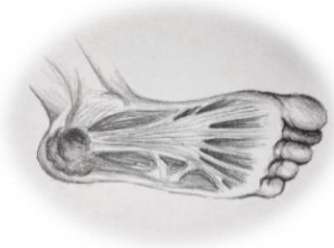
OUTCOME PREDICTION FOR PLANTAR HEEL PAIN

A thesis submitted in partial fulfilment of requirements of degree of Doctor of Philosophy



Halime Gulle

Sports and Exercise Medicine, William Harvey Research Institute,

Queen Mary University of London

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Collaborators

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Morrissey, D., Morrissey, Dylan, Matthew Cotchett, Ahmed Said J'Bari, Trevor Prior, Ian B. Griffiths, Michael Skovdal Rathleff, Halime Gulle, Bill Vicenzino, and Christian J. Barton. "Management of plantar heel pain: a best practice guide informed by a systematic review, expert clinical reasoning and patient values." *British Journal of Sports Medicine* 55:1106-1118 (2021). https://doi.org/ 10.21203/rs.3.rs-36329/v1.

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ABSTRACT

Introduction: Plantar Heel pain (PHP) is a common, problematic disorder with unsatisfactory treatment outcomes. The physical impairments associated with PHP are commonly documented but there is insufficient data to develop multi-variable biopsychosocial models that explain presentation, differences to other conditions, severity or prognosis. In this thesis, I investigated the demographic characteristics and biopsychosocial factors in persons with PHP to develop a prediction model for recovery.

Methods: There were four main parts to the thesis. A systematic review explored the prognostic factors for recovery or successful treatment of plantar heel pain. A feasibility study was performed to investigate the feasibility of data collection procedures and establish equivalence to usual procedures for the questionnaire battery. A case-control study was conducted to identify associated factors of PHP severity. Finally, a prospective cohort study was implemented to develop a prediction model for recovery of PHP.

Results: There are limited biomedical factors which can be used to predict PHP outcome, with a notable absence of high quality prospective cohort studies that consider multiple variables including psychosocial or psychological factors. Questionnaire administration by our online method was valid and reliable. The case-control study showed the factors associated with foot health severity were overall quality of life (QoL) (β=0.35; $p<0.001$), education level (β=−0.22; p=0.003), sex (β=−0.20; p=0.007), morning pain duration (β=−0.18; p=0.01) and disease duration (β=−0.15; p=0.04) in the context of a comprehensive model. The cohort study revealed the risk of still having PHP was 52.5% after 1 year. People who have better general foot health, a shorter symptom duration and have had an injection at any time have a higher chance of recovery. The model provided accurate prediction of the overall recovery (C-statistic 0.68; 95% CI 0.66 to 0.79) for PHP with acceptable discrimination and calibration.

Conclusion: There are assumptions in the literature that prognostic factors for plantar heel pain recovery are mainly physical. My online questionnaire considering a wide range of biopsychosocial variables was valid for remote monitoring of patients for clinical and research purposes, including the cohort study. The developmental models showed severity and recovery are not just determined by physical features of the presentation. Patients presenting with PHP of long duration who score worse on the foot health of FHSQ have a poorer prognosis, irrespective of age, sex and other demographic variables. My results suggest that strategies aimed at preventing chronicity of more severe PHP may optimise prognosis.

ABBREVIATIONS

PHP	Plantar Heel Pain
ANOVA	Analysis of variance
CI	Confidence interval
df	Degrees of freedom
ES	Effect size
HQ	High-quality
ICC	Intra-class correlation coefficient
LOA(s)	Limits of agreement
LQ	Low-quality
MANOVA	Multivariate analysis of variance
MRI	Magnetic resonance imaging
PEDro	Physiotherapy Evidence Database
QMERC	Queen Mary University of London Ethics of Research Committee
RCT(s)	randomised control trial(s)
RF	Radio frequency
RMDQ	Roland Morris Disability Questionnaire
ROM	Range of motion; range of movement
SD(s)	Standard deviation(s)
sEMG	Surface electromyography
SENIAM	Surface EMG for Non-Invasive Assessment of Muscles
SMD	Standardised mean difference
VAS	Visual analogue scale

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CHAPTER 1 INTRODUCTION

> *"Among the minor complaints met with in general practice . . . is one that is characterised by lameness due to pain in the heel when it is pressed on the ground, completely disabling the patient from the ordinary avocations of life."*
>
> *Lowe, 1898*

1.1 Background to the problem

Plantar heel pain (PHP) refers to pain beneath the heel that is typically worse upon weight-bearing activities such as walking or standing (1). The underlying cause of the pain is unknown, and it may originate from a number of structures or tissues, but the plantar fascia is thought to be the main source of this pain (2). People with PHP (PwPHP) experience frustration and struggle to find a care plan that would suit their needs to recovery. A qualitative study revealed there is an uncertainty among PwPHP regarding their diagnosis, causes of pain, prognosis, treatment options and nature of PHP (3).

Current conservative management strategies for PHP usually include stretching, footwear modification, taping and patient education in first-line management, with interventions such as shock wave therapy, injection and orthoses available for those who fail to improve. However, PHP can still remain resistant to treatment (4), and although some studies have reported high levels of spontaneous recovery within one year (5-7), there is now evidence of up to 50% recalcitrance at 10 years (8). Multiple treatment options with unsatisfactory results may arise from the lack of tailoring management strategies with limited understanding of the biopsychosocial factors that affect PHP prognosis. To inform clinical care and delivery and better understand the likely course of an individual's condition, there is a need to identify and evaluate prognostic factors (9, 10).

To provide context for this thesis and highlight the experience of someone with PHP, the following case based on a participant from the case-control study in Chapter 5 is presented.

> *Fatma is a 53-year-old mother of 2 adult children. Her parents immigrated to UK from Bangladesh. However she was born in London. The community she has been living consisted of families from middle-income backgrounds. She works in a factory and office based job for 12-hour shifts. Fatma has a BMI of 25 kg/m^2, some systemic disease such as hypertension, diabetes and back pain. For the past nine months, Fatma has experienced pain in her plantar heel but she maintains the belief that her pain will eventually resolve. Over time, she visited general practices, podiatrists and physiotherapists to resolve the pain several times. After taking advice from clinicians, Fatma tried different management strategies such as calf stretches, cushioned footwear while at work, oral nonsteroidal anti-inflammatory medication, and insole and shockwave therapy. Fatma followed this regime for six weeks with minimal change. In her appointments, she talked to clinicians to understand the reason and pattern of her pain. However, she didn't feel satisfied with the answers received and said "clinicians also don't know why I got this pain and whether I recovered in future". The pain has progressed to become more debilitating and now affects her ability to work. She is now disappointed, frustrated and tired due to trying different treatments with poor outcomes. Recently, she has taken time off work due to the severity of her pain and she is dependent on anti-inflammatories to complete her shifts at work. She feels uncertainty about her future work and life.*

Fatma has tried various interventions such as stretching, orthoses, shockwave therapy without a reduction in her pain, so she requires interventions that can effectively reduce her pain. However, there is uncertainty about which interventions she should use. Therefore, there is a need to understand which interventions are more effective for plantar heel pain, which will allow patients like Fatma to receive greater benefit. With the information presented above in mind, the aim of this thesis is to build a causal model that predict plantar heel pain recovery.

In this chapter, I will present the magnitude of the plantar heel pain problem. I will subsequently provide a broad overview of the literature relating to the epidemiology, anatomy, pathophysiology, associated factors and management for plantar heel pain.

1.2 Terminology

Our decision to choose plantar heel pain (PHP) as the main diagnostic term based on methodological and clinical factors, with the aim of obtaining a pragmatic sample to increase study generalisability. PHP has been used to describe pain under the plantar aspect of the heel, and is used interchangeably with policeman's heel, heel spur syndrome, sub-calcaneal pain, jogger's heel, plantar fasciitis, plantar fasciopathy and plantar fasciosis. However, these terms are not used in an exclusive or unambiguous manner between or within research and clinical groups. The main reason for this inconsistency is that histological examination and medical imaging have illustrated that multiple tissues might be involved and the plantar fascia may not be the only culprit structure. Therefore, it has been suggested the term 'plantar heel pain' would be ideal to describe the condition. Secondly, first-line treatment in clinical practise is likely to be consistent irrespective of the term chosen. Similarly, in the literature, an examination of the terminology by Riel H. et al (2018) suggested using PHP as a term to facilitate clear understanding across researchers and clinicians (11). Our best practice guide considered this issue in detail and settled on the term PHP (12).

1.3 Epidemiology of Plantar Heel Pain

1.3.1 Prevalence

Plantar heel pain is generally considered a common condition in the community, but precise population estimates have not been established (13). The variety of the methodology utilised in each study causes inconsistencies in prevalence estimates, complicating the synthesis of data (Table 1). Overall, prevalence estimates suggest that plantar heel pain is common and ranges from 3% to 10% in population samples. Certain subpopulations such as elderly people, athletes or those who occupations that require prolonged standing have a higher prevalence. However, these results need to be interpreted with caution due to the variety of methodology and the

limited evidence provided. Only two studies, for example, Thomas et al. (2) and Dunn et al. (3), used the similar study design, which was cross-sectional. However, the remaining studies implemented by different study procedure, number of sample size and populations in various countries, which makes difficult to compare them. Therefore, more research will be needed to establish the correctness of each estimate.

Table 1. Summary of prevalence estimates for people with plantar heel pain.

				Sample		
Study	**Country**	**Design**	**Prevalence estimate**	**Number of people**	**Mean age (SD)**	**Population targeted**
Thomas et al.	The UK	Cross-sectional	9.6% (8.8 to 10.5)	5109	NR	Older people (Adults aged > 50)
Lopes et al	Brazil	Systematic review	5.2 to 17.5%	3276	NR	Runners
Werner et al	The USA	Cross-sectional	7.8% (5.6 to 10.8)	407	48.4 (10.3)	Factory workers
Hill et al 2008	Australia	Prospective cohort	3.6% (3.0 to 4.3)	3,206	NR	Adults randomly selected from the community
Dunn et al	USA	Cross-sectional	6.9% (5.3 to 8.8)	784	74.5 (6.0)	Older people (Adults aged > 65)

Key: NR= Not Reported; SD= Standard deviation

1.3.2 Incidence

The incidence of plantar heel pain has been studied more frequently in certain populations such as athletes (runners) than in community samples. *A*s a result, determining the population's incidence is difficult and there is variability in the study design, although certain populations have received more attention. Table 2 summarises the incidence estimates from the studies that are *in the literature*.

Table 2. Summary of incidence estimates for plantar heel pain

					Sample		
Study	**Country**	**Design**	**Incidence estimate**	**Time Period**	**Number of people**	**Mean age**	**Participants**
Albers et al.	Brazil	Retrospective cohort	2.3 per 1,000 person years*	2.3 per 1,000 person years*	10651	36	Adults and children from the community
Lopes et al.	Italy	SR	(4.5 to 10.0%)	(4.5 to 10.0%)	3276	NR	Runners
Di Caprio et al.	Holland	Prospective cohort	31.3%	31.3%	166	31.1	Runners
Taunton et al.	Canada	Retrospective cohort	7.8% (6.7 to 9.2)	7.8% (6.7 to 9.2)	2002	36.2	Runners

Scher et al.	USA	Retrospective cohort	10.5 per 1,000 person years*	10.5 per 1,000 person years*	12,116.044	NR	Military personnel

Key: NR= Not Reported

In summary, the incidence of plantar heel pain differs throughout the studies due to different study design in various countries and time periods utilised to calculate the incidence, or it could indicate that some populations have a higher or lower incidence of plantar heel pain.

For instant, the Scher et al. 2009 (2) study, which utilised a military sample, found a higher incidence than the Albers et al. 2016 (3), which used a community sample, indicating that military members may be more likely to suffer plantar heel pain than the general population. More research with similar methodology and time periods could provide a better knowledge of the incidence of plantar heel pain in other populations.

1.3.2 Healthcare Burden

The financial impact of plantar heel pain on the healthcare system is a significant factor to consider, and knowing this information can help organisations assess the financial cost of this problem. However, only a small amount of study has looked into the direct and indirect expenses of plantar heel pain. An economic analysis of data from patient visits and costs in the United States in 2007 was undertaken in one study (2). According to this study, the economic burden of plantar heel pain was predicted to be between US$192 million and US$376 million in the USA. Given that only one study has investigated the economic impact of plantar heel pain in the United States, and this study is now more than 14 years old, new research from multiple nations is needed.

1.4 Anatomy and function of plantar fascia

1.4.1 Anatomy of plantar fascia

The plantar fascia is also known as plantar aponeurosis and it lies between the calcaneus and toes. It forms a strong mechanical structure beneath the feet (14). The plantar fascia origin is divided into three different components as medial, central and lateral. The central facia band originates from the medial process of calcaneal

tuberosity and runs through and inserts onto the five proximal phalangeal joints. The central part of plantar fascia is also cited as continuation of the Achilles tendon in many studies (14-16). It is accepted as a major part of the plantar fascia because of its triangle shape and functionality which is main structure of windlass mechanism (14-16). Although the central part is often cited as a major component, the medial aspect of the plantar fascia is the main element associated with plantar heel pain. This structure is relatively thin compared to the lateral component which is thick and appears variable in nature (14, 17).

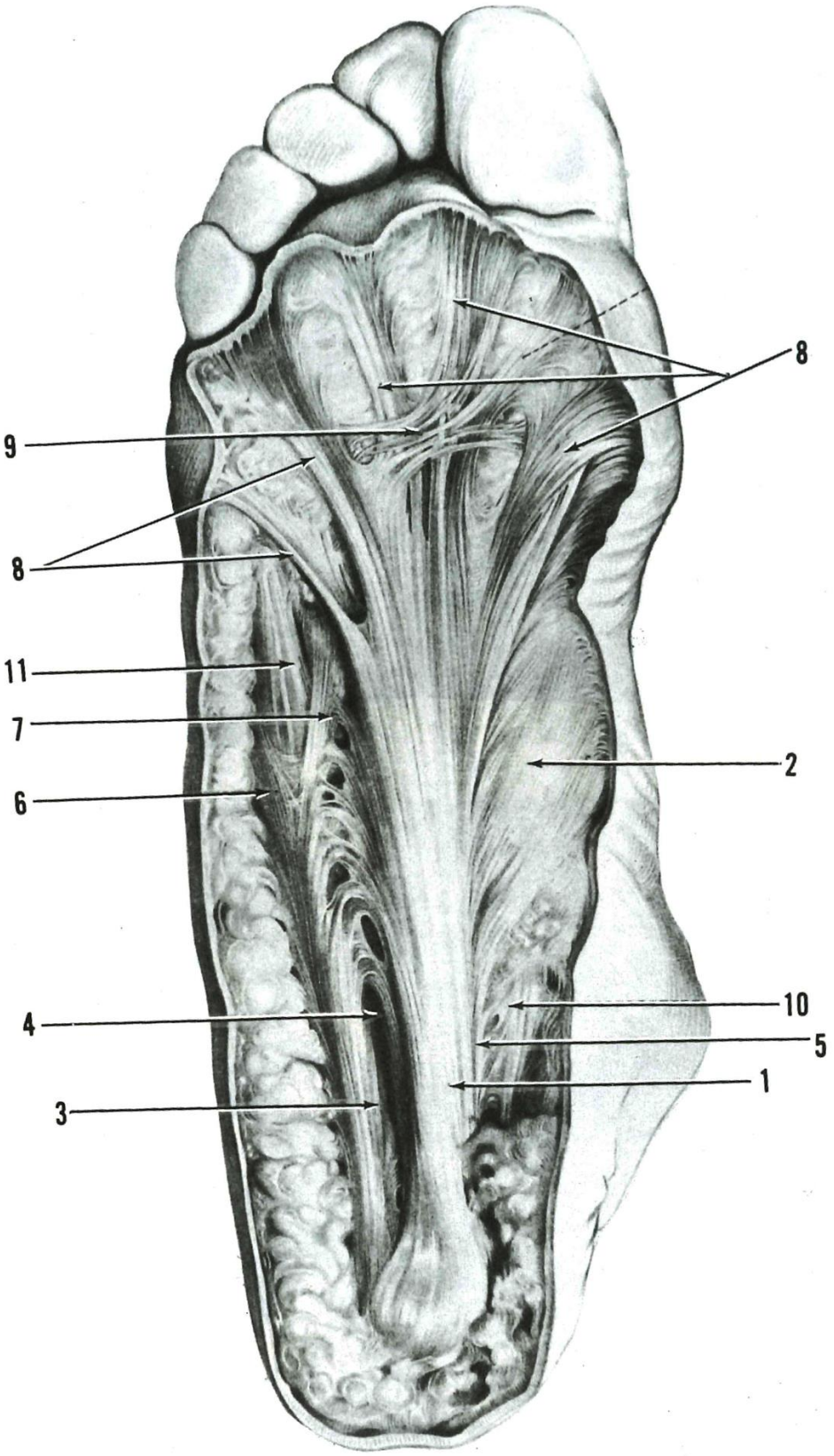

Figure 1. The plantar fascia. Image reproduced from the book of Sarrafian's anatomy, 2011 (18). *Key = 1) Central component; 2) medial component; 3) lateral component; 4) lateral plantar sulcus; 5) medial plantar sulcus; 6) lateral crux of lateral plantar component; 7) medial crux of lateral plantar component;8)superficial longitudinal tracts; 9) transverse superficial tract; 10) abductor hallucis muscle; 11) abductor digit minimi muscle.*

1.4.2 Histology of plantar fascia

The plantar fascia has densely packed type 1 collagen fibres, especially in core region, and placed mostly in a longitudinal axis across the plantar foot from proximal to distal (19, 20).

There are several intermuscular and intramuscular septae that originate from the plantar fascia's inner aspect and extend into the deep fascia of the foot, providing multiple connections (19). The various plantar fascia muscle insertions have been proposed to aid in the coordination of the various superficial and deep muscles of the plantar aspect of the foot (19). The histological features of the plantar fascia's origin is likely to change over time (21). In new-borns, the origin has thick collagen fibres that connect to the Achilles tendon. Through the process of cartilaginous metaplasia, the presence of numerous chondrocytes at the origin of the plantar fascia replaces the fibrous connection between the plantar fascia and Achilles tendon with calcified fibrocartilage (19).

1.4.3. Function of plantar fascia

The plantar fascia has three important functions in assisting with efficient walking. Firstly, plantar fascia pulls and supports function of medial longitudinal arch during weight bearing activities such as walking, running, which is known as windlass mechanism (14, 22). Hicks who attributed that for the first-time defined windlass mechanism as "...When the toes are extended they pull the plantar pads and hence the aponeurosis forward around the heads of the metatarsals, like a cable being wound on to a windlass. The, the arch is caused to rise because the distance between the metatarsal heads and the calcaneus is thereby shortened" (Figure 1) (23). Dysfunction of windlass mechanism led overload on plantar fascia because the load would be born through the fascia rather than the medial arch of the foot, which is considered as an associated factor related to various foot and ankle problems such as plantar heel pain (24).

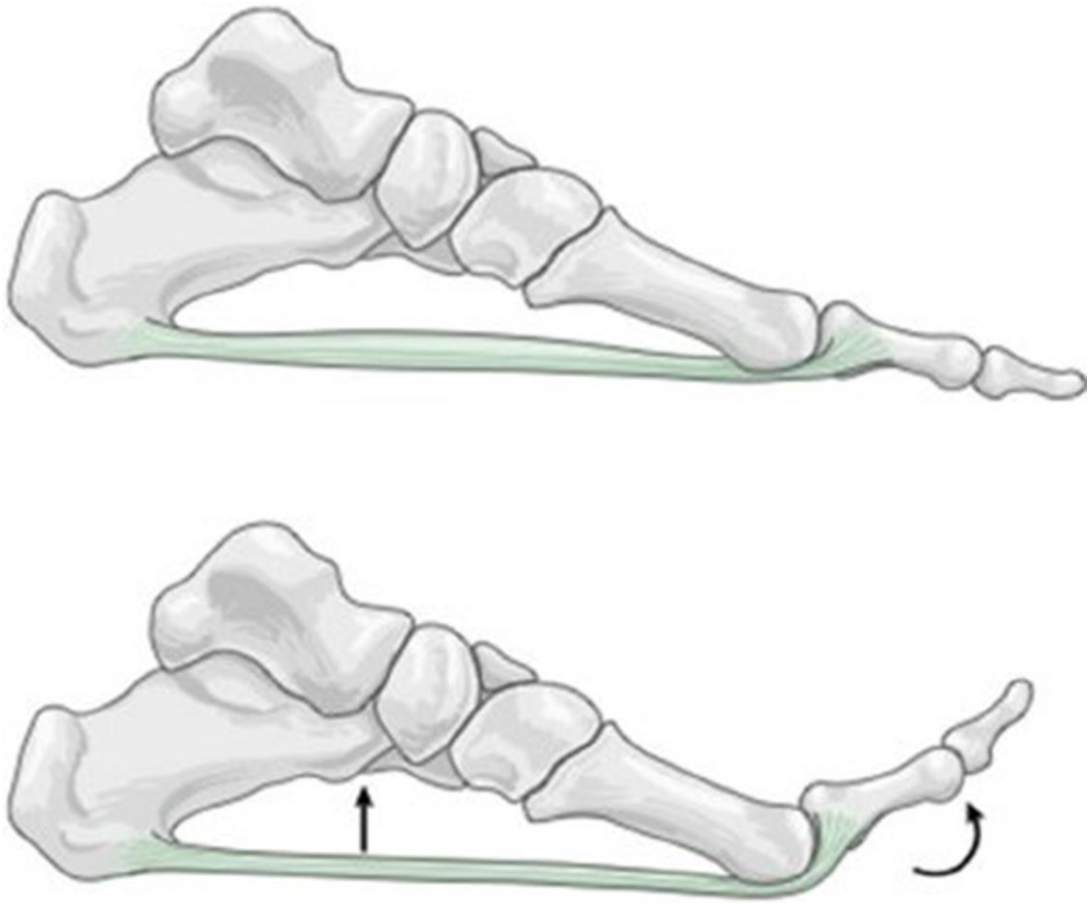

Figure 2. The windlass mechanism. Image reproduced from DiGiovanni & Greisberg.

