intersection of all) may assist to improve our understanding of why active and athletic populations are affected by this condition and if it is different to that experienced by sedentary people.

1.3. Diagnosis of PHP in athletes

PHP is typically diagnosed based on clinical criteria including pain on weight-bearing at the anteromedial plantar heel (plantar fascial enthesis), especially after resting, and following exclusion of other differential diagnoses.[14] Clinicians may order plain film radiographs, magnetic resonance (MR) or ultrasonographic (US) imaging as an objective aid to diagnosis. Plain film radiographs may also show calcaneal spurring, for which a strong association with PHP in sedentary populations has been reported.[15] MR and US imaging may also indicate degeneration within the plantar fascia, and doppler US may show increased vasculature in the region of pain.[15] In the general population, a thickness of more than 4 mm is often used as a threshold for diagnosis or >1 mm difference in PF thickness between symptomatic and asymptomatic heels[15,16]; however, this measure may be troublesome among typically younger athletes as these diagnostic tools and criteria were developed in non-athletic groups, and abnormal findings are common in the plantar heels of asymptomatic runners.[3] Indeed, sex-related differences in non-runners[17] may not be evident in runners.[8] Hence, it is not clear how diagnostic imaging should be interpreted among athletes.

1.4. Rehabilitation of PHP in athletes

PHP is typically though self-limiting in nature, and resolution of symptoms occurs within one to two years for most sufferers.[14] Consequently, conservative treatment is recommended for all but those suffering recalcitrant PHP. The published best practice recommends taping and plantar fascia stretching, and education for load management, related medical conditions, and footwear.[18] Corticosteroid injections may be considered for short-term symptomatic relief,[18] however there should be a consideration for partial plantar fascial rupture with repeated use. Positive symptomatic results for fasciotomy have been reported in non-active populations with recalcitrant PHP.[19] However, plantar fasciotomy has also been associated with reduced gait energetics and secondary complications and is not currently recommended for active populations.[20]

There is limited reporting of treatment outcomes for PHP in athletes and active people. Hence, it is difficult to assess if it is more or less successful than for non-active populations, either for single or combination therapies. Clinicians may consider the recent PHP management recommendations of Morrissey et al. (2021),[18] ESSKA,[21,22] the return to competitive running protocol by Hegedus et al. (2021),[23] and other similar sport-specific protocols. Diagnostic and treatment options are summarised in Table 1.

2. Models for PHP development

Models have been proposed to understand the relationship of extrinsic factors such as vertical ground reaction forces (vGRF) to PHP and musculoskeletal injury generally. Rome proposed a model built upon an earlier proposal by Meeuwisse.[24] Rome's model describes a set of intrinsic risk factors that may predispose an athlete to a particular injury. The athlete is then exposed to extrinsic risk factors, leading to the athlete becoming susceptible to an injury. These were grouped as risk factors for injury and described as distant from the injurious outcome. These intrinsic and extrinsic factors may interact to increase the risk of injury, but the presence of the factors alone does not lead to injury.[24] Instead, an inciting event, be that traumatic or chronic, would become the mechanism of the injury outcome.[24] Rome's adaption specified factors thought to be associated with PHP.

Wearing and Hooper[25] proposed an alternative model in 2010. This model differs in that two alternative mechanisms are proposed to develop PHP. The first suggests a healthy plantar fascia operating under an abnormally high load, while the second proposes a fascia with an inherent weakness exposed to regular loading[25] - analogous to traumatic and pathological bone fractures. When exposed to extrinsic factors such as prolonged weight-bearing or increased physical activity, the fascia cannot maintain its integrity, and accumulated microdamage leads to degenerative change.[25] They further suggest that factors such as arch mechanics and calcaneal fat pad properties may be aggravating rather than causative, possibly accounting for differences in symptomatic and asymptomatic people.[25] In this model, the association of common factors such as age and BMI are uncertain. BMI, specifically fat mass, has been linked with PHP,[26] while age is unclear.

In each model, loading of the plantar fascia occurs as an interaction of muscular power and body mass with resistance applied by the supporting surface to the plantar surface – vGRF. Neither details psychological factors, and the link between pathology and pain is unclear.

Table 1
Risk factors, Diagnosis and Treatment Recommendations for People with Plantar Heel Pain.

	Non-athletic population	Athletic population
Risk factors	• Foot shape (pes planus/pes cavus)[65] • High BMI[18,66] • Prolonged standing/walking[18] • Sedentary lifestyle[65] • Achilles tendon tightness[65]	• Thought to be from: • Excessive running[65] • Overuse[65] • Inappropriate footwear[18,66]
Diagnosis		
Clinical	• Patient history[18] • Palpation of medial plantar heel and plantar fascia[18] • Pain on rising after periods of rest[18]	• Patient history[18] • Palpation of medial plantar heel, enthesis and plantar fascia[18] • Pain on rising after periods of rest[18] • Pain after running[65]
Imaging	Ultrasonography • PF thickness >4 mm[65] • >1 mm difference in PF thickness between symptomatic and asymptomatic heels[16] • Areas of hypoechogenicity[65] MRI • PF thickness[15] • Signal change in the PF[67] • Soft tissue oedema and bone marrow oedema at the PF calcaneal attachment[67] Plain film radiographs • Bone pathology (e.g.) calcaneal heel spurs[15]	• Limited research. Assumed to be as per non-athletic population
Treatment	Acute/Chronic Based on VAS and PROM outcome measures for pain • Custom orthoses[18] (S) • Calf stretching[18] (M) • Taping[18] (M) • Footwear[18] • Corticosteroid injections[18] • NSAIDs[66] Recalcitrant • ECSWT[66] (MS) • Surgery – fasciotomy/nerve release[19,66]	• Limited research. Assumed to be as per non-athletic population