Secondly, the plantar fascia plays an important role in elastic energy storage during weigt-bearing activities such as walking or running by lowering the amount of work required to change joint moments (25, 26). This energy storage feature of plantar fascia also protects the foot from various injuries such as metatarsal stress fracture (27).

1.5 Pathophysiological Mechanisms of Plantar Heel Pain

It is generally accepted two different injury mechanisms play an important role in plantar heel pain development (14). These are repeated plantar fascia strain because of repetitive use and sudden direct trauma to the plantar fascia. In both cases, three different possibilities could manifest and lead to heel pain. Firstly, plantar fascia periosteum can be affected and resulted in pulling of periosteum on medial tuberosity of calcaneus, which causes haemorrhage (28). Secondly, new connective tissue could be formed, and plantar fascia can be thicker, perhaps because micro tears initiate an inflammatory response and increase stress on the plantar fascia

insertion (14). The acute inflammatory response could persist and become chronic, as this stress continues (15, 28). A persistent inflammatory response prevents repair of these tears and increases in fibroblast activity. Due to increased fibroblast and mucoid ground substance, fibro-cartilage can form (29). This leads to disorganisation of the collagen fibres and ossification (28, 30). Lastly, as a consequence of these connective tissue changes, a calcaneal spur could develop in the soft tissue and every weight-bearing activity potentially trigger heel pain (31).

Histopathological studies give an overview of the pathological process in plantar heel pain. Acute inflammation is characterised by oedema and neutrophils inflammation. While chronic inflammation is characterised by mononuclear cell infiltration (e.g. macrophages), tissue damage and attempts to heal the tissue through the growth of new tissue and small vessels (e.g. fibro-vascular hyperplasia fibrosis) (32). Table 3 below summarises the results of previous histopathological studies.

Table 3. Summary of histopathologic findings

Study	Participants	Method	Histological findings
Jarde et al. 1996	12 heel spur samples	Not reported	Chronic granulomatous tissue in 100% of samples. Angiofibroblastic hyperplasia in 100% of samples. Chondroid or cartilage metaplasia in 10% of samples. Fibromatosis in 10% of samples.
Leach et al. 1986	15 athletes	Not reported	Chronic granulomatous tissue, mucoid degeneration in some instances. Partial rupture in 13% of samples. Local inflammatory reaction.
Lemelle et al. 1990	2 participants	Electron microscopy	Participant 1: fibrocartilaginous degeneration, fibrovascular hyperplasia. Participant 2: irregular staining, fraying of collagen fibres, no fibrosis or lymphocytic infiltration.
Lemont et al. 2003	50 heel spur samples	Not reported	Normal histological appearance in 20% of samples. Collagen fragmentation in association with mucoid degeneration in 32% of samples. Vascular ectasia of adjacent bone marrow in 24% of samples. Crystalline deposition in 4% of samples. No evidence of inflammation.
Schepsis et al. 1991	25 athletes	Not reported	Collagen degeneration, collagen metaplasia, calcification.
Snider et al. 1983	9 males 1 amputated control limb	Light microscpy	Four variations noted: collagen degeneration in 100% of samples, angiofibroblastic hyperplasia in 56% of samples, chondroid metaplasia in 22% of samples, matrix calcification in 11% of samples.
Tountas & Fornasier 1996	21 participants, 5 amputated control limbs	Not reported	Varying amounts of: collagen degeneration, mucoid degeneration, fibrinoid degeneration, fibrovascular proliferation, partial rupture, no active inflammation.

1.6 Factors associated with Plantar Heel Pain

In the literature, most of the earlier studies have cross-sectional design, which only allow conclusions regarding the association of factors rather than evidence for a causal relationship. The overall associated variables can be divided into two categories as intrinsic and extrinsic factors. Intrinsic factors are anatomical and biological characteristics of individuals that predispose them to injury. Biological factors suggested in the literature include increasing age, increasing body mass index (BMI), height and weight gain; anatomical factors include limited ankle dorsiflexion, leg length discrepancy, heel pad thickness, increased plantar fascia thickness, pes planus (excessive pronation of the foot), cavus (high arched) foot, muscle imbalance, limited first metatarsophalangeal joint (MPJ) range of motion (ROM) and calcaneal spur. Postulated extrinsic factors include prolonged weight bearing, improper shoe fit and wear, previous injury and running variables such as surface, speed, frequency and distance per week.

Table 4. List of intrinsic factors

Variables	Studies investigated	Design of the studies	Results
Biological			
Age	Rano et al. 2001 Werner et al. 2010 Rome et al. 2002	Cross-sectional Cross-sectional Cross-sectional	• Increased prevalence in older athletes • Age related degenerative changes may result in fascia's inability to resist normal tensile loads • Associated with increased heel fat pad thickness and loss of elasticity • Decreased fascial elasticity associated with decreased shock absorbing capabilities in older patients
BMI	Irving et al. 2007 Rano et al. 2001 Rajput et al. 2004 Hill et al 1994 Ozdemir H et al 1992	Case-control Cross-sectional Case study Case-control	• Increased BMI associated with increasing heel fat pad thickness and loss of heel pad elasticity • Significant positive correlation between BMI and PF thickness causing chronic stretch, overloading and focal pressure of PF
Gender	Orchard J 2012 Taunton 2002 Rano et al. 2001	Systematic review Retrospective case-control	• Current literature inconsistent: - Increased prevalence in men - Increased prevalence in women
Anatomical and biomechanical features			
Ankle dorsiflexion	Kibler et al. 1991 Sullivan et al. 2015	Case-control Case-control	• Ankle dorsiflexion was significantly lower in the plantar heel pain group ($P < 0.01$)*. • Flexed ($P = 0.011$) and straight knee lunge ($P = 0.003$) were significantly lower in the plantar heel pain group.

Table 4. List of intrinsic factors (continued)

Foot posture	Irving et al. 2007 Ribeiro et al. 2011	Case-control Case-control	• A pronated foot posture was 3.7 (95% CI, 1.6 to 8.7) times more likely in the plantar heel pain group when measured with the Foot Posture Index. • A pronated foot posture was associated with plantar heel pain (P = 0.009) when measured with the Arch Index.
Plantar heel pad	Leeuwen V et al. 2016	Meta-analysis	• Participants with plantar heel pain had greater unloaded (MD 0.8 mm; 95% CI, 0.1 to 1.5) and loaded heel pad thickness (MD 1.0 mm; 95% CI, 0.3 to 1.8).
Hamstring flexibility	Labovitz et al. 2011	Cross-sectional	• Participants with plantar heel pain were 8.7 times (95% CI, 4.4 to 17.2) more likely to have lower hamstring flexibility on the painful limb compared to the symptomatic contralateral limb (P < 0.0001).
Muscle strength	Sullivan et al. 2015 McClinton et al. 2016	Case-control Case-control	• Participants with plantar heel pain had reduced strength with eversion (P < 0.01) and toe flexion (P < 0.05).* • Participants with plantar heel pain obtained lower scores on the Modified Paper Grip Test of the great toe (P = 0.022) and the lesser toes (P = 0.037).*
Flexibility of 1st MTPJ	Wearing et al. 2004 Sconfienza et al. 2013	Case-control Case-control	• A significantly smaller ROM in the PF group was reported in a single study for active extension, passive flexion and active flexion. MTP mobility was found to be lower in extension in PF cases
Psychological			
Depression, anxiety	Cotchett et al. 2016	Case-control	After controlling for age, sex, BMI, and years of education, symptoms of depression, anxiety, and stress were significantly associated with having plantar heel pain.
Kinesiophobia & Catastrophization	Cotchett et al. 2017 Cotchett et al. 2018	Case-control Cross-sectional	After controlling for age, sex and BMI, kinesiophobia and pain catastrophizing are significantly associated with foot function, and pain catastrophizing is associated with first step pain in people with PHP.

Incomplete recovery may be attributed to patient characteristics as age, body mass, gender, psychosocial presentation and physical activity levels identified and associated with outcome predictors of plantar heel pain. Although the aetiology of PHP is likely to be multifactorial, mechanical overload has been cited as the principal factor involved in the development of the condition. As with most overuse-type injuries, both intrinsic and extrinsic risk factors have been anecdotally reported to precipitate the development of PHP. While the onset of musculoskeletal injuries of the lower limb has largely been attributed to extrinsic factors, Taunton et al. proposed that intrinsic factors, such as pes planus and subtalar joint pronation, provided the most significant contribution to the development of PHP. Typical training programs for novice conscripts include running long distances, marching, and calisthenics, crawling, jumping, lifting, and carrying loads. Each of these are extrinsic factors that can result in overuse injuries in the lower extremities (Jones,

Cowan, & Knapik, 1994). The requirement that trainees be on their feet for long periods is thought to increase the risk of developing PF (Owens et al., 2013).

A combination of extrinsic factors, such as a vigorous training program and inappropriate footwear, and intrinsic individual, anatomical, and biomechanical factors are thought to predispose trainees to developing PF and other lower-extremity overuse injuries (Krivickas, 1997; Pujalte & Silvis, 2014).

1.7 Treatment modalities for plantar heel pain

Considering recovery rate of various treatments, this is variable between 50% -80% (33). An exercises trial involving 101 participants showed that only 52% of plantar heel pain patient who were treated with an exercise program which is stretching of plantar fascia can recovered at eight weeks (34). Another study was recruited 103 subjects were randomly assigned to one of three treatment categories and were treated for 3 months with anti-inflammatory and multi-model treatment. 23% (7 of 31) of the anti-inflammatory group had their treatment terminated and 42% (11 of 26) of the multi-model group had their treatment terminated because of treatment failure (35). A trial study for shockwave with 254 people with chronic painful heel syndrome showed that overall success rate 61.0% in shockwave therapy group compared with 44.2% in placebo group at 12 weeks (36). On the other hand, although the conservative treatment methods are supported to recovery of PHP, approximately 18% to 50% of individuals continue to have symptoms after conservative treatment and 30% have recurrent symptoms (37). Therefore, it can be thought that these patients are resistant to recovery.

Table 5. Summary of interventions for plantar heel pain

Intervention	Outcome measure		Short term[b]	Medium term[b]	Long Term[b]
Interventions with Primary proof of efficacy					
Custom orthoses	Pain	Between group efficacy	Strong Positive(38-41) 0.41 (0.07 to 0.74)	Limited Positive(40) 0.55 (0.09, 1.02)	Moderate Neutral**(38)** 0.04 (-0.37 to 0.45)
		Within group outcome	1.24 (1.00, 1.49)(38-42),[c]	1.65 (1.12, 2.18)(40),[c]	
	First step pain	Between group efficacy	Limited Neutral(39, 41) -0.32 (-0.91, 0.26)		
		Within group outcome			
	Function	Between group efficacy	Moderate Neutral(38, 40, 41) -0.21 (-0.48, 0.06)	Limited Neutral(40) -0.39 (-0.85, 0.07)	Moderate Neutral**(38)** -0.12 (-0.53, 0.29)
		Within group outcome			
Prefabricated orthoses	Pain	Between group efficacy	Moderate Neutral(38, 41) -0.25 (-0.59, 0.09)		Moderate Neutral**(38)** -0.08 (-0.50, 0.33)
		Within group outcome			
	First step pain	Between group efficacy			
		Within group outcome			
	Function	Between group efficacy	Moderate Neutral(38, 41) -0.06 (-0.40, 0.28)		Moderate Neutral**(38)** -0.08 (-0.50, 0.33)
		Within group outcome			
Magnetised insoles	Pain	Between group efficacy	Moderate Neutral**(43)** 0.00 (-0.39, 0.39)		
		Within group outcome			
Radial ESWT	Pain	Between group efficacy	Strong Positive(44, 45) 1.64 (-1.06, 4.33)[d]	Limited Positive (45) 3.77 (2.82, 4.72)	Strong positive(44, 45) 0.78 (-0.15, 1.72)[d]
		Within group outcome	3.78 (-1.38, 6.17)(44-47)[d]	5.81 (3.57, 8.05)(45, 46)	6.41 (4.99, 7.83)(44, 45)
	First step pain	Between group efficacy	Moderate Positive **(44)**,[c] OR: 1.66 (1.00, 2.76)[d]		Moderate Positive**(44)** OR: 1.78 (1.07, 2.96)
		Within group outcome	1.19 (0.76, 1.63)**(48)**[b]	1.74 (1.26, 2.21)**(48)**[b]	2.93 (2.34, 3.51)(48),[b]

Table 5. Summary of interventions for plantar heel pain (continued)

	Function	Between group efficacy	Moderate Positive(44) 0.35 (0.10, 0.60)	Limited Positive (45) 2.39 (1.65, 3.12)	Limited Positive (45) 0.90 (0.32, 1.49)
		Within group outcome	3.47 (2.57, 4.37)(45),[b]	4.57 (3.48, 5.65)(45),[b]	2.81 (2.02, 3.61)(45),[b]
Focused ESWT	Pain	Between group efficacy	Moderate Positive (49) 0.36 (0.11, 0.61)		
		Within group outcome	1.33 (0.94, 1.72)(47, 50)[c]		
	First step pain	Between group efficacy	Strong Positive (49, 51) OR: 1.89 (1.18, 3.04)	Limited Positive(52) 1.31 (0.61, 2.01)	Limited Positive(52) 1.67 (0.88, 2.45)
		Within group outcome	2.11 (0.75, 3.48)(53, 54)	2.84 (1.94, 3.73)(52)	3.33 (2.78, 3.87)(52)
	Function	Between group efficacy	Moderate Positive (49) 0.36 (0.10, 0.61)		
		Within group outcome	1.26 (0.99, 1.53)(49)		
Combined Radial and Focused ESWT	Pain	Between group efficacy	Strong positive (44, 45, 49) 1.08 (0.20, 1.97)	Limited Positive (45, 50) 3.77 [2.82, 4.72)	
		Within group outcome	2.72 (1.39, 4.05)(45-47, 50)	4.33 (1.12, 7.55)(45, 46, 50)	
	First step pain	Between group efficacy	Strong positive(44, 49, 51) OR 1.78 (1.26, 2.52)		OR 1.95 (1.22, 3.12)(44, 52)
		Within group outcome	1.79 (0.92, 2.66)(48, 53, 54)		3.14 (2.74, 3.54)(48, 52, 54)
	Function	Between group efficacy	Strong positive(45, 49) 1.03 (-0.36, 2.42) [d]		
		Within group outcome	2.32 (0.16, 4.49)(45, 49)		

Table 5. Summary of interventions for plantar heel pain (continued)

Dry needling	Pain	Between group efficacy	Moderate Neutral**(55)** -0.33 (-0.76, 0.10)		
		Within group outcome			
	First step pain	Between group efficacy	Moderate Neutral**(55)** -0.42 (-0.85, 0.02)		
		Within group outcome			
	Function	Between group efficacy	Moderate Neutral**(55)** 0.11 (-0.31, 0.54)		
		Within group outcome			
Wheatgrass	Pain	Between group efficacy	Moderate Neutral**(56)**,[c]		
		Within group outcome			
	Function	Between group efficacy	Moderate Neutral**(56)**,[c]		
		Within group outcome			
Calf stretching	First step pain	Between group efficacy	Moderate Neutral**(57)** -0.39 (-0.80, 0.03)		
		Within group outcome			
	Pain	Between group efficacy	Moderate Neutral**(57)** 0.00 (-0.40, 0.41)		
		Within group outcome			
	Function	Between group efficacy	Moderate Neutral**(57)** -0.24 (-0.65, 0.17)		
		Within group outcome			
Low dye taping	First step pain	Between group efficacy	Moderate Positive**(58)** 0.47 (0.05, 0.88)		
		Within group outcome	1.21 (0.77, 1.66)**(58)**		

	Pain	Between group efficacy	Moderate Neutral**(58)** 0.30 (-0.11, 0.71)		

Table 5. Summary of interventions for plantar heel pain (continued)

		Within group outcome			
	Function	Between group efficacy	Moderate Neutral**(58)** -0.05 (-0.46, 0.36)		
		Within group outcome			
Interventions with Secondary proof of efficacy					
Plantar fascia stretching	First step pain	Between group efficacy	Moderate Positive**(48)** 1.21 (0.78, 1.63)	Moderate Positive**(48)** 0.64 (0.24, 1.04)	Moderate Neutral**(48)** -0.04 (-0.43, 0.35)
		Within group outcome	2.81 (2.27, 3.35)**(48)**	3.25 (2.67, 3.83)**(48)**	

1.8 Literature GAP

There are some studies investigating outcomes for sciatica pain, low back pain, breast cancer and neck pain (59-62). They aimed to obtain knowledge about disease prognosis to help guide expectations of patients and health care providers, while also helping clinicians choose the most effective interventions based on predictive models (63).

For PHP, in particular, it has been suggested that effective clinical decision-making or such knowledge mentioned above is almost non-existent due to the lack of evidence on prognostic factors. Although there has been much PHP research, these studies are generally small sample case-control and cross-sectional studies thus only providing a "snapshot" in time(64, 65). Such studies can only suggest possible prognostic associations due to inability to detect time of occurrence. Any such factor found to be associated with plantar heel pain at one point in time could be a risk factor or a prognostic factor for non-recovery/recovery (63). These study types are therefore not ideal to inform clinicians or researchers about course of disease or prediction factors.

Furthermore, clinical predictions rule studies (CPRs) assessed the outcome of PwPHP with single variable model (37, 66). However, a multiple variable model is better to identify outcome predictors of non-recovery than strongest single variables (67), because this helps to understand prognosis in the context of recognising the complexity of presentation and management. Understanding disease prognosis is crucial as recognizing the path or pattern of the disease can help clinicians to make important decisions. Therefore, studies investigating prognosis and prognostic factors in PHP are needed to improve clinical practice by supporting decisions.

CHAPTER 2 AIMS AND OBJECTIVES

2.1 Overarching aim

The overarching aim of this thesis was to synthesise and extend the existing knowledge base, in order for clinicians, patients and researchers to have the information required to improve clinical decision related to recovery of plantar heel pain in adults. More specifically, I aimed to determine outcome predictors for explaining prognosis in plantar heel pain which is derived from model specific to plantar heel pain and suitable to be used in clinical practice. This required detailed steps with specific research questions and methodological developments. The specific aims, objective and alternative hypotheses below were clarified in each steps in order to achieve this overarching aim. The impact of success would be improved clinical decision process and guides expectations for recovery and assists in planning health care policies, formulating interventions for plantar heel pain.

2.2 Specific aims and objectives and alternative hypotheses (H1)

The purpose of introduction (Chapter 1) was to summarise the current literature related to plantar heel pain prevalence, associated factors and management strategies. This was conducted to assist in identifying gaps in the existing literature and determine the direction of studies within the thesis. The studies to be conducted as a part of this PhD have following aims, objectives and hypotheses:

1. Predicting outcome of plantar heel pain in adults: a systematic review of prognostic factors – *see chapter 3*.

    - **Aim:** Identifying prognostic factors from prospective cohort studies and single arm randomized controlled trials in existing literature. This also aimed to help researchers generate better hypotheses and direct their efforts more effectively, perhaps with prospective cohort studies.

- **Objectives:** a) Determining which baseline patient characteristics were associated with outcome in observational cohorts or after specific interventions, and b) analysing the quality of the available research and the gaps within it (i.e. identify biomedical, physical and psychosocial variables that have yet to be investigated).

- **H_1:** That there would be an extended range of variables but less strength of evidence, for potentially prognostic factors for PHP. In addition, these prognostic factors would be of relevance to clinicians treating people with PHP.

2. Study development – *see chapter 4*.
    - **Aim:** Optimising the success of a prospective cohort study.
    - **Objectives:** a) explaining the study protocol and justifications of developed steps b) providing details of questionnaire, clinical and biomechanical testing procedure c) presenting the list of the key achievements and trainings during PhD as a part of personal development processes
3. Online questionnaire clinical and biomechanical measurements for outcome prediction of plantar heel pain: feasibility for a cohort study – *see chapter 5*.
    - **Aim:** Optimising the success of a prospective cohort study.
    - **Objectives:** a) investigate feasibility by testing data collection procedures and gaining feedback from participants in order to refine data collection b) establishing equivalence to usual procedures for the questionnaire battery; known-group validity for clinical and imaging measures; and initial validation and reliability of biomechanical
    - **H_1:** Online questionnaire modifications applied would be valid and useful compared to the original paper version of the questionnaires. Clinical and biomechanical measurements would be valid, reliable and feasible in current sample of the planned cohort.

4. The association of demographic, psychological, social and activity factors with foot health in people with plantar heel pain: an international case-control study– *see chapter 6*.

    - **Aim:** improving the understanding of PHP by constructing explanatory models from the baseline data of a large international cohort study of people with PHP. This included a wide range of self-reported biopsychosocial factors.
    - **Objectives:** were to better understand the severity of compromised foot health in this population, and explore what combination of self-reported factors distinguish people with PHP from other foot pain (OFP).
    - **H_1:** Severity of PHP would be more than just a mechanical or biomedical problem. Those with PHP would be higher associated levels of a range of psychological, social and activity related factors than people with OFP.

5. Outcome predictors for plantar heel pain in adults: a prospective cohort study– *see chapter 7*.

    - **Aim:** improving the understanding of PHP by constructing prediction models from a large international prospective cohort study with 12 months follow-ups of people with PHP. This included a wide range of self-reported biopsychosocial factors.
    - **Objectives:** determining what combination of self-reported factors predict the successful (recovery) outcome of plantar heel in 12 months follow up periods.
    - **H_1:** Those with PHP who less severe and shorter disease duration would have higher chance to being recovery at the end 12 months period.

CHAPTER 3 PREDICTING THE OUTCOME OF PLANTAR HEEL PAIN IN ADULTS: A SYSTEMATIC REVIEW OF PROGNOSTIC FACTORS

There are multiple systematic reviews and clinical practice guidelines that have evaluated the effectiveness of interventions for PHP (presented in Chapter 1). But, there is no review of prognostic factors for PHP, aiming to be investigated in this thesis.

Preliminary results of this review were presented at the 2021 Australian Podiatry conference in Australia. This review currently is under revision process for publication in the Musculoskeletal Science and Practise Journal.

The results presented within this chapter informed the subsequent cohort study investigating the outcome predictors for plantar heel pain (chapter seven), given the absence of data pertaining to prognostic factors for PHP in this patient group.

3.1 Introduction

Plantar heel pain (PHP) is one of the most troublesome and common foot conditions, with an estimated prevalence between 4% and 10% in the comminity (1, 68-70). PHP is characterised by pain in the inferior-medial aspect of the rear-foot that is typically worse upon weight-bearing activities such as walking or standing (1). Consequently, there is a strong negative effect on quality of life due to limited activities of daily life for people with PHP (PwPHP) (71).

Multiple treatment options are available for PHP. A recent comprehensive systematic review summarized various randomized controlled trials (RCTs) with a range of treatment strategies (4). Current conservative management strategies for PHP usually include stretching, footwear modification, taping and patient education in first-line management, with interventions such as shock wave therapy, injection and orthoses available for those who fail to improve. However, PHP can still remain resistant to treatment (4), and although some studies have reported high levels of spontaneous recovery within one year (5-7), there is now evidence of up to 50%

recalcitrance at 10 years (8). Multiple treatment options with unsatisfactory results may arise from the lack of tailoring management strategies with limited understanding of the biopsychosocial factors that affect PHP prognosis. Prognostic factors are variables at baseline which are associated with a subsequent outcome such as pain, function and disability and can be evaluated with specific research designs such as prospective cohort studies, analysis of singel arms in randomized controlled trials and clinical prediction rule derivation studies. To inform clinical care and delivery and and to better understand the likely course of an individual's condition, there is a need to identify and evaluate prognostic factors (9, 10).

In other musculoskeletal conditions, prognostic factors such as increased mid-foot mobility may predict those who have a successful outcome to foot orthoses in people with patellofemoral pain (72). A recent systematic review of prognostic factors in tendinopathy showed that limited evidence exists linking psychological variables and tendinopathy, and suggested that using validated screening tools for the presence of psychological variables should be a part of their holistic management (73). While there are multiple systematic reviews and clinical practice guidelines that have evaluated the effectiveness of interventions for PHP there is no review of prognostic factors for PHP.

The aim of this review was to inform clinical care planning for PHP by 1) determining which baseline patient characteristics were associated with outcome in observational cohorts or after specific interventions, and 2) analysing the quality of the available research and the gaps within it (i.e. identify biomedical, physical and psychosocial variables that have yet to be investigated). This second aim will help researchers generate better hypotheses and direct their efforts more effectively, perhaps with prospective cohort studies. This will guide future work to improve our understanding of outcomes and therefore treatment decisions for this troublesome, common, recalcitrant condition.

3.2 Methods

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) was followed as a guideline for the search strategy (74) and a published guideline for

prognostic factors systematic reviews followed to determine design and reporting (75). The review protocol was registered on PROSPERO (CRD42020205005).

3.2.1 Search strategy

Electronic databases (Ovid MEDLINE, Scopus, Embase, Pubmed and Web of Science) were searched from inception to June 2020. Key search terms used in the selection process relating to PHP were [plantar heel pain OR plantar fasci* OR heel pain syndrome], which were adapted from previous studies with similar search strategies (4, 76). Keywords of [success*, factor*, predict*, charact*, prognos*] were used in combination with the keywords related to PHP, aiming to capture primary prognostic research (72). The complete search terms and strategy is reported in Table 6. Screening of RCT arms was also checked by combing through the search returns of our recent systematic review (4).

Table 6. Search terms

Construct		Keywords
Participants	AND [tiab]	Painful-heel-syndrome OR plantar-fasciitis OR plantar-fasciopathy OR subcalcaneal-bursitis OR medial-arch-pain OR subcalcaneal-pain OR stone-bruise OR calcaneal-periostitis OR subcalcaneal-spur OR calcaneodynia OR Heel-Spur-Syndrome OR Chronic-Plantar-Fasciitis OR Fasciitis-Chronic-Plantar OR Plantar-Fasciitis-Chronic OR Fasciitis-Plantar-Chronic OR plantar-heel-pain
Factors/ variables	AND [tiab]	Predict* OR prognosis* OR prognostic OR indicat* OR disease course OR disease progression OR follow-up OR natural history OR factor* OR associated factor*
Study type	AND [tiab]	Observational OR cohort OR prospective OR case-control OR Longitudin* OR randomised controlled OR randomized controlled OR randomised clinical OR randomized clinical
Study type	NOT [ti]	retrospective OR cross AND sectional OR systematic AND review OR literature AND review OR scoping AND review OR meta AND analysis

3.2.2 Eligibility criteria

Studies investigating baseline characteristics with follow-up of patient-reported outcomes relating to indicators of recovery (e.g. pain and/or function) after at least one week were included. Studies were also required to clearly define recovery and provide an effect size for the prognostic estimate. Prospective cohort studies, RCTs with analysis of single arms reporting prognostic factors and studies developing clinical prediction rules were included. No publication date limits or language restrictions were set. Meeting, letter, editorial, review, abstract, retrospective, cross-sectional, case series, case study, cadaveric, pilot study and in vivo studies were excluded (Table 7). As RCTs are not single arm prognostic research studies and

retrospective studies have low level of evidence, we excluded them and the data was synthesised using the remaining five studies (Figure 4).

3.2.3 Types of participants

Studies which investigated adult participants over 18 years of age with a clinical diagnosis of PHP were included. To be consistent with previously published criteria (76), a PHP diagnosis was defined as a greater than one month duration of heel pain that is worse on weight bearing, or on weightbearing after periods of rest, and palpation of the medial tubercle of the calcaneus. Studies including participants without a clear diagnosis of PHP, or describing pain in areas other than the plantar aspect of the heel, and also studies focusing on other foot pathologies were excluded (Table 7).

Table 7. Inclusion criteria for eligible studies.

Inclusion criteria
Design: • Prospective cohort study; randomized controlled trial or clinical prediction rule derivation study;
Participants • Inferior heel pain, that is pronounced with weight bearing or upon weight bearing after periods of rest and pain in palpation of the medial tubercle of the calcaneus for more than 1 month.
Main outcome and outcome measures • Recovery of plantar heel pain by measuring pain and function (i.e. VAS, FFI, GROC, PSFS)
Measures of effect size: • At least one possible effect size measure e.g. odds ratios, risk ratios, hazard ratios, positive likelihood ratio, and area under curve.
Language: • No restrictions, with translators readily available.

Key: VAS= Visual analog scale, FFI=Foot function index, GROC=Global rating outcome scale, PSFS=Patient specific functional scale

3.2.4 Review process

Identified studies were imported into Endnote X6 (Thomson Reuters, Carlsbad, California, USA) where duplicates were removed, before uploading to Rayyan QCRI (Computing Research institute, QATAR) for title and abstract screening. Two reviewers (HG and XL) independently assessed study titles and abstracts, screened full-texts, verified eligible papers, and completed quality assessments. A third reviewer (DM) was available for difficult decisions and to resolve discrepancies.

3.2.5 Quality and risk of bias assessments in individual studies

The quality of prescriptive, derivation-based clinical prediction studies and clinical trials were evaluated using the modified Quality Assessment of Diagnostic Clinical

Prediction Rule (QUADCPR) tool (77). It consists of 23 items divided into four sections, with each item scoring yes (score = 2), no (score = 0) or unclear (score = 1). The first section includes a checklist of items related to the sample and participants; the second section focuses on the reporting of outcome measures; the third section relates to the quality of tests and measures; and the final section focuses on the quality of reporting related to statistics (77).

The quality of observational cohort studies were evaluated using the Epidemiological Appraisal Instrument (EAI). It includes 43 items which are scored as yes (score = 2), partial (score = 1), no (score = 0) or unable to determine (score=0) (78). Questions 10, 22, 23, 24 were removed as they are not applicable to intervention studies. The EAI has proven to be a valid and reliable evaluation method that can be used in different applications, such as systematic evaluations and meta-analyses (78).

The total score of both quality assessment scales were calculated by summing all applicable items, then presented as percentages. Each assessment tool was used by two reviewers independently, with results then compared and discussed to ensure agreement.

Risk of bias (RoB) was assessed with the Quality in Prognostic Studies (QUIPS II) tool, which was developed by Cochrane Prognosis Methods group for prognostic studies (79). The QUIPS II tool has been found to be useful and reliable for systematic reviewers, study authors, and readers to guide comprehensive assessment of bias in studies of prognostic factors (79). It includes 24 items across 6 domains: 1) study participation 2) study attrition 3) prognostic factor measurement 4) outcome measurement 5) study confounding 6) statistical analysis and reporting. Overall assessment of the six risk of bias domains is undertaken by considering the signalling items for each domain, which leads to judgments scored as yes, partially, unsure or no (80). Each of the six domains needs to be rated independently by two reviewers. Overall reports should be documented for each domain to inform readers and researchers, and flag improvements needed for subsequent future studies. A recommendation for total score of risk of bias is that "*defining studies with an overall "low risk of bias" as those studies where all, or the most important domains (as determined a priori), are rated as having low (or low to moderate) risk of bias"*(75).

3.2.6 Data extraction

Data was extracted from studies on September 2020 according to the CHecklist for critical Appraisal and data extraction for systematic Reviews of prediction Modelling Studies (CHARMS) (81). The CHARMS checklist gives explicit guidance about key items that should be extracted from primary studies investigating prognostic factors, and the reason for extraction (75). The following data were noted in a standardised form: author and type of design; study characteristics including total number of participants, number of recovered participants, gender, age, BMI, treatment strategies applied/allowed, outcome criteria and follow up length, and characteristics of analysis such as model development methods and prognostic factors identified. As studies had different duration, follow lengths were categorized in three groups (short, medium and long-term). Studies which had a one week to three months follow-up period were categorized as having a short time period of PHP duration; two studies had six months follow-up length was considered a medium period of PHP duration. Finally, a study which had five to fifteen years follow-up length was considered a long-term of PHP duration.

3.2.7 Data synthesis and Level of Evidence

All results, including non-significant prognostic factors, were extracted from each study. Any prognostic factors investigated by multiple studies for different time periods, while using characteristics of the factors studied, effect measures and scores (e.g., Hazard ratio (HR), +Likelihood ratio (LR+), Area Under Curve (AUC), P value, and 95%CI) and level of evidence, were tabulated and presented graphically. The ranges of effect size measures were determined according to previous published criteria (82-84). Small, medium, and large HRs for a standard deviation increase in the predictor would be 1.14, 1.47, and 1.9, respectively (84). LR+ 5–10 generate moderate probability; LR+ 2–5 generate small but important probability; LR+ 1–2 generate small but rarely important probability (82). Regarding AUC, If ROC= 0.5, this suggests no discrimination, if 0.7 < ROC < 0.8 this is considered acceptable, if 0.8 < ROC <0.9 considered excellent and if ROC> 0.9 considerate outstanding (83). Due to the diverse range of effect sizes, study methodologies, and adjustments for covariates, pooling and subsequent meta-analyses were not performed.

Evidence levels were established based on the modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework (85). When evaluating the overall quality of evidence, phase of investigation was considered as a starting point. As all included articles were phase 1 explanatory studies, they were judged as moderate level of evidence at the beginning according to recommendations (85). Afterwards, evidence levels were upgraded or downgraded according to limitations in study design, inconsistency of results across studies, imprecision, and publication bias (10, 85) (Figure 3). QUIPS appraisals were used to make a "risk of bias" judgement of GRADE for each prognostic factor.

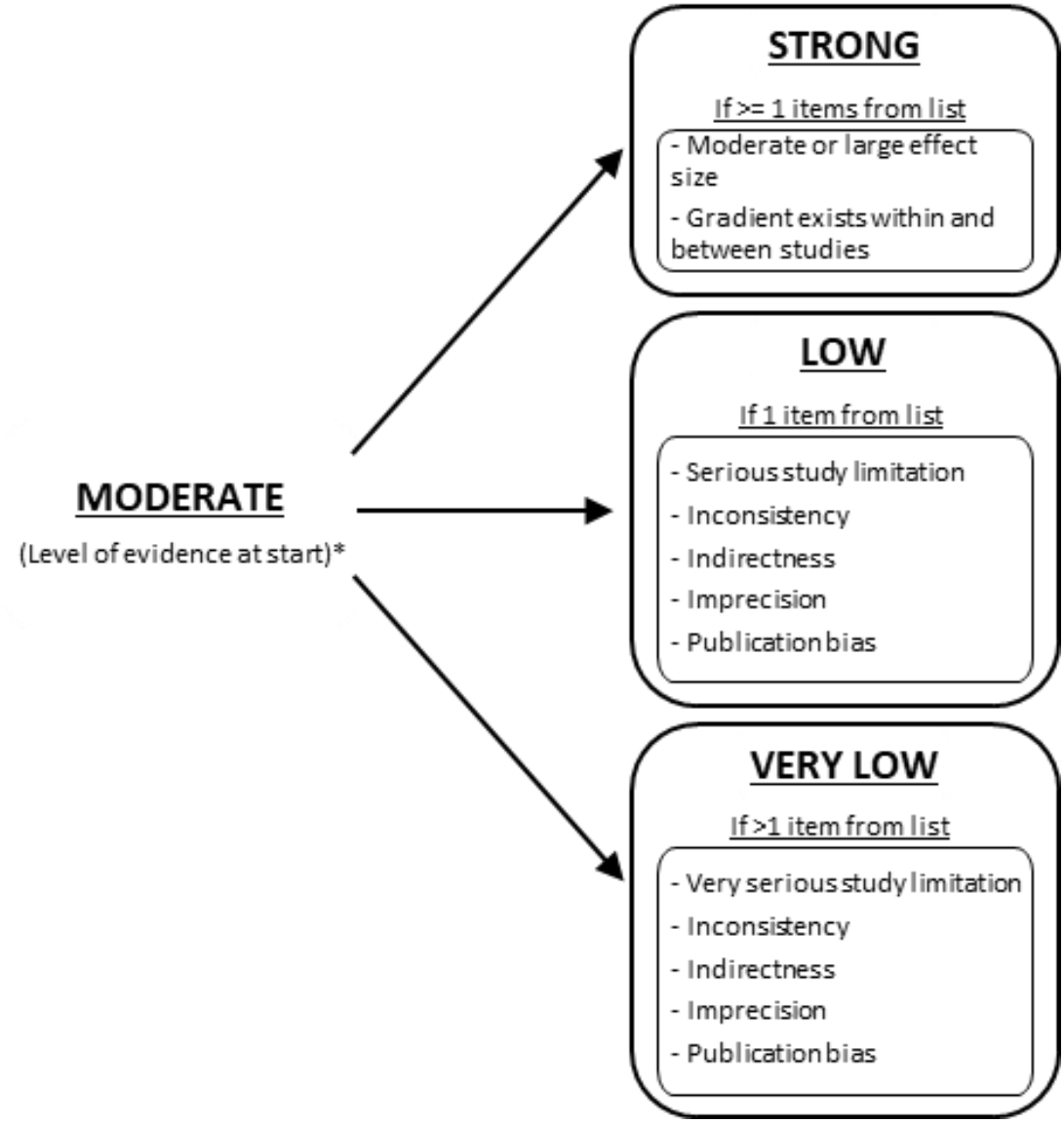

Figure 3. Guide for adjustments to the quality of evidence for prognosis. *This diagram is adopted from Huguet et. al (2013). * In this review, moderate level of evidence is the starting point for outcome prediction research or explanatory research aimed to identify associations between potential prognostic factors and the outcome (Huguet et. al., 2013).*

3.3. Results

3.3.1 Search results and critical appraisal of methods

Initially, 1235 citations were identified and 592 duplications were removed. After abstract and title screening, 292 papers were identified for full text screening. Eighteen studies were recognized as investigation of PHP prognosis; which consist of one prospective cohort study (8), seven retrospective (33, 37, 86-91), two clinical prediction rule (CPR) studies (66, 92), two single arm clinical trials (93, 94) and six RCTs (95-100). The number of patients included in the studies ranged from 74 to 278, with a total of 811 PwPHP. Details of data extraction from the five studies in our final article pool are given in Table 9.

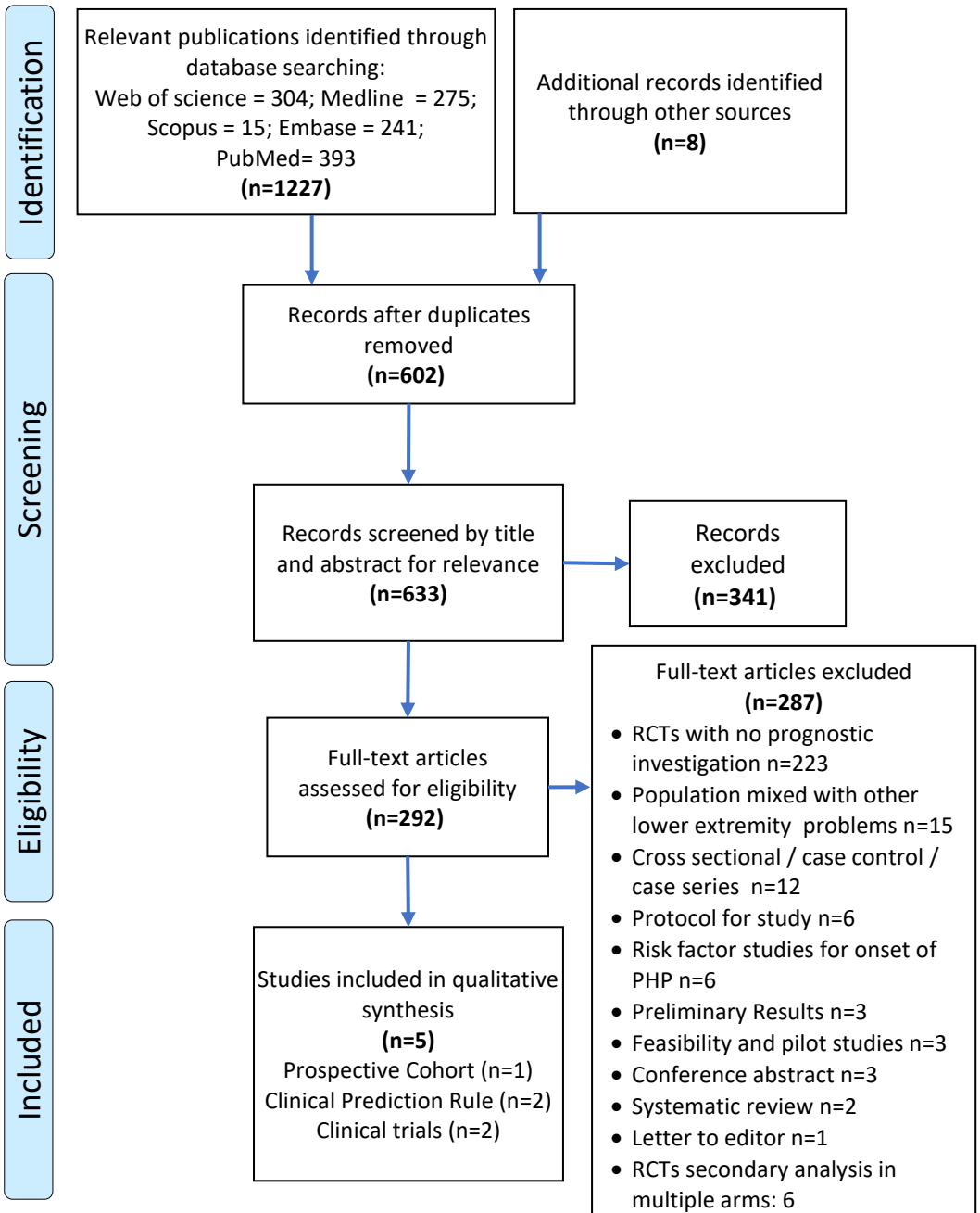

Figure 4. PRISMA flow diagram. Key: n=number; RCTs=Randomized controlled trials.