Athlete A person training to improve performance for competitive advantage,[8] *BMI* Body mass index, *PF* Plantar fascia, *MRI* Magnetic resonance imaging, *ECSWT* Extracorporeal shock wave therapy, *VAS* Visual analogue scale, *PROM* Patient-reported outcome measure. *NSAIDs* Non-steroidal anti-inflammatory drugs, *S* Strong evidence for short-term outcomes, *M* Moderate evidence for short-term outcomes, *MS* Moderate-strong evidence for short-term outcomes.
NB Strength of recommendations are based on a system developed by Morrissey et al.[18]

3. Factors for PHP in athletes

3.1. Mechanical/gait

Work-related prevalence of PHP varies by the nature of the occupation. Weight-bearing professions, such as assembly plant workers, reportedly have a higher prevalence of PHP.[27,28] Studies involving military populations have observed a higher prevalence among military arms involved in weight-bearing activities (army, marines) than those that are not (navy, air force).[1] This suggests mechanical loading is a key factor in PHP. An injury is analogous to a work-related injury for athletes in a running-related sport. However, there is less available literature for PHP in this group, and what exists is unclear. Training volume and intensity were not found to increase the risk of RRI in general,[29] but few PHP diagnoses were made, and the study's participants were recreational runners, limiting its generalisability to athletes. In contrast, an earlier study of competitive runners found a relationship between training volume, competitive status, and race distance – where athletes competing in middle distance events were more likely to develop PHP than long distance.[8] This suggests that increasing load via distance, time, and/or speed, may be missed in studies without athletes.

An analysis of vGRF and their distribution across the plantar surface may in part explain these findings. Wearing et al. discussed inconsistent findings regarding vGRF and its association with PHP, concluding that additional research into vGRF and regional plantar loading was needed.[30] Some evidence exists linking a change in vGRF and injury. Johnson and Davis recently published a retrospective case-controlled study suggesting higher vGRF loading rates are associated with hamstring injuries[31] and previously with PHP and patellofemoral pain.[32] Similarly, Hollander et al.,[33] in assessing running injury determinants, reported a weak association for hip injuries with higher peak vGRF but stronger associations with foot strike and Achilles and triceps surae injury.

Higher vGRF has been linked with an increased internal compressive force inferior to the calcaneal tuberosity,[34] and rearfoot vertical touchdown velocity has a non-linear relationship to internal heel pad stress.[35] Such modelling may support the premise that PHP is compressive in nature in both rearfoot walking and running. However, forefoot and midfoot strikers land lightly on the heel or not at all.[36] Forefoot striking generally comprises as few as 6% of runners but is a more significant proportion of high-performance runners.[37] Chen et al. reported significant decreases in arch height, increases in arch length, and increases up to 200% in plantar tissue stress in a simulation of forefoot striking versus rearfoot striking.[38] The mechanical determinants of plantar heel tissue stress, whether tensive, compressive, bending, shearing, torsion, or a combination, and associated injury may vary by foot strike.

While the relationship of vGRF with PHP is uncertain, previous studies have found changes in walking loading patterns across the plantar surface of people with PHP.[39,40] Studies assessing static and walking forces in non-active participants have found reduced medial rearfoot pressure and increased forefoot and lateral pressure have been reported.[40] This may suggest an offloading strategy by those with PHP. Whilst this contrasts with earlier studies reporting no effect from vGRF on symptomatic heels,[41,42] none of these studies investigated symptomatic runners. The literature typically has not assessed this group, despite the prevalence of the condition. It is only relatively recently that dynamic measures in runners with PHP have been reported within the literature. In 2009, Pohl et al. reported higher vGRF loading rates for asymptomatic female runners with a history of PHP compared to controls with no history of PHP.[43] This study was limited to a unilateral investigation of previously symptomatic limbs, so it is unknown if the contralateral limb exhibited similar increases. Mixed results were reported in a recent systematic review by Vannatta et al.[44] of factors associated with running-related injuries. They reported that peak vGRF and loading rate association with RRIs were inconclusive.[44] Ribeiro and colleagues found higher peak force and force-time integrals in the symptomatic limbs of participants with PHP.[45] This is in keeping with Pohl et al.'s findings and suggests runners with PHP and previously with PHP may not be employing a load reducing protective mechanism. However, as these studies only focus on unilateral analyses, it is not clear whether this higher loading in runners is bilateral or if there is a degree of asymmetry above what is seen in those without PHP. Further investigation of the bilateral loading patterns in those with PHP is needed to understand how the load is distributed and managed in athletes with PHP from running-related sports.