3.3.2 Quality assessment

We evaluated quality of 4 studies using the QUADCPR and the cohort study quality of Hansen et. al (2018) using the EAI tool. The reporting of study aim, setting, description of sample characteristics, and predictors' test measures were found to be of good quality. However, there were a lack of details regarding reliability and validity of the main outcome measures used, first order interaction in the statistical analyses, statistical significance/fit of the model, and covariate/confounders analyses for the factors. Only two clinical studies (93, 94) included clinicians that were blinded to the completion of the outcome measures. Details of the quality assessments are presented in Table 8.

Table 8. Quality assessment of studies using QUADCPR and EAI

QUADCPR	Wu, 2019	Wu, 2018	Yin, 2019	Yin, 2017	*Hansen 2018*	EAI for Hansen 2018 only
setting and location	2	2	2	2	*Yes*	*Study aim*
Inclusion / exclusion	2	2	2	2	*Yes*	*Exposure description*
sample characteristics	2	2	2	2	*Yes*	*Main outcome measure*
Sampling	2	2	2	2	*Yes*	*Study Design*
Outcome measures	2	2	2	2	*Yes*	*Source of population*
Outcome measure parameters	2	2	1	1	*Yes*	*Eligibility Criteria*
Blinded outcome measures	0	0	2	2	*Yes*	*Participation rates*
Outcome measure definition	2	2	2	2	*Yes*	*Participant characteristics*
Predictors test	2	2	2	2	*Yes*	*Participants characteristics for dropout*
Predictor test performed	2	2	2	2	*No*	*Intrinsic patient characteristics*
Predictor test and measures	2	2	2	2	*No*	*Extrinsic factors described*
Predictor tests/measures acceptability	2	2	2	2	*Yes*	*Statistical methods*
Examining clinicians blinded	0	0	2	2	*Yes*	*Main findings of study*
Treating clinicians blinded	0	0	2	2	*Yes*	*Reported variability of data*
Reliable predictors tests	2	2	2	2	*Yes*	*Statistical parameters*
Appropriate time interval	2	2	2	2	*No*	*Sample Size calculations*
Equivocal or indeterminable results	2	2	2	2	*Yes*	*Comparability of case/control*
Adequate sample powering	2	2	2	2	*Yes*	*Participation rates case/control*
First order interactions were assessed	0	0	0	0	*Yes*	*All groups are recruited the same period*
Statistical significance/fit of the model	0	0	2	2	*Yes*	*Subject loses taken into account*
Confidence intervals of the analyses	2	2	2	2	*UTD*	*Exposure variables reliable*
Irrelevant predictors removed	2	2	2	2	*UTD*	*exposure variables valid*
Results were reported using %95 ci	2	2	2	2	*Yes*	*Methods similar for each group*
Intervention procedures are explanation	2	2	2	2	*Yes*	*Exposure prior to outcome*
Intervention(s) method suitability	2	2	2	2	*No*	*Blinded observers*
Comparator procedures details	2	2	2	2	*Yes*	*Subjects blinded*

Comparator intervention method suitability	2	2	2	2	*UTD*	*Main outcomes measures reliable*
					UTD	*Main outcome measures valid*
					Yes	*Assessment method for all groups*
					Yes	*Observations taken at same time point*
					No	*Covariates/confounders analyses intrinsic*
					No	*Covariates/confounders analyses for extrinsic*
					UTD	*Sufficient follow-up time*
					No	*Analyses different lengths of follow-up*
					No	*Levels of exposure outcome*
					Yes	*Reported data for subgroups of subjects*
					Yes	*Generalizability to study populations*
					Yes	*Generalizability to other populations*
Total score	**44/54**	**44/54**	**51/54**	**51/54**	**57/90**	
Total Score (%)	**81.4**	**81. 4**	**94.4**	**94.4**	**63.1**	

Key= UTD: Unable to Detect; QUADCPR: Modified Quality Assessment of Diagnostic Clinical Prediction Rule; EAI: The Epidemiological Appraisal Instrument; 2= yes; 1= unclear; 0= no. Inter-rater agreement between the quality assessors was 82% across all 5 papers.

Inter-rater agreement between the quality assessors was 92% across all 13 papers.

*Modified in accordance with the TRIPOD statement[23] recommendation for a minimum of 10 participants in the limiting sample size (ie, those who experienced the least frequent outcome) for each potential predictor variable included in the analysis.

3.3.3 Risk of Bias assessment

There were 30 domains in total across the five studies, with 12 domains (40%) classed as low, 13 (43%) classed as moderate, and 5 (17%) classed as high RoB. All five studies were classed as having a moderate RoB overall, but low RoB on the study attrition domain. There were no missing data for prognostic factors (PF) measurements in four studies, but these were either inadequately described or not reported in the fifth (8). For outcome measurements, three studies were classified as having moderate RoB because specific clinical or imaging outcome measurements were either inadequately described or not stated. Regarding the study confounding domain, all studies were scored as having a high RoB because definitions of confounding factors or adjustments were either unclear or not reported. Finally, all studies had moderate RoB on the statistical analysis domain as data were presented with insufficient detail, with the justification for statistical modelling outlined but no evidence of selective reporting.

Table 9. Characteristics of the six trained studies. Key= Ss= total sample size, NR= Not Reported

Study		Participants	Treatment		Outcomes to be predicted		Analysis		
Study and design	**Ss and events**	**Demographics (age, BMI, gender f:m)**	**Prescribed Treatments**	**Permitted Treatment**	**Positive Outcome criteria**	**Follow-up length**	**Modelling method**	**Factors (n)**	**Prognostic factors identified**
Hansen, 2018 Cohort study	174 80	Age: 26 - 88 years, BMI: 17.8 - 43.3 kg/m2 Gender: 91 (52%): 83 (48%)	93% US-guided injections	Various physiotherapy modalities	Scored >0 on the NRS in either rest, during walking, during running, or on pressure	5 to 15 years	Multiple Cox regression	9	1. Gender 2. Bilateral heel pain 3. Age
Wu, 2019, Clinical Prediction Rule	75 49	Age: 48.4 ± 14.5 years, BMI: 23.8 ±3.7 kg/m2 Gender: 57 (77%):17 (23%)	Anti-pronation taping and customized foot orthosis	Not allowed	(1) Reducing the pain intensity > 2 points or 50%, (2) Decreasing the FFI score > 7 points or PSFS score > 50% (3) Improving GROC scale of + 4	6 months	Multiple logistic regression	63	1. Change in pain after taping, 2. Range of ankle PF > 54°, 3. Unbalanced strength of ankle PF, 4. Range of hip IR < 39°, 5. Range of hip ER > 45°
Wu, 2018, Clinical Prediction Rule	74 28	Age: 48.4 ± 14.5 years, BMI: 23.8 ±3.7 kg/m2 Gender: 58 (77%): 17 (23%)	Anti-pronation taping and customized foot orthosis	Not Reported	(1) Reducing the pain intensity > 2 points or 50%, (2) Decreasing the FFI > 7 points or PSFS score > 50% (3) Improving GROC scale of + 4	1 week	Multiple logistic regression	79	1. FFI score less than 33.3, 2. Unbalanced hip adduction angle, 3. Unbalanced ankle PF and hip abductors, 4. Unbalanced on ankle invertors, 5. > 2 painful sites in lower extremity regions.
Yin, 2017, Clinical Trial	278 186	Age: 55 ± 13.3 years, BMI:107(38.5%) <26 kg/m2, 147 (52.9%) 26-30 kg/m2 24 (8.6%) >30 kg/m2 Gender:136(49%):142(51%)	ESWT	Not Reported	Reducing the pain intensity > 2 points or 50%,	3 months	Multiple stepwise logistic regression	10	1. Morning pain, 2. Oedema 3. heel spurs
Yin, 2019, Clinical Trial	210 140	Age: 54.1 ± 13.6 years, BMI: 76(36.2%) <26 kg/m2, 112 (53.3%) 26-30 kg/m2 22 (10.5%) >30 kg/m2, Gender: 98 (43%):112(57%)	ESWT	Not Reported	Reducing the pain intensity > 2 points or 60%	6 months	Artificial neural networks	10	1. VAS, 2. Heel spurs 3. duration of symptom

3.3.4 Summary of Findings

Studies in this review reported two directions (favourable vs unfavourable) of a statistically significant relationship. All estimate sizes of the relationships were presented in a form of multivariate analyses in the studies.

3.3.4.1 Patient characteristics associated with outcome from observational cohort

There was only one study investigating patients' baseline characteristics associated with a poor outcome of PHP(8). Nine patient-reported and anatomical characteristics were investigated, nevertheless the multiple Cox regression analyses revealed only three patient characteristics (age, sex and having bilateral heel pain) were associated with a poor outcome of PHP. As the study follow-up period was more than 5 years, findings were considered as long-term outcomes (Table 9).

Demographics

There was low evidence of a small effect that a patient being female was a predictor of an unfavourable outcome in the long term (HR: 0.49 [0.30 - 0.80]) (8). Similarly, there was low evidence of a small effect that a patient older than the age of 40 was a predictor of an favourable outcome in the long term (HR: 1.93 [0.99 - 3.73]) (8). BMI and smoking were not shown to be significant prognostic factors at this time-point (Table 10).

Pain

There was low evidence of a small effect that having bilateral heel pain was a predictor of an unfavourable outcome in the long term of PHP when controlling for sex, age BMI, smoking, physical work, time to ultrasound, fascia thickness and heel spur (HR: 0.33 [0.15 - 0.72]) (8).

Others

Fascial thickness and physical work were not shown to be statistically significant predictors for prognosis of PHP in the long term (8).

Patient characteristics associated with outcome after a specific treatment

Two different specific treatments, orthosis and extracorporeal shock wave therapy (ESWT), were investigated in four studies (66, 92-94). Fourteen patient

characteristics, categorised as pain, physical and function-related, were reported to be associated with a successful outcome after a specific treatment. Since the follow-up times of the studies ranged from 1 week to 6 months, the findings obtained from these studies were evaluated as short to medium term prognosis of PHP.

Demographics

Sex, age, BMI and being right dominant were not shown to be significant predictors for the success of foot orthoses and ESWT interventions in the short to medium term (Table 10).

Pain

Pain related prognostic factors that were evaluated included duration of symptoms, severity of first step pain, average pain intensity, number of painful sites in the lower extremity, onset of pain, and pain response to low-dye typing. There is very low evidence of a small effect size that number of painful sites in the lower extremity was a predictor of foot orthoses intervention success in the short term (+LR: 1.60 [0.90 - 2.70]) (66). Similarly, there is moderate evidence of a large effect that decreased pain by over 1.5 points (10 point scale) as a response to taping was a predictor of foot orthoses intervention success in the medium term when controlling for bilateral imbalances in hip adduction angle, strength of hip abductors, ankle invertors and ankle plantar flexors, and having more than two painful sites in the lower back and lower extremity regions (+LR: 2.17 [1.19 - 3.90]) (92) (Table 10).

There was very low evidence of a small effect that a shorter history of symptoms and average pain intensity predicted a favourable outcome following an ESWT intervention in the medium term when controlling for presence of heel spur (AUC: 0.52 [0.43 – 0.6], 0.73 [0.65 - 0.80], respectively) (93). Average pain intensity was also a predictor of a favourable outcome in the short term, for the same intervention, when controlling for presence of oedema and a heel spur (AUC: 0.75 [0.69 - 0.08]) (94). There were no associations found between PHP prognosis and either bilateral heel pain, first step pain or onset of pain (P value > 0.05).

Patient Reported Outcome Measures (PROMs)

Four studies tested three PROMs as potential predictors for PHP (Table 10). There was low evidence of a small effect that scoring lower than 33.3 on the foot function index (FFI) was a predictor of foot orthoses intervention success in the short term (+LR: 1.81 [1.50 - 3.18]) (66). Results show no significant evidence about predictive effects of the other two variables, patient specific functional scale (PSFS) and Roles and Maudsley score (RM), on prognosis of PHP or favourable outcome to an intervention (P values > 0.05) (Table 10).

Physical factors

The prognostic indications from seventy-three physical variables on prognosis of PHP or favourable outcome to an intervention were tested across all four studies. Only nine variables were found to be associated with a favourable outcome. There was very low evidence of a small effect that increased ankle plantar flexor ROM (> 54°), reduced hip internal ROM (< 39°) and increased hip external rotation (> 45°) were positive predictors of foot orthosis intervention success in the medium term (+LR: 1.38 [0.80 - 2.37], 1.79 [0.96 - 3.30], 1.53 [0.98 - 2.40] , respectively) (92). In addition to this, there was moderate evidence of a large effect that higher or equal ankle plantar flexor strength compared to the asymptomatic side predicted a favourable outcome of foot orthoses in the medium term (+LR: 2.17 [1.20 - 3.95]) (92). However, there was only low evidence of a small effect size that the same strength variable was a positive predictor of the favourable outcome of foot orthosis in the short term (+LR: 1.50 [1.00 - 2.10]) (66). There was low evidence of a small effect that greater hip adduction angle in the symptomatic side was a positive predictor of foot orthosis intervention success in the short term (+LR: 1.40 [1.10 - 1.90]). There was very low evidence of a small effect that higher ankle invertor strength in the asymptomatic side, and hip abductors in the symptomatic side, were positive predictors of favourable outcome for the same intervention in the short term (+LR: 1.20 [0.90 - 1.80], 1.30 [0.90 - 2.70], respectively) when controlling for average pain intensity decreased by over 1.5 points with taping, ankle plantarflexion ROM, the strength of ankle plantar flexors, hip internal and external rotation in a multivariate analysis (66).

There was low evidence of a small effect that not having oedema was an indicator of a favourable outcome of ESWT intervention in the short term (AUC: 0.65 [0.60 - 0.71]) (Table 10).(94). Finally, there was moderate evidence of a large effect that not having a heel spur predicted a favourable outcome of ESWT in the short to medium term when controlling for oedema and average pain intensity (AUC: 0.88 [0.82-0.93], 0.85 [0.81-0.89], respectively) (93, 94). There were also other lower extremity variables that were tested, however, none of them were found as statistically significant predictors of PHP prognosis (P values > 0.05).

Activity

Results show that physical work was not associated with the outcome of ESWT or orthosis intervention in the short and medium term. Standing hours and exercise behaviour were not associated with the outcome of foot orthoses in the short and medium term. (Table 10).

Table 10. Investigated prognostic factors across long, medium and short term follow-up duration, with effect measure, size, direction and GRADE

Prognostic factors investigated	*Total n (cases)*	*Follow-up duration*	*Studies*	*Effect measure*	*Multivariate Effect size (95% CI)*	*GRADE*				*Summary*
						Consistency	*Mod./large effect size*	*Precision of results*	*Publication bias*	
DEMOGRAPHICS										
Sex (findings relate to being female)	811 (447)	L	H18	HR	*0.49 (0.30 - 0.80)	NA	×	✓	×	↓
		M	W19	NR	NR	✓	×	×	×	⇔
			Y19	NR	NR		×	×	×	
		S	W18	NR	NR	✓	×	×	×	⇔
			Y17	NR	NR		×	×	×	
Age (findings relate to being over 40)	811 (NR)	L	H18	HR	*1.93 (0.99 - 3.73)	NA	×	×	×	↑
		M	W19	NR	NR	✓	×	×	×	⇔
			Y19	NR	NR		×	×	×	
		S	W18	NR	NR	✓	×	×	×	⇔
			Y17	NR	NR		×	×	×	
BMI	811 (NR)	L	H18	HR	0.65 (0.40 - 1.06)	NA	×	✓	×	⇔
		M	W19	NR	NR	✓	×	×	×	⇔
			Y19	NR	NR		×	×	×	
		S	W18	NR	NR	✓	×	×	×	⇔
			Y17	NR	NR		×	×	×	
Smoking	174 (39)	L	H18	HR	0.88 (0.51 - 1.52)	NA	×	✓	×	⇔
		M	-	-	-	-	-	-	-	
		S	-	-	-	-	-	-	-	
Right dominant Leg	149 (135)	L	-	-	-	-	-	-	-	
		M	W18	NR	NR	NA	×	×	×	⇔
		S	W19	NR	NR	NA	×	×	×	⇔
PAIN										
Bilateral heel pain	736 (174)	L	H18	HR	*0.33 (0.15-0.72)	NA	×	✓	×	↓
		M	Y19	NR	NR	NA	×	×	×	⇔
		S	W18	NR	NR	✓	×	×	×	

			Y17	NR	NR		×	×	×	⇔
Shorter duration of symptoms / pain history	637 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	NR	×	×	×	×	↑
			Y19	AUC	*0.52 (0.43 - 0.60)		×	✓	×	
		S	W18	+LR	1.00 (0.60 - 1.60)	✓	×	×	×	⇔
			Y17	NR	NR		×	×	×	
First-step pain	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	NR	NA	×	×	×	⇔
		S	W18	NR	NR	NA	×	×	×	⇔
Lower average Pain intensity	637 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	1.14 (0.70 - 1.17)	×	×	×	×	↑
			Y19	AUC	*0.73 (0.65 - 0.80)		✓	✓	×	
		S	W18	NR	NR	×	×	×	×	↑
			Y17	AUC	*0.75 (0.69 - 0.08)		✓	✓	×	
Response to taping (decreased pain)	75 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	*2.17 (1.19 - 3.90)	NA	✓	✓	×	↑
		S	-	-	-	-	-	-	-	
Number of painful sites in LE	74 (NR)	L	-	-	-	-	-	-	-	
		M	-	-	-	-	-	-	-	
		S	W18	+LR	*1.60 (0.90 - 2.70)	NA	×	×	×	↑
Onset, (gradual)	149 (97)	L	-	-	-	-	-	-	-	
		M	W19	NR	NR	NA	×	×	×	⇔
		S	W18	NR	NR	NA	×	×	×	⇔
PROMs										
FFI score (<33.3)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	1.50 (1.00 - 2.30)	NA	×	✓	×	⇔
		S	W18	+LR	*1.81 (1.50 - 3.18)	NA	×	✓	×	↑
RM	488 (NR)	L	-	-	-	-	-	-	-	
		M	Y19	NR	No effect*	NA	×	×	×	⇔
		S	Y17	NR	-	NA	×	×	×	⇔

PSFS	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	NR	No effect*	NA	×	×	×	⇔
PHYSICAL										
Fascial thickness	174 (NR)	L	H18	HR	1.20 (0.72-1.98)	NA	×	×	×	⇔
		M	-	-	-	-	-	-	-	
		S	-	-	-	-	-	-	-	
Ankle PF ROM (>54 degree)	75 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	*1.38 (0.80 - 2.37)	NA	×	×	×	↑
		S	-	-	-	-	-	-	-	
Ankle PF strength (ct. asymptomatic side)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	*2.17 (1.20 - 3.95)	NA	✓	✓	×	↑
		S	W18	+LR	*1.50 (1.00 - 2.10)	NA	×	✓	×	↑
Ankle inventors strength (ct. asymptomatic side)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	+LR	*1.20 (0.90 - 1.80)	NA	×	×	×	↑
Hip internal rotation (> 39 degree)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	*1.79 (0.96 - 3.30)	NA	×	×	×	↑
		S	W18	NR	No effect*	NA	×	×	×	⇔
Hip external rotation (>45 degree)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	+LR	*1.53 (0.98 - 2.40)	NA	×	×	×	↑
		S	W18	NR	No effect*	NA	×	×	×	⇔
Higher hip adduction angle (ct. asymptomatic side)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	+LR	*1.40 (1.10 - 1.90)	NA	×	✓	×	↑
Higher hip abductors strength (ct. asymptomatic side)	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	+LR	*1.30 (0.90 - 2.70)	NA	×	×	×	↑
Not having heel spur	662 (304)	L	H18	HR	0.88 (0.51 - 1.52)	NA	×	✓	×	⇔

		M	Y19	AUC	*0.88 (0.82-0.93)	NA	✓	✓	×	↑
		S	Y17	AUC	*0.85 (0.81-0.89)	NA	✓	✓	×	↑
Not having oedema	488 (108)	L	-	-	-	-	-	-	-	
		M	Y19	NR	No effect*	NA	×	✓	×	⇔
		S	Y17	AUC	*0.65 (0.60 - 0.71)	NA	×	✓	×	↑
Other physical variables	488 (NR)	L	-	-	-	-	-	-	-	
		M	Y19	NR	No effect*	NA	×	✓	×	⇔
		S	Y17	NR	No effect*	NA	×	✓	×	⇔
ACTIVITY										
Physical work	323 (NR)	L	H18	HR	0.68 (0.46 - 1.20)	NA	×	×	×	⇔
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	NR	No effect*	NA	×	×	×	⇔
Standing Hours	149 (NR)	L	-	-	-	-	-	-	-	
		M	W19	NR	No effect*	NA	×	×	×	⇔
		S	W18	NR	No effect*	NA	×	×	×	⇔
Exercise behaviour	74 (39)	L	-	-	-	-	-	-	-	
		M	-	-	-	-	-	-	-	
		S	W18	NR	No effect*	NA	×	×	×	⇔
PSYCHOLOGY										
	L	-	-	-	-	-	-	-		-
	M	-	-	-	-	-	-	-		-
	S	-	-	-	-	-	-	-		-
SOCIAL										
	L	-	-	-	-	-	-	-		-
	M	-	-	-	-	-	-	-		-
	S	-	-	-	-	-	-	-		-

*KEY= - : not investigated; Bold characters show statistically significant results. NA: not applicable, HR: Hazard Ratio, RR: Relative Risk, AUC: Area under the curve, +LR: positive likelihood ratio, NR: Not Reported, L: Long Term, M: Medium term, S: Short-term outcomes. *: No reported effect, studies provided only p value. Ct: Compare to. Articles: Cohort study =**H18**: Hansen et. al, 2018; RCTs=**W18**: Wu et. al, 2018; **W19**: Wu et. al, 2019; **Y17**: Yin et. al, 2017; **Y19**: Yin et. al, 2019. Red, orange, yellow and green show very low, low, moderate, and high-level of evidence, respectively. Grey is no investigation/evidence in relevant period. Arrow key: Up arrow: the value of the*

factor have positive effect on prognosis; down arrow: the value of the factor have negative effect on prognosis; Horizontal arrow: Prognosis probability is not affected by change in the value. Publication bias and study limitation of GRADE's domains are not shown in the table due to same results across all studies (negative). Regarding precision of studies, studies scored as unclear- not having SD or CI are considered as imprecise.

3.4 Discussion

This systematic review aimed to provide an exhaustive examination of patient characteristics associated with a poor or successful outcome from 811 people with PHP. We found that people who are female, and having bilateral heel pain are at risk of poor outcome for PHP from one cohort prospective study. Immediate effect of low-dye taping, symptom duration and number of painful sites are also prognostic indicators of recovery, also there are several ankle and hip related clinical associations such as increased ankle plantar flexion, hip internal and external rotation range. The absence of high quality cohort and prognostic studies validating outcome predictors means significant findings should only be considered as preliminary indicators of poor or successful outcome prediction. This emphasises that there is a major need for high quality, detailed, adequately powered prospective study of prognostic factors. These should cover the biopsychosocial domains we have identified to be of relevance in this common, problematic, recalcitrant condition.

3.4.1 Patient characteristics prospectively associated with a poor outcome in cohort studies

The single cohort study showed two of five measured demographic factors predicted outcome, age and sex. Being female was a predictor of negative prognosis (8) (Table 10). Several studies reported that it is well established that sex differences in pain and recovery exist; (101, 102) however, the specific underlying mechanisms contributing to this disparity are far from clear. It has been suggested that an interaction of biological, psychological, and sociocultural factors likely contribute to these differences (103). Therefore, further research exploring the effect of sex on recovery of PHP is needed and earlier intervention might be considered to prevent chronicity for females. On the other hand, relationship between being older than 40 and a more positive PHP prognosis is noteworthy, as this contradicts the more common finding that being older is usually associated with poorer recovery in MSK conditions (104) and is based on analysis of single factors rather than models of recovery where confounding factors, such as baseline severity, are simultaneously considered.

One study reported a poorer outcome for patients with bilateral heel pain (8). The reason of this could be the biomechanical faults in long-term mechanism of PHP. PwPHP usually develop PHP in a single foot initially (105-107), with symptoms becoming present in the contralateral foot as severity increases, possibly due to altered gait or because intrinsic and extrinsic risk factors apply to both limbs. Further, those with bilateral symptoms are likely to be more severely affected (108), so it may again be that baseline severity is the main driver of compromised recovery.

3.4.2 Patient characteristics associated with outcome after a specific treatment identified in single trial arms

Baseline severity was found to be associated with poorer outcome in the single trial arm data analysis. Number of painful sites in the lower back and lower extremity regions predicts orthoses intervention success (92). Multiple painful sites in other body areas rather than rear-foot have been associated with inflammatory disorders such as seronegative arthropathy, inflammatory bowel disease, gout, rheumatoid arthritis and psoriasis (109); and may also be associated with more severe pain states such as altered pain processing (110). PwPHP who respond positively to anti-pronation taping would also benefit from the customized foot orthoses (66, 92). Based on this result, pain response to low-dye typing predicting orthoses intervention success can indicate that kinetic changes, particularly foot pronation, in lower extremity may be predictive of a favourable outcome. This is also supported by the concept of 'treatment direction test (TDT)' introduced by Vicenzino et al. (111, 112), which means that using anti-pronation taping to determine if controlling excessive foot pronation would help recovery.

Shorter symptom duration with lower frequency of pain can indicate that severity of these symptoms may be predictive of a favourable outcome following ESWT. Similarly, higher pain severity at baseline and longer pain duration have also shown association with poor prognosis in other musculoskeletal pain conditions (104). Irrespective of type of treatment strategy investigated or musculoskeletal condition, these findings highlight the clinical importance of implementing an effective pain intervention programme early in stages in order to increase the likelihood of intervention success.

Regarding PROMs in prognostic research, there may be an investigation need for developing a different PROM that works best for PHP prognosis. PROMs are effective tools for measuring outcome and detecting severity of a condition. If we can well estimate the severity at baseline, it allows us to predict better of the outcome. For instance, foot function index score was identified as significant PROMs predictor of foot orthoses intervention success by measuring functional severity at baseline. There are also some other PROMs with higher responsiveness score for PwPHP such as FHSQ and FAAM. (13, 113). However, it is important to note that these are lack morning pain question which is one of most prominent feature of PHP condition. Therefore, if we develop a better PROM that can predict the outcome, future studies could assess its utility as a screening tool for detecting prognosis of PHP in a way better.

Two studies reporting clinical prediction rules for foot orthoses and biomechanical anti-pronation taping (BAPT) showed that various physical factors were associated with a favourable outcome in the medium and long terms (66, 92). The current results suggested that excessive foot pronation could play a role of underlying kinetics reflected by increased ankle plantar flexion (114), hip internal (115) and external rotation angle (116), and having stronger hip adductors on the most affected side than the contralateral side (117) and having greater abduction angle of the most affected side than the contralateral side (118). In addition to this, PwPHP who had no oedema measured by ultrasound still retained appropriate foot function and also had a higher chance to respond to the foot orthosis and BAPT treatment (119).

3.4.3 Future direction

The absence of research of prognosis or successful outcome prediction related to the psychosocial aspect of PHP is an area where further research is clearly needed. The role of psychosocial symptoms in several musculoskeletal conditions' development and maintenance of symptoms (73, 120) has received significant attention within several case-control and cross sectional studies (121-124). Interventions focused on psychosocial factors have also shown favourable outcomes in other musculoskeletal conditions (125). Therefore, identification of such predictors has the potential to

significantly increase understanding of outcomes of PHP and treatment efficacy as well. Additionally, developing prognostic models is a process with several steps; starting from evaluation of prognostic factors, followed by development of model and validation of it (126, 127). It should be emphasised that the current evidence base is relevant only to the initial stage of prognostic research, none of them followed the next steps of this process to validate a prognostic model. Therefore, second and third phase prognostic studies from the derivation stage of design are clearly needed for the validity and incorporating these outcome predictors to be reliably included into a targeted intervention strategy.

3.4.5 Limitations and strength

The most commonly found limitation across the studies was the reporting of statistical approaches used. The studies did not clearly report findings about first order interaction of variables, confounding factors and goodness of fit parameters. These studies also did not provide estimate rates from the univariate analyses, which limited interpretation of the individual association of variables on prognosis. It is hoped that recommendations which aim to improve the transparency of prognosis research will help the quality of evidence available in the future (75). Regarding limitations of the reviewing process, although for this review relevant databases were thoroughly searched using keywords, there is always the risk of certain studies having been missed, particularly for single arm trial. In order to avoid missing any study, we performed double screening of RCT arms through the search returns of our recent systematic review (4). Moreover, both reviewers were blinded to the authors of the papers included for appraisal (80). Previously, in the literature, similar studies used either QUADCPR or QUIPS II for quality assessment. However, as Butner et al. points out, the former tool assesses methodological quality of studies whereas the latter is focusing on risk of bias. In this study, we used both QUADCPR and QUIPS II tools in conjunction with each other (80). Finally, to the best of our knowledge, this is the first systematic review that has evaluated prognostic factors for recovery of PHP using specific prognostic research appraisal and synthesis tools.

3.5 Conclusion

There are limited biomedical factors which can be used to predict PHP outcome, with a notable absence of high quality studies that consider multiple variables from which prognostic models or robust clinical guides could be constructed. In order to better understand PHP recovery or persistence, high quality prospective studies should evaluate the prognostic value of a range of variables, including psychosocial factors.

CHAPTER 4 STUDY DEVELOPMENT

This chapter will provide insight into how the study was developed and detail my overall PhD progress including personal and academic learning. The study design explained in this chapter mostly focused on development steps of prospective cohort study (chapter 7). As some sections were already detailed in other chapters such as participant's features, inclusion and exclusion criteria, starting/ending point of the cohort study, those parts were not presented in this chapter to avoid repetition.

The qualitative analysis results section in this chapter was accepted for publication in the British Journal of Sports Medicine (DOI: 10.21203/rs.3.rs-36329/v1) as part of study development process. The preliminary results of the graded loaded challenge test validity and repeatability as a part of biomechanical assessment were presented at the 44th Meeting of the American Society of Biomechanics conference in Atlanta in 2019

The protocol presented within this chapter was informed by the subsequent feasibility study (chapter five), which is online questionnaire, clinical and biomechanical measurements for outcome prediction of plantar heel pain; case-control study (chapter 6), which is the association of demographic, psychological, social and activity factors with foot health in people with plantar heel pain; and cohort study (chapter 7), outcome predictors for plantar heel pain.

4.1 Overall Study design

The primary aim of this thesis was to build a model of plantar heel pain (PHP) that predicts recovery. It was desired to have excellent accuracy and be specific to PHP in order to be useful to clinicians judging prognosis, researchers who want to understand causal relationships and perhaps for sufferers seeking to understand their conditions. Therefore, the study was planned on three levels;

1. Questionnaire battery which would have a high volume of data comprised biomedical, psychosocial and social components of health.

2. Clinical and ultrasound assessments which would have a medium volume of data comprised biomedical and physical components of PHP
3. Biomedical assessments which would have a low volume of dense data concerning the kinetic and kinematics aspects of PHP.

Overall, the cohort study required detailed design and development steps considering each stage such as the questionnaire, clinical and ultrasound and biomedical assessments. Those steps represent various formatting changes, key lessons and strategies in order to optimise the success of a prospective cohort study.

4.2 Identifying candidate predictors

The candidate predictors were identified based on literature review (chapter 1), systematic review (chapter 3), on clinical grounds through discussion of a multidisciplinary group including members of the research team and a qualitative analysis of patient values for a practice defining international guide to management of Plantar Heel Pain (12).

In order to capture patients' perspective, open ended questions were asked to participants using an online survey (www.surveymonkey.co.uk), which explored a persons' experience of living with PHP, understanding of the nature of their PHP, expectations of clinicians, strengths of PHP management and areas for improvement. These open ended questions were determined with research team based clinical and academic experience. Forty people responded to the online survey with the Framework analysis resulting in one overarching theme of 'patient experience' with 8 sub-themes. Answers were transferred to excel spreadsheet to determine subthemes and main themes and conduct Framework analyses approach (128).

The Framework Method for the management and analysis of qualitative data has been used since the 1980s(129). The method is becoming an increasingly popular approach in medical and health research which provides an explicit and transparent process to reducing qualitative data with varying reporting styles, including thin description and multiple quotations. This approach to data synthesis has three stages: Free line-by-line coding, organisation of 'free codes' to construct 'descriptive'

themes and the development of 'analytical' themes (130). The text included participant quotations, themes and subthemes. The descriptive themes were re-interpreted inductively, developing analytical themes to answer the review question. To support the robustness, all subthemes and main themes were checked with research team by comparing and contrasting to ensure being comprehensive all participants and not losing any data.

According to participants answers, we determined 8 sub-themes namely, thoughts on condition cause, thoughts on pathology, expectations, improvements, strengths of management, experience, key information and source of information. We tabulated all key words and quotations based on sub-themes as summary finding of the qualitative research (table 11).

Table 11. Framework analysis of 40 patient survey responses yielding 8 sub-themes from BPG for PHP. The results have been used to determine patient's values and consecutively identify candidate predictors

Patient values		
Sub-Theme	Findings	Illustrative quotes
Thoughts on condition cause	Foot arch height; age; activity pattern; new load increase; long periods weight bearing; standing on hard surfaces; minimally supportive footwear; limb length asymmetry; rapidly changing load; altered gait; altered movement due to other conditions	Q: Walking on the outside edge of my foot when I was having pain in my second toe (PN) Q: Heel spurs, arthritis Q: Long shifts on my feet in facilities with hard floors. Q: Excess loads with inadequate progression Q: a number of contributory factors which is why is occurred now
Thoughts on pathology	Tissue irritation; degeneration; inflammation; tearing; inadequate tissue capacity; contracture	Q: Tissue band has become irritated through age/overuse Q: It feels like it is tearing. I think I have torn a ligament Q: Inflamed damaged pf which needs to heal/repair. Q: Struggling to cope with the demand and non adapted tissue Q: tendon contracture is wanting to happen all the time.
Expectations	More information; quick recovery-unrealised; exercise programme esp. foot strengthening; pain elimination; access to orthoses; specific treatments; better explanation of treatment/condition and causes	Q: Expected to get a steroid shot and was hoping for deep tissue manipulation to break down the scaring or thickening tissue. Wasn't offered Q: I assumed wrongly I would need insoles. I expected to be back on my feet within a few weeks (very optimistic). Q: as swift a recovery as possible, relief from the pain and programme of exercises to treat
Needed improvements	Facilitation of earlier recognition by patients; better communication as adherence promotion; Intervention strategy for pain; Easier access to, and more information on, specific treatments; Standardised treatment across sectors; Clarity of treatment and expectations; reduced waiting times	Q: better understanding of symptoms and types of patients prone to PHP Q: More explanation for the mechanism of the symptoms in order to motivate me to do the exercise Q: Get rid of the pain forever Q: Standardised treatment from NHS across the country. I've gone private as Dr can't refer.
Strengths of management	From no strengths to positive experiences; fast decisions; specific interventions; clear plan; individual preferences accounted for; detailed explanation; specific interventions	Q: Range of options considered and clearly explained Q: Spent time explaining in detail the condition/cause/treatment
Experience	Restricted activity; intermittent severe pain; reduced exercise; altered activity; morning	Q: It restricted the activities I wished to carry out

	pain; painful; emotionally affected; large impact on ADL; long, uncertain recovery	Q: It's very painful under my heel when I get up in the morning Q: Miserable 6 months. Had a huge impact on daily activities. Q: Very long process and uncertain outcome
Key information	Time course of recovery; self-management advice; how pain relief works; long term effects; explanation of what was not done; unsure; statistics on usual timescales for effects	Q: What can I do to reduce my pain and improve function Q: Will pain reliever actually address the issue or just mask the pain? *Q: When* they could make the pain go away Q: Expected outcome at the end of rehab
Sources of information	Range of online methods predominated; clinicians, friends, magazines; lack of clear guidance	Q: I can google it all day, and there isn't much out there Q: Patient groups on Facebook aren't even very helpful, because everyone using them hasn't found relief. Q: online forums, confusing as everyone's cause is different therefore treatment different

4.3 Questionnaire Battery design

4.4 Content of Questionnaire battery

The initial questionnaire battery was constructed and administered using 'Survey Monkey'. The standard patient reported outcome measures (PROMs) format was reproduced as closely as possible using the same wording of the items and instructions. The online survey consisted of eight PROMs and miscellaneous questions and designed to collect individual predictors, consisting of age, BMI, pain severity, and physical activity level, quality of life, kinesiophobia, restriction level of some activities and perception of pain which are considered as relevant factors for prediction of PHP prognosis. The Foot Health Status Questionnaire (FHSQ) was used to assess severity of foot/ankle problems, activity limitations, and participation restrictions associated with heel pain/plantar fasciitis (13, 131). Psychosocial features were evaluated by Pain Catastrophizing Scale (PCS) and Fear-Avoidance Belief Questionnaire (FABQ) (132) (133). Because psychological variables, including catastrophic thoughts and kinesiophobia, are common in people with chronic musculoskeletal pain and are associated with pain and function (134). Physical activity level was assessed with Global Physical Activity Questionnaire (GPAQ)(135) as evidences suggest that a history of occupational/ daily activities involving long periods of standing may be associated with PHP (64). Additionally, PHP has a significant negative impact on foot-specific and general health-related quality of life. Hence, quality of life in PwPHP was assessed by using Health-related Quality of Life (EQ-5D-5L) (71, 136). In order to observe patient's prognosis, Global Rating of Change

Scale (GROC), Patients Acceptable Symptom (PASS), Single Assessment Numeric Evaluation (SANE) was selected (37, 137, 138). Online questionnaire forms for baseline, monthly and three monthly assessment were presented in appendix B.

4.5 Piloting and testing of Questionnaire Battery

Couple of pilot studies and feasibility performed to test of data collection process and finalize study design. In every study, we asked some questions to participants and our collaborators to obtain their feedback about the study. All main feasibility and pilot tests are listed within temporal sequence. Apart from these, many small-scale piloting was performed to test the system, question type, order, logic and exporting data.

Table 12. Main feasibility and pilot tests with in temporal sequence.

Test type	Name	Aim	Test Time	Participant number	Survey link
Pilot	Outcome Predictors for Plantar Heel Pain: a pilot study	Test to working properly	15/3/2018	4	https://bit.ly/2IIHloO
Feasibility	Outcome Predictors for Plantar Heel Pain: a feasibility study	Assess to validity reliability, feasibility	20/3/2018	36	https://bit.ly/2WLlIcu
Pilot	Stress test	Try to break limits out with long and different answers	7/02/2019	3	NA
Pilot	3T pilot study	Checking export data and eligibility survey working properly	9/02/2019	3	NA
Pilot	3T Feedback	Test to understanding of questions in different age, gender and literacy	11/02/2019	18	https://bit.ly/2XgRZfO

Questions for catching the feedback;

- Which pathway(s) have you reviewed and what were your first thoughts?
- Please comment on pain charts you reviewed.
- Please type the repetitions you found in the survey. Please specify with the pathway and question number.
- What is it not in the survey you would expect? Please specify for each pathway you reviewed.
- What it is not working properly in the survey? (e.g. logic errors in the survey) Please specify for each pathway you reviewed.
- Anything else you think we should know?

- Do you have any questions?
- Which device did you use? Phone, pc-mac, pc-Microsoft, tablet, other…
- Which browser did you use? Chrome, firefox, safari, internet explorer, other…
- Have you had any trouble about the system like completing survey, skipping question?
- Is there any question(s) that you had difficulty to understand?
- Do you think that survey is relevant with your condition and cover your problem history?

These feedback questions asked participants/collaborators via survey monkey and emailing. (https://www.surveymonkey.co.uk/r/3Tfeedback). All feedback analysed and some answers are summarized.

Table 13. Participants and collaborators feedbacks from feasibility and pilot studies with some relevant quoted answers. Key: Q, Quotation

Findings		Illustrative quotes
Participant and collaborators feedbacks (values)		
First Thoughts on online survey	Comprehensive and seek information on different facets, detailed, Good layout, Long repetitive, time consuming, irrelevant questions, workable. Easy to use	Q1: The survey is comprehensive and seek information on different facets. However, it seems a bit long and I got lost halfway. Q 2: The questionnaire is really long. I think the risk is to have a lot of withdraw… It should be shortened. Q3: Why is it useful to know the highest studies degree, if the subject is married or not… Q4: Easy to use just a little difficult as a control and definitely length which may put some people off.
Comments on pain chart reviewed	Workable, easy to use, imaginable, good to have different pain options. Difficult to draw on foot part, Could be more detailed.	Q1: very good, it was not obvious at the start that the different pain options were available in the drop down, also the 0 to 10 pain scale did not open correctly on my page. The side bar was too narrow for the verbal description. Q2: hey look fully workable to me! The only thing I found clunky was the body chart Q3: What if patient has several pain types. Q4: It was straight forward. Not clear how the pain scale would apply to more than one site of pain. Would be good to have enlarged diagrams of the smaller anatomical areas such as the foot.
Repetitions or difficult to understands you found in the survey	questions about emotional status, understandable, not too much repetition,	Q1: There are a lot of repetitive type questions on emotion etc. I understand these are part of validated questionnaires, but the last section is quite lengthy Q2: No, nothing!
Any Error or anything not working properly	Skipping questions, going back previous page, irrelevant questions for control groups, dormant survey link, email title, grammar mistakes, VAS scale,	Q1: I completed this as a control with no current pain. Certainly, the earlier part of the questionnaire made this a little difficult / confusing. There may need to be some options for controls. Q2: This looks like SPAM and not particularly good either. The email title does not refer to anything recognisable sorted out. The English is not great spelling and grammar checked Q3: just the 0 to 10 slider description did not open correctly
Expectations / needed improvements	Be shorten, being informed people for next stage, more instructions and explanation for some medical terms, some question types are difficult to answers/ confusing options. Being easy to answers of	Q1: If it could be shorter, that would be better Q2: The screen at the end of the eligibility could have warned me to expect another email Q3: What do you mean by 'symptoms' Q4: The date of birth system is quite clunky and could annoy someone. Q5: in some questions you as patients if they had electrotherapy? will a patient know what this is? Q5: in the foot health status questionnaire the comment 'fairly many times' is a confusing term. is this standard in this questionnaire?

	questions in all devices, reminding of previous survey answers, pain drawing at the end of follow-up.	Q6: Seeing the full question on screen is difficult Q7: Adding several instructions or making buttons visually better might help. Q8: In 3 months survey, I did not remember what I wrote before. If these could be listed, that might help. Q9: Drawing at the end would be useful to compare my condition
Others	Comprehensive	Q1: well done, it is very comprehensive!