3.2. Body composition

Mechanical factors are suspected to be significant contributors to PHP development due to a higher incidence of PHP in people with a high BMI, distance runners, and occupations with prolonged weight-bearing periods.[28,46] Studies have repeatedly found an association between high BMI and PHP,[27,47–49] including an odds ratio six times greater when BMI

exceeds 30 kg m^{-2}.[28] A recent systematic review, however, found inconclusive evidence for this association among runners.[50] Although most studies report on BMI, few examine body composition for a relationship between PHP and pain. A study from the general population investigating body composition and foot pain found that a higher BMI and fat mass corresponds with increased foot pain, but muscle mass does not.[26] It is unknown if it is possible to generalise these findings to athletic populations where BMI may not correlate with fat mass or account for increased muscle mass.[51] This may be an important area to research, as adipose tissue and lean tissue are metabolically different, with adipose tissue typically associated with a low-grade systemic inflammation that may change perceptions of pain.[52] Indeed, the *type* of body composition, rather than the overall body volume, could be an important factor. At a local level, body composition has been found to affect the plantar contact area of the foot, with fat-free mass correlating with the forefoot and rearfoot area.[53] It is unclear how this influences mechanically derived pathology and whether it offsets possible gains from reduced fat mass and pain management.

3.3. Psychological factors

Research has focussed mainly on the mechanical and physical characteristics of PHP. However, the complexity of pain (particularly chronic pain) is multidimensional. It has been shown that biological, psychological, and social factors influence pain perception, with recent research highlighting an association between PHP and psychological factors such as depression, anxiety, stress, and catastrophisation.[54]

Catastrophising refers to an exaggerated negative mental state,[55] and has been associated with "first-step" pain in people with PHP.[56] Moreover, pain catastrophising and kinesiophobia have a significant association with self-reported foot function, as measured by Foot Health Status Questionnaire, in people with PHP.[56] Furthermore, other psychological and psychosocial influencers (such as low mood and adverse health beliefs) have been reported to influence the chronicity of non-specific musculoskeletal pain and associated disability.[57] It is unknown what impact these factors may have on athletes with PHP.

In other areas of orthopaedic medicine, psychological factors are increasingly being understood to play a prominent role in the development and recovery from injury and surgery. Pre-operative psychological factors can even predict postoperative pain outcomes, and research has shown that pre-operative anxiety and pain catastrophising are positively associated with postoperative pain.[58] Conversely, dispositional optimism, common among athletes,[59] has been associated with improved pain tolerance, reduced pain sensitivity,[60,61] and improved postoperative pain outcomes.[60] High-quality studies of psychological health and PHP athletes, who often have access to psychology services, may improve management strategies.

Athletes are believed to experience pain differently compared to the general population.[4] However, there is discordance in the literature regarding how athletes perceive pain, which is likely impacted by when and how their pain perception is evaluated. For example, one article assessing exercise-induced analgesia showed that following intense exercise, pain perception in athletes is reduced for a period of time.[62] Another study[4] found that triathletes displayed greater pain tolerance and conditioned pain modulation, and lower perceived pain when compared to healthy controls. However, when testing athletes at rest, some studies have found normal[63] or lower pain thresholds but elevated pain tolerance.[64]

Whilst the literature suggests there is a strong association between psychological and psychosocial influencers and pain perception in musculoskeletal injuries and surgery, there is a paucity of research investigating whether these same factors also influence athletes with PHP.

4. Summary

PHP is among the most common causes of lower-limb pain; however, its aetiology and clear objective diagnostic criteria remain elusive. Much of the research informing our understanding of the condition and associated treatment is largely based upon a sedentary population and may not be generalisable to athletes. Few studies have assessed PHP in a running and active population, and scarce research has investigated highly-trained athletes over an extended period. While models of potential mechanisms of injury have been proposed within the literature, investigation of vGRF in athletes is limited, and the existing models do not incorporate recently proposed psychological factors. Research outlines two clear groups with PHP: younger and active, older and sedentary, yet despite significant differences in their demographics, the injury is clinically similar and treated based mainly on research in the older and non-athletic population. It remains unclear how gait, body composition, and psychological factors may differ in an athletic population with and without PHP.

5. Future research

Researchers should consider investigating active and athletic populations to better inform the aetiology and diagnostic criteria of PHP in these groups. Understanding how PHP manifests in athletic populations may lead to clinical trials involving athletic-specific interventions and focused rehabilitation, ultimately improving outcomes for this population.

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Informed consent (patient/guardian), mandatory only for case reports/clinical images

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Submission declaration

This work has not been published elsewhere and is not under consideration for publication elsewhere, and the work has been approved by all authors, and if accepted will not be published elsewhere in the same form, in English or any other language, including electronically without the written consent of the copyright holder.

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Hamish Harvey – Conceptualization, Writing – original draft,

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Declaration of competing interest

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