4.6 New versions in Smart Trial and Navigate Pain

Smart Trial

During study development process, we moved the questionnaire battery over from Survey Monkey to Smart Trial (ST). ST (15005-ST-0021, MEDEI ApS, Aalborg, Denmark) is an electronic platform to Collect and manage clinical data for regulatory compliance. It is fully streamlined registered online electronic case record form (eCRF) and investigators can directly collect data from subjects via email and SMS. It is enables quick and validated study setup that empowers clinical teams to be in full control of their activities. Regarding data protection, Smart Trial has a set of standard operation procedures (SOP) which state how information security shall be managed within this company. It strives to achieve a high degree of data and communication security as sensitive information stored in relation to the usage of Smart Trial.

In order to optimise questionnaire design, maximise data security, facilitate automated follow-up and enable eligibility screening we redesigned the survey to work on the SmartTrial platform In doing so, the repetition from the original survey was removed, without compromising questionnaire validity, and the process streamlined to reduce time and inconvenience. The streamlining included the addition of logic functions that enabled respondents to skip to a future question or page in the survey based on their answer to a previous close-ended question. Additionally, in the new versions participants were able to resume and complete a survey having taken a break. Participants who are struggling with the initial questionnaires were also offered support with completion if required. A decision to add health literacy assessment was taken in order to ensure population characteristics and data credibility.

Transferring the previous questionnaire into new Smart Trial software took considerable time and effort as it was required to fill different forms, instructions and logic design for each questionnaires, also it needed to schedule follow-ups for each

months and organize the content of SMS and emails on monthly basis. Additionally, stress tests and piloting were also performed after constructing the questionnaire battery to check grammar, spelling, logics between questions and answer limits.

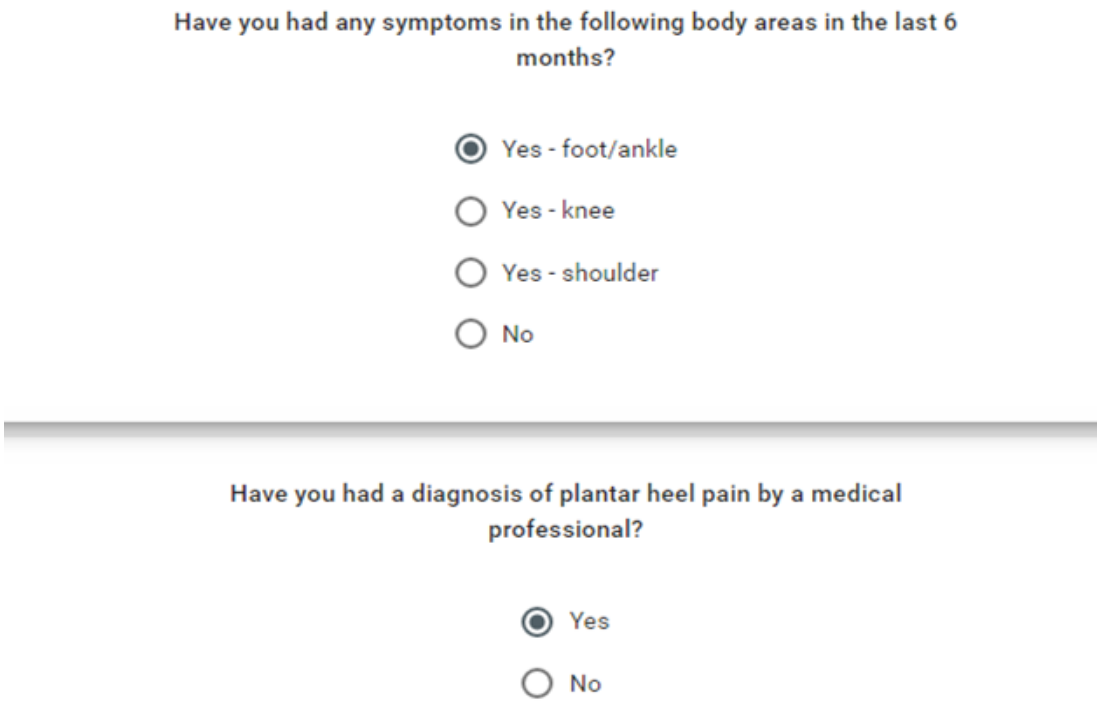

Figure 5. Questions in eligibility survey

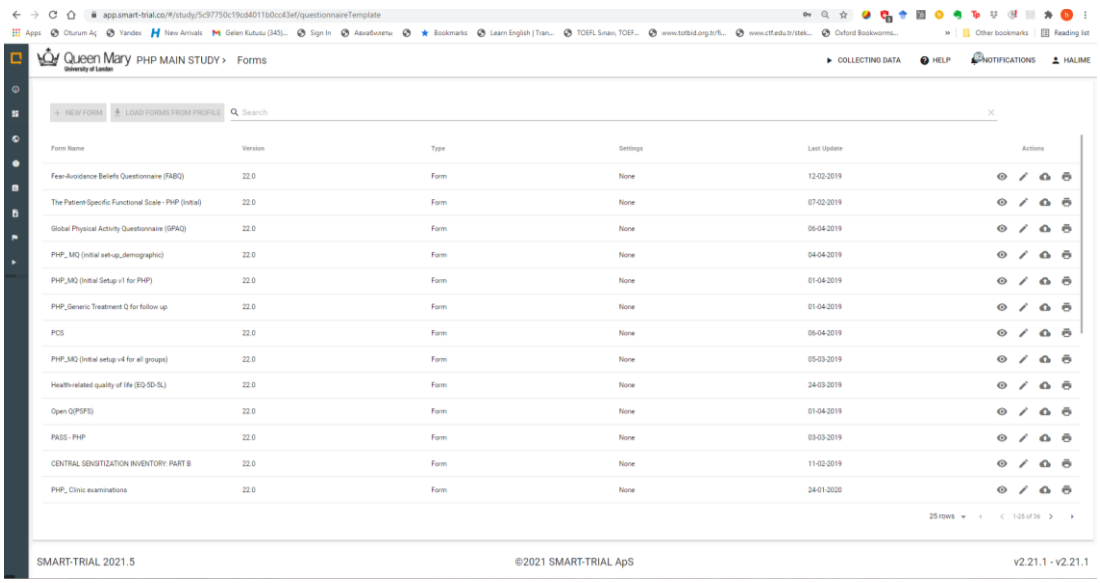

Figure 6. A screenshot from Smart Trial to illustrate the each single forms in the questionnaire battery and development process.

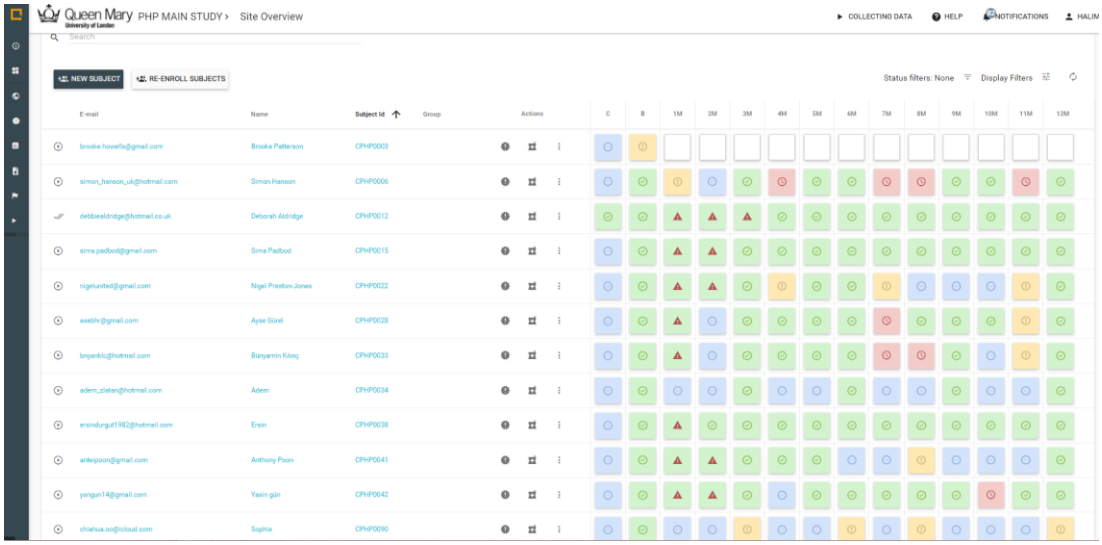

Figure 7. A screenshot from Smart Trial to illustrate each participant recruitments process and follow-ups

Navigate Pain

NavigatePain is pain tracking and mapping software launched by Aglance Solutions recently and advanced Navigate Pain (Version 1, Aalborg University, and Aalborg, Denmark). The software tool creates pain charts for quantifying pain areas, tracks pain intensity and detailed location over time and has high standards data protection. It also supported by several research addressing where-related questions about pain and discomfort.

Previously participants reported their pain in a foot picture which had located with numbers and grid lines. However, in feasibility study, participants reported that they struggled to show different pain type and the grades were relatively small for some anatomical areas. In order to enhance data collection of pain, pain mapping was moved to a high-resolution and detailed digital-body chart using the NavigatePain application Version 1 (Aalborg University, Aalborg, Denmark).

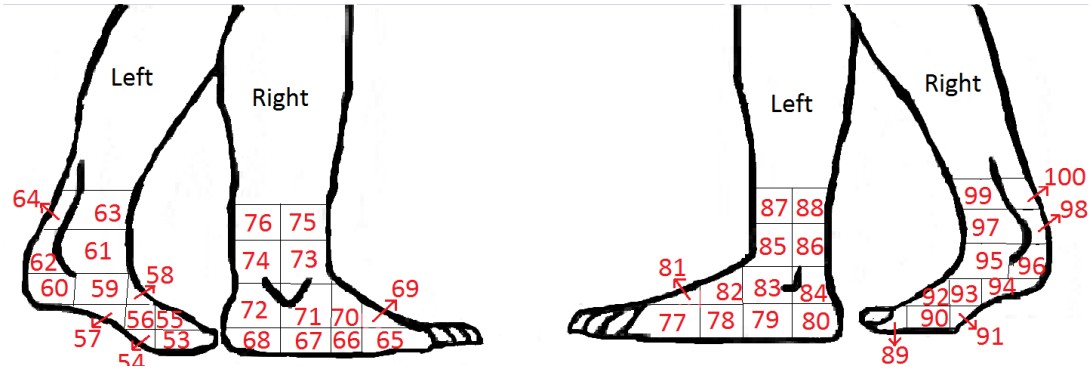

Figure 8. Pain mapping used in feasibility study

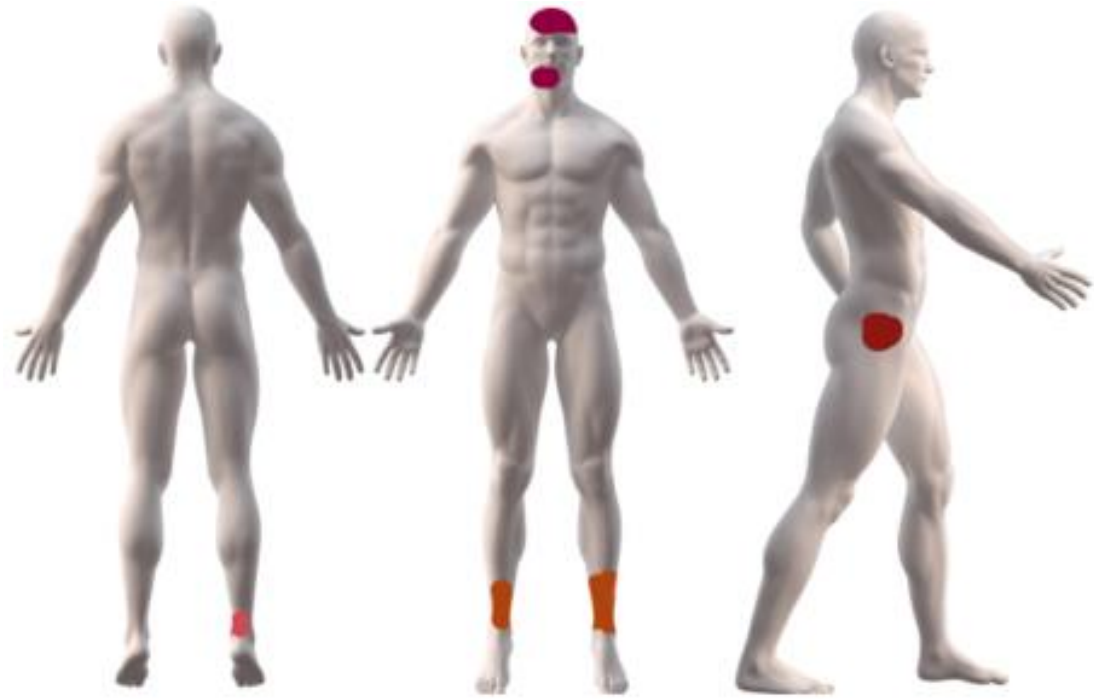

Figure 9. Body charts examples from Navigate Pain

4.7 Clinical and Ultrasound examinations of Proximal and Distal Lower Limb -inter- and intra-tester repeatability – a two part study to improve methods

Clinical measures are selected for assessing anatomical and biomedical characteristics based on clinical practice guidelines (2, 13) and research suggesting the physical impairments relevant to PHP prognosis. These measures included lower limb strength and range of motion; midfoot mobility and ankle mobility; palpation of sensitive and painful places in the foot; changes of pain level with aggravator activities and ultrasound assessment of plantar fascia thickness and other features.

Ultrasound scanning were performed over the plantar aspect of the rear foot to examine the plantar fascia at insertion of calcaneus and 0.5 cm away from that point. Long-axis sonograms were obtained medial to the midline of the plantar surface of the foot where the plantar fascia was most well defined using a GE Logiq S8 US scanner with a 7.5-Hz probe (129). The following were recorded from the US examination: plantar fascia thickness from insertion of calcaneus and 0.5 cm away from that point, thickness of the heel fat pad, echogenicity, bony erosions, heel spurs, ossification, and signs of (prior) fascia ruptures. Colour Doppler activity was graded using a modified Ohberg grading scale from 0-5 (139). The plantar fascia thickness and heel fat pad were measured longitudinally. The measurement of heel pad was at the shortest distance from the superficial border of the fascia to the skin above the calcaneus (129).

Each of the assessments used in the present study has been shown to be reliable in the context of lower extremity examination (13). Justification of selected measures were presented in.

In order to allow selection of useful measures for the cohort study and explore methods for improving measurement accuracy, known-group validity (I.e. ability to detect differences between the three groups), and repeatability (intra-rater & inter-rater) of the clinical measurements were examined. Validity of clinical assessment results were presented in the chapter 5 feasibility study.

A group of 10 symptomatic and 3 asymptomatic individuals (26 limbs) were recruited for initial stage (Stage 1). All participants were assessed using the clinical tests protocol (Described in detail in Appendix D) by two examiners (HG and DC). The same tests were repeated by both examiners one week later (stage 2). During each session, participants were randomly assigned to either a ‘HG then DC' or a ‘DC then HG' test order. After stage 2 was completed, intra-class correlation coefficients (ICCs) for the two examinations were determined across the 26 limbs to establish levels of intra-rater and inter-rater agreement between sessions.

If a low correlation ($ICC_{(3,1)} < 0.4$) was observed by both examiners, HG and DM decided whether there were any identifiable and feasible changes that could be

made to increase the test's reliability. If this could not be achieved, the test was excluded from further consideration. The figure presents the proposed methods to improve clinical and ultrasound testing procedure.

Table 14. Justifications for included clinical measures

Associated anatomic & biomechanic intrinsic factors	Plausible explanation (Plausibility of Bradford Hill criteria)	Tools	Reasons of the using related tool	Justifcation of inclusion (how much possibly can affect outcome)	justifcation for exclusion (criticism)
Foot type *(Bolivar et al., 2013; Irving et al., 2007; Martin et al., 2014; Rome et al., 2002; van Leeuwen et al., 2016; wrobel 2016).*	excessive pronation ↑intensile loads + everted heel → displacement of the plantar calcaneal fat pad→ ↓shock absorption	Foot posture index (FPI)	Quantify variation in the position of the foot easily and quickly in a clinical setting. (Keenan, 2007) and also give seperated information on rear-mid and fore foot posture.	Inconclusive, Factors with evidence of a non-significant difference between case and control groups (p > .05) But large effect size	
Foot mobility & MLA *(wearing, 2015; McPoil, 2009)*	Dynamic arch shape → the loading of the plantar fascia.	Arch height ratio device and calipers	Very good studies (Mcpoil, 2009) showing utility. It has a very good reliability and validity.	Inconclusive, Factors with evidence of a non-significant difference between case and control groups (p > .05)But large effect size	Time consuming

Table 14. Justifications for included clinical measures (continued)

Limited ankle DF *(Bolivar, Munuera, & Padillo, 2013; Martin et al., 2014; van Leeuwen et al., 2016)*	10 degrees of ankle dorsiflexion with the knee extended was required. Limiting DF→ excessive pronation →↑ tensile loads on PF A non-linear relationship may exist between ankle dorsiflexion ROM and plantar fascia strain. If the relationship were Ushaped, both extremes of movement (increased and decreased ROM) would predictor to CPHP(Cook,2007).	Lunge Test + navicular drop	Non-weight bearing methods is less reliable. Measurement error is higher in the mechanical goniometer than inclinometre . Combining with navicular drop helps to compare/understand STJ or midfoot mobility and tibiofemolar joint movement relationship.	Weak association,Negligible effect, Factors with evidence of a non-significant difference between case and control groups ($p > .05$)	Dorsiflexion Lunge Test is that the test procedure makes no effort to control for pronation or supination of the foot. It is difficult to determine where hold on it and placement. Patient's rotation can change measurement accuracy.
Limited 1.MTPJ movement *(Martin et al., 2014; van Leeuwen et al., 2016),*	1,MTPJ= active mechanism of arch stabilization. Windlass: pronation of the forefoot, inversion of the hindfoot, and elevation of the longitudinal arch, locking of the transverse tarsal joints and , stiffen the foot at toe-off (Carlson,2000)	Goniometer (supine)+ windlass test	Measurement error is less in the mechanical goniometer. Easy to performed detailed assesstment. Realibility and validity was completed by previous studies.	Weak association, Factors with evidence of a significant difference between case and control groups. But huge effect size	

Table 14. Justifications for included clinical measures (continued)

Hamstring tightness *(Bolivar et al., 2013; van Leeuwen et al., 2016),*	Tight hamstrings ↑ knee flexion → prolonged forefoot loading → windlass mechanism + ↓Ankle DF	SLR (Cut off: 70 degree)	The ROC curves for the SLR showed high specificity and sensitivity. One of the most used methods in the literature. Therefore ıt would be easy the discuss when write-up.(Bolivar et al., 2013)	Inconclusive, Factors with evidence of a non-significant difference between case and control groups (p > .05)	
Low ankle PF strength *(Martin et al., 2014; van Leeuwen et al., 2016, harutaichum,2018),*	Ankle PF → propulsive phase → ↑MLA and supinate STJ → arch stability; the hip and knee were thus flexing and externally rotating to propel the body forward	Single heel raising test (25 heel-rise repetitions as the standard for normal) (Lunsford,1995)	non-weight-bearing manual test of ankle plantar-flexion strength is inadequate because of the inability of the examiner to counter References the torque produced by the plantar flexors with normal arm strength.	Inconclusive, Factors with evidence of a significant difference between case and control groups	
Low toe flexor strength *(van Leeuwen et al., 2016, harutaichum,2018)*	Activity onset 30% early in the gait cycle (Rachel,2003)and the PIMs → ↑ stiffening of the MTP joint in late stance→ propulsive push-off (Farris,2018)	oxford scale (cut off:5)	Very good studies showing utility. It has a good reliability and validity. (Rachel, 2003;)	Inconclusive, Factors with evidence of a significant difference between case and control groups	
Varus Knee alignment *(di cabrio, 2010)*	Such alignments→ the body weight is transferred to the medial side of the foot earlier in walking→ stress on medial foot structures + PF. ↓ the strength of primary foot and ankle muscles	observational posture analysis (varus/valgus/recurvatum)	time saver and easy to perform	Inconclusive, Factors with evidence of a non-significant difference between case and control groups (p > .05)	

Table 14. Justifications for included clinical measures (continued)

Lower limp discrepancy ***(messier,1998)***	discrepancy → ↑ pronation on the side of short leg. + LLD → overuse injury. LLD → bilateral compensatory movements. (messier,1998)	Observational in prone position based on medial malleols (L=R / L>R / L<R)	time saver and easy to perform	Inconclusive,Factors with evidence of a non-significant difference between case and control groups (p > .05)	
Femoral anteversion & pelvic angle ***(harutaichum,2018)***	Such alignments→ the body weight is transferred to the medial side of the foot earlier in walking→ stress on medial foot structures + PF. ↓ the strength of primary foot and ankle muscles	Observational in standing position. **Pelvic angle**: according to pelvic tilt **Femoral antieversion** : Hip IR (Normal / flex / lax)	time saver and easy to perform	Inconclusive, Factors with evidence of a non-significant difference between case and control groups (p > .05)	
PF thickness & heel spur & heel pad ***(van Leeuwen et al., 2016)***		USS assessment: from insertion of calcaneus and 0.5 cm from insertion calcaneus.	One of the gold standart for thickness. Additionally, I will use force measurment tool to get more standardization.	Strong association and Factors with evidence of a significant difference between case and control groups	
Pain	Pain localisation/ type/ severity/ frequency	Digital Pain Map Drawing/Form and palpation	Security for data storage. User-friendly	Strong association and Factors with evidence of a significant difference between case and control groups. Huge size effect	

Table 14. Justifications for included clinical measures (continued)

Secondary foot injuries	Tarsal Tunnel syndrome (TTS) & Calcaneal stress fracture	Tarsal Tunnel test & Calcaneal squeeze	Tests are often positive in TTS and CSF (Alshami, 2008 & Toomey, 2009)	NA	TTS mechanically challenge various structures because it strain tibial nerve as well! (Alshami, 2007)
Foot mobility & MLA (wearing, 2015; McPoil, 2009)	Foot arch height	Navicular Drop Test	show pronation in static stance and give information about foot mobility		Their reliability and validity are not goog compare to other methods for measure of foot mobility.
Foot mobility & MLA (wearing, 2015; McPoil, 2009)	Med-lat nacivular shift	Navicular Drift Test	Another indicator of foot mobility nad posture		Their reliability and validity are not goog compare to other methods for measure of foot mobility.
Foot mobility & MLA (wearing, 2015; McPoil, 2009)	MLA arch angle	Goniometer	Important indicator for ability to dissipate plantar pressure forces. Plus, it is good to compare it with biomechanics findings in terms of validity.	Goniometer is the cheap and easy way to measure of it	

Table 15. Proposed method modifications for clinical testing

Test	Proposed Modifications for optimisation	Method
All Strength Measures	Training/Familiarisation	Measurement method was not be changed. However, the outcome were dichotomised as below 5 (Oxford MT) or above 5. This would serve to make easier data analysis process.
Hip Internal/ External Rotation ROM	iPhone inclinometer & neoprene strap	IPhone strapped to the middle shank and the knee flexed to 90˚ and stabilized with strap. Care taken to prevent lifting of the contralateral pelvis during external rotation and the ipsilateral pelvis during internal rotation.
Ankle dorsi-flexion ROM	Use of iPhone inclinometer and neoprene strap	iPhone strapped to the middle shank, 'zeroed' in a neutral standing position, and the participant instructed to lunge forward with the contralateral limb until stretch felt in the calf of the tested limb. Measures recorded with the knee straight and knee bent whilst heel of test leg maintained on the floor.
1st MTPJ Extension	Use of iPhone inclinometer, training/familiarisation	Measurement method was not be changed. However, the outcome were dichotomised as below 70 or above 5. This would serve to make easier data analysis process.
Foot Mobility	Use a tool for Measurement of Medial Malleolar Drift and Medial Longitudinal Arch Height	Subjects were asked to sit on chair or adjustable stretcher. Hip and knee angle with 90 degree. Feet are placed the platform with few touch and without weight as much as possible. Then dorsal arch height and midfoot width distance during sitting and standing using a modified digital calliper.
Leg length discrepancy measurement	Changing the measurement outcome	A direct measurement using a tape measure can be utilized to measure the true leg length from the anterior superior iliac spine (ASIS) to the medial malleolus. The apparent leg length is measured from the umbilicus to the medial malleolus. The outcome were categorized as left side equal to right side, left side is higher than right side or right side is higher than left side
Ultrasound measurements	Some of ultrasound parameter were excluded. It was also decided heel pad thickness were measured using pressure assessment device	The subjects lay in a prone position on the couch with legs extended. Subcutaneous adipose thickness was measured on-screen using electronic calliper, defined by the perpendicular distance between the upper border of the dermal interface and the upper border of the fascia interface at medial calcaneal tubercula. In meantime time, the compression force applied was measured via another software to be standardised the assessment protocol.
Hamstring Flexibility	iPhone inclinometer, neoprene strap & straight leg raise	IPhone strapped to the middle shank, 'zeroed' in a rested knee extended position, and a passive straight leg raise manoeuvre performed. The measure was recorded at the end of range, just prior to observed knee flexion or posterior pelvic tilt.

Due to COVID-19 pandemic, proposed number of clinical and ultrasound examinations were not able to achieve.

Figure 10. Ultrasound assessment for plantar fascia

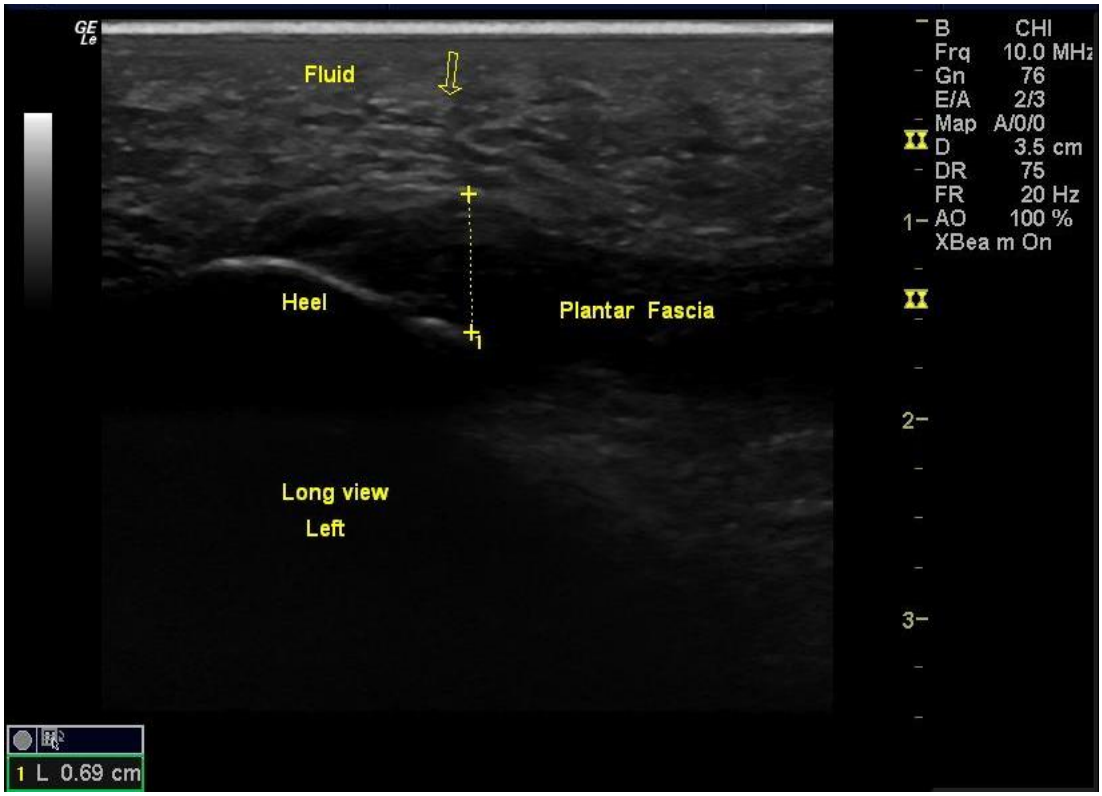

Figure 11. Thickness of plantar fascia from proximal calcaneus in longitudinal plane

4.8 Biomechanical assessments of foot and ankle complex

Determining severity of PHP is usually based on a patient's symptom description, physical examination such as manual palpation of the painful area. Objective severity grading is challenging to obtain. Therefore, a novel graded loading challenge (GLC) test that attempt to develop to determine severity of patients from a biomechanical perspective. The variables which can provide prognostic information were also aimed to use in final model.

The Human Performance Laboratory (HPL) in Mile End was used for biomechanics data collection. Participant height was measured through a calibrated stadiometer. Weight was measured using calibrated weighing scales allowing calculation of body mass index (BMI). Leg length measurement was achieved through tape measure measuring from the ASIS to medial malleolus of the leg on the same side. Foot length was also measured through a foot gauge.

The participant then performed the protocol consisting of the GLC's 5 levels. The first level involved a normal step length walking pattern. The second incorporated an increase in step length by 50%. The third required to participant to walk with a

normal step length but with a vest increasing their weight by 25%. The fourth required both the increased step length and weighted vest. These exercises took place on two Kistler force plates and one trial was defined as one gait cycle over the force plates. 5 trials were taken of the right foot landing on the force plate and 5 trials with the left. Trials were discounted should the foot not completely land on the force plate or if the participant did not execute the trial appropriately. The participant was asked to quantify their pain on a scale of 0-10 after every level.

Each participant was allowed time to familiarise themselves and ensure that starting position was appropriate. Moreover, to ensure high quality data was collected, starting positions were modified in each grade to ensure adequate contact on the force plate for every trial. This was through the participant walking from the force plate and marking where the 4th step lands in normal walking trials and the 2nd for longer step trials.

In data processing, a custom script was produced in MATLAB for progression. 'vGRF' was filtered with a 50Hz 4th order low pass Butterworth filter with 0 lag. Contact on force plate was defined as a vGRF of greater than 30N for each trial. Two peaks were then located from the first and second halves of the gait analysis. From this the outcomes of vGRF, time to first peak, time from second peak to toe-off, APf, RFDev and RFDec were extracted.

Descriptive statistics were compared for each outcome between groups. The differences between the biomechanical values of the two groups were compared through the means at each level of the GLC. This was achieved through collating the data on SPSS software and conducting a one-way ANOVA test for each variable with a p-value of <0.05 considered statistically significant. The independent factor was the level of GLC while the dependent being the measured outcomes of biomechanical analysis. These outcomes included vGRF, APf, RFDev and RFDec.

A group-known validity of biomechanical testing procedure were implemented in the feasibility study (The results and testing procedure were described in detail in chapter 5). According to patients' feedback and tester experience, the main feasibility lesson were reducing time and effort in each assessment session. The

testing completion time was around 1 hour. However, due to COVID-19 pandemic, proposed number of biomechanical assessments were not able to achieve.

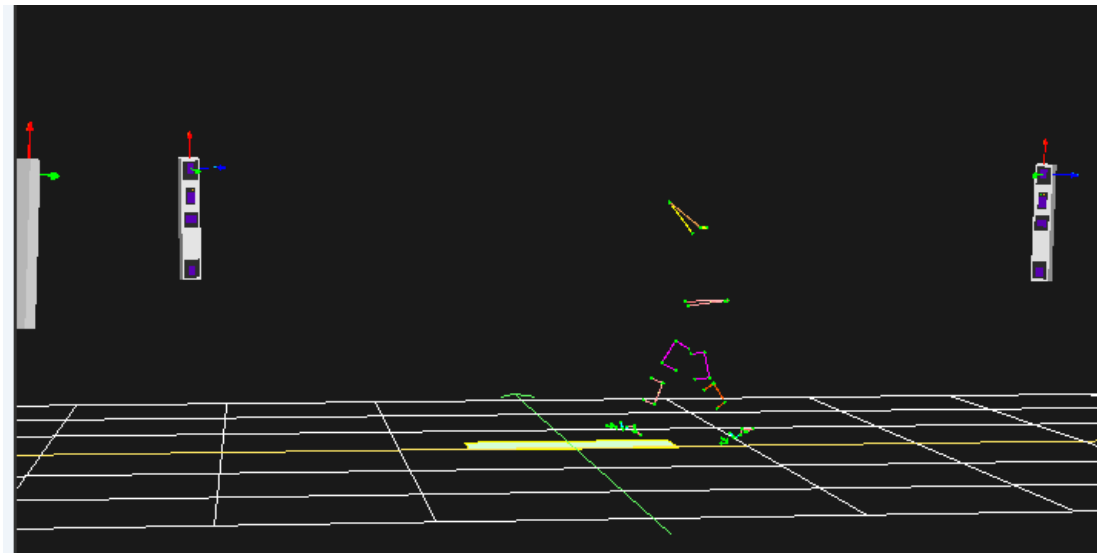

Figure 12. Image from the codamotion during biomechanical assessment.

Figure 13. Walking with weighted west as biomechanical assessment task

Figure 14. Markers placement on foot and shank

4.9 Recruitment strategies & Retention Process

Social Media: Facebook, Twitter, Instagram. Advertisements, info-graphics, which are about the study, were posted to Facebook, Twitter and Instagram. Every advertisement includes a link or QR code which access to common initial eligibility survey (https://bit.ly/2UAP2W3). If potential participants are interested in the study, they can scan QR code and directly fill out the eligibility survey. Once someone has been identified as eligible for participation and has given consent, they can proceed to the online survey.

All advertisements are detailed with the name and address of the clinical investigator and/or research facility, condition under study and/or the purpose of the research, eligibility criteria, a brief list of participation benefits (e.g. no-cost examination), the time or other commitment required, location of the research and the person or office

to contact. Participant can also communicate with us via messages on these platforms or our contact details.

Clinic: Private sector by arrangement. We will not recruit people from the NHS at this stage, we collaborated with some clinics and universities in the UK and abroad.

If clinicians decide a patient to eligible our study, they are sharing participant details by filling eligibility survey. Clinicians who recruit patients can also record physical examination and ultrasound findings. Reliability studies are conducting for these assessments.

Posters: Designed leaflets, brochures and flyers. Leaflets, brochures and flyers were designed to draw attention. In posters, some details about study such as name of the research facility, purpose of research and eligibility criteria (briefly stated), time commitment, study contacts and QR code for eligibility survey are given Appendix E.

Snowballing: Calling two peers. When a participant comes to the clinic or does the survey, we asked participants to consider recruiting two of their peers who are either healthy or have similar symptoms to join the study. All participants are assessing carefully based on eligibility criteria.

Regardless where participants came from, everyone must fill out our eligibility survey. After screening participants' condition and identified as eligible, we enrolled them to relevant group (PHP or OP) and send specific online survey link for baseline questionnaire. After the participants complete the baseline survey, the follow up surveys send monthly. Some participants who agree to participate in the clinic examination and/or biomechanics assessment are invited to the Human Performance Lab at QMUL, and for the examinations and graded biomechanical activities.

Figure 15. Study flyer used for recruitment

4.10 Patient and Public Involvement (PPI) event

On January 7, 2019, a PPI event was held, and attendees recognised a variety of risks and benefits associated with the planned cohort study. Patients were concerned about data sharing with external parties or private companies, as well as the requirement for repeated consent if the data was being used for multiple purposes.

Participants also proposed different thoughts on recruitment and retention techniques, mailing times, and factors that motivated them to participate in the study, which shaped our recruitment and retention strategies. Details of PPI events were presented in the report below.

Patients Public Involvement (PPI) event report:

2 sessions were completed, and 4 participants were recruited for each session.

1st session has been run by Team_Cohort (AT, HG and MD) plus GP and last an hour.

2nd session has been run by only Team_Cohort and last 45 minutes.

Participants' answers reported as below.

Baseline Section

Q1. What is the best way to explain long (around 45 mins) initial questionnaire aim? Is this kind of explanation acceptable to convince people?

Answers:

- Inform people individually, like "we need your help/this info to help you" to convince them!
- 10 minutes is acceptable for a day to fill out the survey (e.g. 10 mins/day to finish all, 1-hour survey could take 6 days)
- Some of them were not happy about the duration and one of them said that the study is not going to work, and we can have a high rate of drop out. (He also said he wouldn't attend this study)

Judgement: We should focus on the positive features of the study, then use these features to sell the study.

Q2. Please tell us 3 things how to motivate people to join the study and fill out the long survey including monthly follow-ups?

Answers:

- To be able to go back to survey wherever they left as a feature would be great Good titles for the email subjects
- Examples of happy participants from previous studies
- Some results from previous research they have attended would be a good motivation for them
- End goals are important for participants to join a study
- Getting better is more important than money for them.
- Flexibility for the time to complete the survey could be good

Judgement: We should focus on our previous study outputs and happy participants in order to recruit new people for the cohort study. Need to prepare a clear explanations for the end goals which are the benefits taking out the study.

Q3. What time of the day you want to fill in the survey?

Answers:

- Lunch time could work
- The time of the day is not really important as it is an online survey and available all the time

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Judgement: We are going to send the survey link after enrolling the participant.

Q4. How do you want to receive reminder? (Calling, mailing, text, etc.)

Answers:

- SMS and email for reminders
- Good titles for the email subjects
- Calling participants is not a good option
- They do not answer phone calls
- If they did not fill out the survey for a long time (e.g. 2 weeks), we should think that they do not want to do it!

Judgement: We have already planned to use SMS and email at the same time. This event is confirmed we are on the right truck. We should consider an attractive subject title for the emails as well.

Q5. If it is email: How can we ask you to add our email address in your address list in case of receiving study reminders in junk/spam box?

Answers: Junk/spam; participants can confirm our emails (e.g. confirmation emails from companies, so smart trial may work on it?)

Judgement: We will investigate whether we can find out to use a confirmation email via Smart Trial.

Q6. What kind of way is more useful to attend to the study? Why? (Social media, by clinician, etc.)

Answers:

- Social media is highly recommended
- They recommended us to find some people from Facebook groups (sports related, disease related, etc.)

Judgement: We will use social media advertisement to spread our study as planned.

Retention Section

Q1. What would it be helpful to complete monthly follow-up surveys?

Answers:

- Rewards are also important for them, especially treatment.
- It is difficult to remember a month ago for them
- Short follow-up is good

Judgement: We should stick with short follow ups and also consider about how they can easily remember their last month. Keeping a diary?

Q2. During follow-up, if we can't reach a person when exact time they need to fill-out the survey or they left the survey half way through, how frequently should we call or send a reminder without leading any disturbance.

Answers: Every 3-day for the frequency of reminders is good enough, but still need to put some limit (e.g. maximum 3 reminders) for this.

Judgement: The ideal number of reminder would be once in three days.

Q3. What kind of things would be helpful to complete study as a reward? (drawing, voucher, money, gift, food & drinks)

Answers:

- Rewards are also important for them, especially treatment.

- Giving explanation/advice on their condition for self-management

Judgement: Some people are expecting to receive any benefits. The benefit can be an advice, information about their condition or treatment. To provide that, we are planning to prepare a report as mentioned below.

Q4. How we can keep you in the study when you recovered and don't have problem anymore as the study requires follow up even after getting better?

Answers:

- After getting better: they all said yes to continue study to help other people
- We can sell this idea to get people as well (or to keep them) "You recovered but we still following your condition" to provide information for you and other people.

Judgement: 'Feeling good' as a component is discussed in the overall part.

Q5. Apart from the survey, we have some parts like recording video, keeping diary. How can we motivate people to perform these extra things?

Answers:

- Video and diary issue: need to give an example of a good participant.
- Monthly video recording is too much, 3- monthly video recording is acceptable.
- One person does not record own video because of personal reason such as being topless
- Talking about data protection can convince people for video record and other extra things.
- Some of them were not happy for any other study parts as they thought it is already too much.

Judgement: Patient information sheet for video recording can be reorganized by highlighting data protection and explaining clearly what we want them to do. Frequency for video recording can reconsider as 3-monthly.

4.11 Liaising with collaborators

Another strategy that we used was to work with collaborators from different clinics and countries to increase number of recruitment. That would also provide more generalizable data for the study. In total, more than fourth researchers and clinicians were contacted from ten different countries. Open ended questions were asked to potential collaborators using an online survey (https://www.surveymonkey.co.uk/r/3T_10000), which explored their targeted populations, potential number of patients they can provide and their settings in clinics. After identifying collaborators who can join into the cohort study, we prepared a recruitment package for on-board recruiters and explained the study details either video call or in person meetings. Recruitment package included;

Guideline for the recruitment package: Brief explanation of documents and how to use the package.

- Video showing how to enrol a participant into the survey: shorturl.at/jCDIV.
- The main eligibility survey short cut link.
- Ten Thousand Tendons study protocol.
- Ten Thousand Tendons study Queen Mary ethics application and approval letter.
- Ten Thousand Tendons study presentation from Prof Dylan Morrissey: shorturl.at/moyzL
- Ten Thousand Tendons study recruitment presentation_08.05.19: Brief presentation about the study and recruitment process chart.
- Eligibility criteria of the study and key points.
- Study flyers (Appendix 8).
- The package link is here: shorturl.at/tMU25

4.12 Learning and Skills gained during PhD

During your PhD, I didn't just learning about my research topic. You are trained in an extensive set of skills that can be applied to other jobs both in and out of academia.

4.12.1 Academic/research learnings and skills

I have attempt to learn various statistical methods and software to provide robust results from the studies. For example, to improve my coding skills in MATLAB, I took an online course (version R2018b, Mathworks, Natick, MA) for a month even though I didn't have experience in this field previously. However, Aleksandra Birn-Jeffery, my second supervisor and a biomechanics data analysis specialist, was helped me to create proper scripts and data analyses for my feasibility study.

Furthermore, I have worked on SmartPLS software to conduct structural equations modelling analyses of case-control data. I completed various online courses (linear regression, logistic regression using STATA/ I was also able to learn how to utilise STATA software and STATA codes as a result of the training. In a month, I completed

the course. Additionnaly, the Queen Mary, University of London Postgraduate Research Fund (QMPGRF) has been successfully awarded (12.11.2020) for a 3-day statistical analysis course titled "Statistical techniques for risk prediction and prognostic models." I learned how to do survival analysis with internal validation of a built model thanks to this training. In the cohort analysis, the statistics were employed.

4.12.2 Project management and collaboration

During this time, make a realistic timeline, overcome setbacks, and manage stakeholders were important steps. I had to manage long-term projects at the same time as short-term goals which requires strong organizational skills. Every three months I have prepared my short-term plan and discussed with my supervisor. Also working with people from different departments such as engineering, statistics, sports science and podiatry help me to understand different perspective and thinking/communication ways they used.

Additionally, I worked with MSc and iBSc students and being supervised them for their research. My mentoring abilities improved as a result of the experience. In 2019, I also taught 10 hours in a Biomechanics and Rehabilitation Module practise session. In addition, I assisted with the conference planning for the Sports & Exercise Medicine 21st Annual Scientific Meeting.

4.12.3 Clinical skills

I attended the Joint Research Management Office's Good Practice for Interventional Studies (08.11.2017) and Good Clinical Practice Refresher (28.10.2019) workshops. The course provided me with a better understanding of the ethical and scientific quality requirements that apply to clinical research in the United Kingdom. In order to obtain ethics approval, the training was also necessary. At addition, from 17.12.2018, I have worked as an honorary physiotherapist in Barts National Health Service (NHS) Trust with NHS outpatients. This gave us a chance to recruit NHS patients.

I had never utilised ultrasound imaging or gathered biomechanical data before starting my PhD. I took the Sports Medicine Ultrasound Group's (SMUG) ultrasound imaging course since we wanted to employ ultrasound in clinical assessment. It contains basic information, an introduction to ultrasonic assessment, and an examination of the foundations of body parts and muscles such as the shoulder, knee, ankle, and foot. It took two days to complete. I also attended two Codamotion Group-hosted training sessions to understand the fundamentals of the motion capture system and how to gather data using the CODA system and ODIN software.

CHAPTER 5 ONLINE QUESTIONNAIRE, CLINICAL AND BIOMECHANICAL MEASUREMENTS FOR OUTCOME PREDICTION OF PLANTAR HEEL PAIN: FEASIBILITY FOR A COHORT STUDY

In the study development procedure presented in chapter 4, various stages were determined to obtain robust data collection for the success of cohort study. Furthermore, it was judged that online questionnaire would enable easier access to more participants, but modifications mentioned in chapter 4 require validation compared to the original paper version of the questionnaires as we combined numerous PROMs into a questionnaire battery with various formatting changes. This chapter therefore presents a study designed to investigate the feasibility of online questionnaire, clinical and biomechanical measurements in order to optimise the success of a prospective cohort study.

Preliminary results from this study were presented at Annual Conference on Sports and Exercise Medicine in Queen Mary University of London at September 2018 and International Scientific Tendinopathy Symposium in University Medical Centre Groningen, Holland at October 2018. This study was accepted for publication in Journal of foot and ankle research (impact factor 1.919) after two rounds of robust peer review.

5.1 Introduction

Plantar heel pain (PHP) is one of the most common foot and ankle problems, causing pain on the plantar aspect of the rear-foot, particularly at the inferio-medial heel and accounting for approximately 11-15% of all foot symptoms requiring professional care.(140) People with PHP (PwPHP) often complain that the most severe pain occurs during the initial step, after a period of prolonged non weight-bearing(2). The course of the disease has long been regarded as self-limiting but this is now known not to be the case.[(2)]

Various treatment strategies are proposed for PwPHP, but outcomes are not satisfactory, with no accepted treatment of choice [8] and no clear prognostic indicators. Recovery rates from the many tested interventions vary between 50-80% at 6 months.[33] Footwear modification, foot orthosis , taping, stretching and shockwave therapy (ESWT) have the best evidence for managing PHP (141, 142). However, approximately 50% of individuals continue to have some symptoms after conservative treatment and at least 30% have recurrent symptoms.[37] The associated factors relevant to prognosis are thought to be a high body mass index (BMI) or sudden weight gain, excessive running, prolonged standing/walking, occupational environment, work-related weight bearing activities, limited ankle dorsiflexion, a cavus foot, excessive foot pronation and psychological symptoms (e.g., depression, anxiety, and stress).[76, 143] However, the prognostic evidence of these factors is neither complete nor causal.[8]

Prospective research for PwPHP has typically considered single or limited numbers of outcome predictors with analysis limited by relatively small sample sizes.[8],[144] Although numerous studies using cross-sectional or matched case-control designs have been conducted,[65],[145] at best single variable prediction models have been created.[37] In order to increase treatment success enabling prognosis determination could be helpful by taking multiple factors into consideration as in case for other pathologies. For example, prognostic screening tool such as the StartBack, which is an easily completed multiple scale that combines potentially modifiable prognostic factors including pain, function and fear avoidance behaviour, can increase health benefit and yield cost savings for low back pain.[146] Therefore, high-quality prospective cohort studies with a large sample size are needed to identify the relative importance of multiple outcome predictors. The impact of revealing these outcome predictors would be useful to clinicians judging prognosis, researchers who want to understand causal relationships and perhaps for sufferers seeking to understand their condition if presented in suitable translational materials. Multi-variable models that perform better than single variables or overall clinician judgement of outcome would be of particular use,[67] with a planned cohort study having been designed to build an accurate prognostic model for PHP outcome. Importantly, it may be that the

model is specific to PHP but not other foot pain (OP), and so the investigation of people with other foot problems is needed to compare the two and determine factors that are specific to PHP.

We judged that online questionnaire would enable easier access to more participants in a wider variety of locations at lower cost. The advantages of online delivery were central to maximising cohort study recruitment, but modifications applied require validation compared to the original paper version of the questionnaires according to ISPOR ePRO guidelines (147). These stipulate that moderate modifications require validation hence, as we combined numerous PROMs into a questionnaire battery within a complex study design with various formatting changes, it was essential to perform an equivalence study.

Therefore this study primarily aimed to investigate feasibility by testing data collection procedures and gaining feedback from participants in order to refine data collection. Establishing equivalence to usual procedures for the questionnaire battery; known-group validity for clinical and imaging measures; and initial validation and reliability of biomechanical measures in the form of a graded loading challenge were secondary aims. These data were required in order to optimise the success of a prospective cohort study.

5.2 Methods

5.2.1 Study population

A convenience sample of thirty-six participants with equal numbers of people with PHP, people with other foot pain (PwOP) and healthy controls were recruited from private clinics and local facilities in London, UK from an initial sample of 48 over a three month period in 2018. The inclusion criteria were a diagnosis of PHP for the PHP group and a different diagnosis of an ankle or foot musculoskeletal condition for the PwOP group. A podiatrist with over 30 years' clinic experience (TP) diagnosed both groups of conditions based on reported symptoms, clinical examination; subjects with early morning and first step pain for more than one month and pain on palpation of the plantar medial tubercle of the calcaneus were classified as people with PHP compared to other foot problems(13). Healthy controls were defined as not

having any foot and ankle related problems before. People under 18 years of age were the only exclusion.

The study procedures were ethically approved by [redacted] Written informed consent was sought from each recruited participant prior to study entry either via the online questionnaire or face-to-face. The consort-PF[148] guidelines were consulted to guide study design.

5.2.2 Measures

5.2.2.1 Questionnaire battery

An online survey was constructed and administered using 'SurveyMonkey' (www.surveymonkey.com). The standard patient reported outcome measures (PROMs) format was reproduced as closely as possible using the same wording of the items and instructions. The online survey consisted of eight PROMs and miscellaneous questions designed to collect outcome measures, consisting of pain severity, restriction level of some activities, kinesiophobia, and report of pain location with a pain map, physical activity level, quality of life, age and BMI, which are all considered as relevant factors for prediction of PHP prognosis

The Foot and Ankle Outcome Score (FAOS) was used to assess foot and ankle problem severity, activity limitation, and participation restriction.[13, 131] The FAOS is an adaptation of the KOOS and consists of 42 questions with five subscales: pain (nine questions); symptoms (seven questions); activities of daily living and limitations (17 questions); ability to perform sports and recreational activities (five questions); and quality of life related foot/ankle (four questions). Score are calculated by summing the scores of the individual items. The total score is yielded into a 0–100 scale, with 100 representing no symptoms or limitations.(131) The validity and reliability of the original FAOS, as well as other different translated versions, is considered good.(131, 149)

Psychological variables are common in people with chronic musculoskeletal pain and are associated with pain and function[134] Those psychosocial features were evaluated by the Pain Catastrophizing Scale (PCS) and Fear-Avoidance Belief Questionnaire (FABQ).[132]

PCS was used to measure pain-related catastrophizing with 13 items that yield an overall score [132] which greater than 24 have been associated with higher catastrophization (150). Reliability and validity of the PCS have been established (132, 151, 152). FABQ is designed to assess fear of avoidance beliefs on movement for patients with musculoskeletal condition and chronic pain(153). The questionnaire is consisted of two subscales that relate to work (7 questions) and physical activity (4 questions) with 7-point Likert scale. Higher values are indicating a greater fear of movement. The FABQ demonstrates high levels of internal consistency and test-retest reliability. (154, 155), (156)

Evidence suggests that a history of occupational/daily activities involving long periods of standing or inactivity may be associated with PHP.[13, 64] Physical activity level was assessed with the Global Physical Activity Questionnaire (GPAQ).[135] GPAQ comprises 16 items that measure physical activity in work, transport, leisure activities, and time spent in inactivity my measuring intensity, duration, and frequency. The GPAQ showed acceptable evidence of short- and long-term test–retest reliability by activity category and modest validity evidence. (157)

Additionally, PHP has a significant negative impact on foot-specific and general health-related quality of life, itself assessed by using the Euro quality of life (Euroqol) five dimension 5 level questionnaire (EQ-5D-5L).[71, 136] EQ-5D-5L measures generic health status by taking into account five dimensions; mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Total score can be converted into a single preference-based index anchored on a scale where 0 and 1 represent being dead and full health, respectively. (158)

5.2.2.2 Clinical examination & Ultrasound assessment

A subset of eighteen participants underwent a lower-extremity physical examination by a physiotherapist, consisting of selected clinical measures based on clinical practice guideline[2, 13] and clinical experience indicating relevance to prognosis. These measures included lower limb strength of gastrocnemius and hip extensors and hip internal rotation and ankle dorsiflexion and 1MTPJ dorsi flexion range of motion measures.[13, 159-161] Mid-foot mobility was measured via navicular drift, navicular drop and medial longitudinal arc (MLA) angle.[162, 163] Finally, we palpated

the midpoint of the heel, medial insertion of plantar fascia and insertion of Achilles tendon and gastrocnemius muscle belly to detect painful areas.[2]

Ultrasound scanning (US) was used to examine the plantar fascia at its origin and mid-section, with long-axis sonograms using a 7.5MHz probe (GE Logiq S8, Milwaukee, WI, USA). Heel pad thickness, echogenicity, bony erosions, heel spurs, ossification, and signs of fascia rupture or fibroma were sought as reduced fascia thickness and other US findings could also be a sign of PHP recovery.[8] Neovascularization was graded using a modified Ohberg grading scale from 0-5.[139]

5.2.2.3 Biomechanical assessment

Biomechanical assessment was performed twice (2-7 days between tests) with a subset of nine participants. A graded loading challenge (GLC) was developed to assess pain response and movement features in response to increasing step length and weight carried. The test consisted of four different difficulty levels: 1) normal walking with self-selected speed and step length, 2) walking with a 25% longer step length of participants' original step, 3) normal walking while carrying a load of 25% of body mass (BM), and 4) walking with the 25% longer step length plus the extra 25% load, which is a combination of tasks two and three. Participants performed each level 10 times, with each repetition consisting of six (level 1 and 3) or four (level 2 and 4) steps prior to the force plate and the same number of steps after; the total walking distance of walking was approximately 11 meters. Participants carried load via a double-sided weighted vest (HOMCOM, MHSTAR, England). Step length was guided by indicators of the individually-determined required step length on the ground.

Kinetic and kinematic motion capture were performed during the GLC utilising in-floor force plates (500Hz; 9281CA, Kistler) and an infrared motion analysis system (100Hz; CX-1, Codamotion, Charnwood Dynamics Limited, Leicestershire, UK), respectively Thirty infrared markers were used, consisting of 14 individual markers on foot anatomical landmarks using Leardini protocol,[164] four rigid clusters of four markers were placed bilaterally on shank and thigh, and four markers were located on the anterior and posterior superior iliac spine.

5.2.3 Validity, Reliability and Feasibility of Procedures

Thirty-six participants were divided into two groups based on willingness to participate in the clinical and biomechanical examinations (Figure 1, left arm). Group one (eighteen participants) undertook the questionnaire clinical and ultrasound measures – with a subset of nine performing the biomechanical measures on two occasions (second aim). Group two (the remaining 18 participants) undertook the questionnaire battery both online and face-to-face in a randomised order (Figure 1, right side) to assess validity and reliability of online questionnaire (first aim).

5.2.3.1 Validity

Questionnaire Validity

To assess the validity of delivering the questionnaires online, the delivery was conducted online and face-to-face in a randomised order. Randomisation was conducted by an independent person who was not otherwise involved in the study, using an online true random-number service (www.random.org).

Clinical and Biomechanical Validity

Validity of the clinical and biomechanical measurements was assessed utilising known-group validity (I.e. ability to detect differences between the three groups). This approach was considered to allow selection of useful measures for the proposed cohort study.

5.2.3.2 Reliability

Survey reliability was evaluated by testing the consistency of measures regardless of administration type. Biomechanical measures were compared between the two testing sessions for consistency. Re-tests were implemented between 2-7 days.

5.2.3.3 Feasibility

Feasibility was assessed by completion time and feedback from participants/assessor.

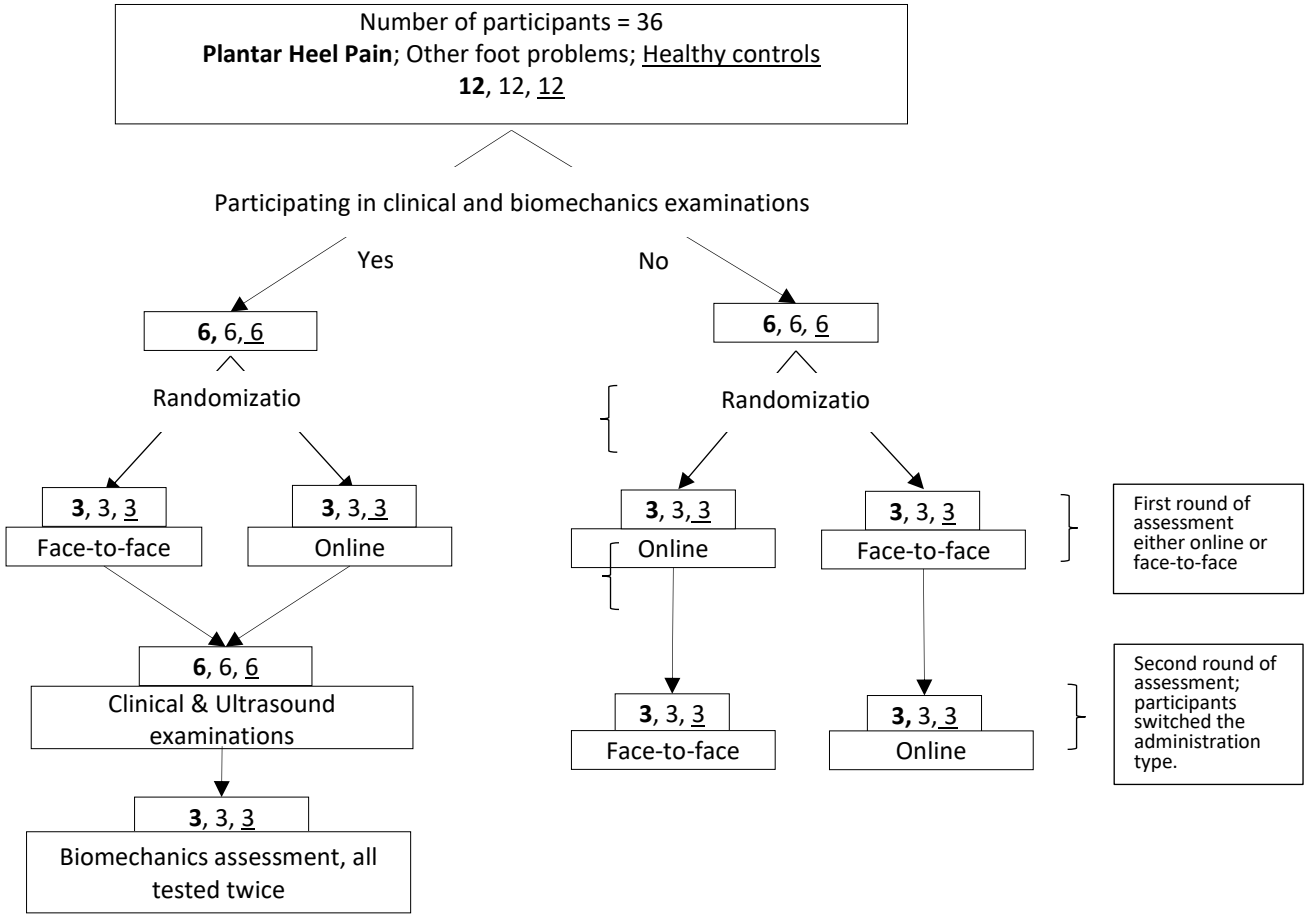

Figure 16. **Feasibility study design with randomization. Thirty-six participants were divided into two groups based on willingness to participate in the clinical and biomechanical examinations. In the first group, eighteen participants undertook all assessments, which are questionnaire, clinical and biomechanical assessments. In the second group, the remaining 18 participants undertook the only questionnaire either online or face-to-face in the first round. Second round of assessment; participants switched the administration type.**

5.2.4 Calculation of Sample Size

The sample size was calculated separately for validity and reliability. Validity sample size was calculated using G*Power (version 3.1), based on the FAOS foot function subscale. According to previous studies showing mean scores of 57.8 ±24.4, 74.61±21.94, 96.1±12.4 for PwPHP, PwOP and C, respectively,[71],[165] a minimum of 18 participants was required for validity based on 90% power, and an α level of 0.05. Sample size calculation for reliability was based on ICC values. A method that explicitly incorporates a prespecified probability of achieving the prespecified width or lower limit of a confidence interval was utilized.[166] This resulted in 14 participants being required based on ICC limits of 0.6 and 0.9. A final sample size of 36 participants was determined, consisting of 18 for validity, reliability and for feasibility.[159]

5.2.5 Data analysis

A list of all the measures (battery of questionnaires, and clinical and biomechanical assessments) is shown in Table 1 (results section).

To allow for ease of comparison and presentation of findings across different PROMs, all scores were adjusted to a scale of 0-100 if necessary. Specifically, the GPAQ, FABQ and PCS scores were multiplied by a hundred, and then divided by the maximum score possible on the scale.

To assess reliability of the pain maps, participant-selected locations were marked with 1 if they matched, and 0 if they did not, with unselected locations also counted as matching; total percentage similarity was then used for reliability.

Biomechanical data was processed and analysed using custom-written scripts in MATLAB version R2018b (Mathworks, Natick, MA). Force plate data were low-pass filtered (Butterworth, 6th-order and cut-off frequency of 10 Hz). The peak vertical ground reaction force (vGRF) at loading response (first peak) and terminal stance (second peak) were selected based on previous research[108]. Kinematic marker data were low-pass filtered (Butterworth, 4th-order and cut-off frequency of 12 Hz). Medial longitudinal arch (MLA) and first metatarsophalangeal joint (MTPJ1) angles were analysed at 50% stance and toe off, respectively. Toe off was identified using

the markers on the MTPJ1, hallux and navicular bones, verified with vertical GRF. Both kinematic variables were calculated in sagittal plane [164].

5.2.6 Statistical analysis

For validity of online delivery, differences between online and face-to-face questionnaires were tested using Limits of agreement with Bland & Altman plots [167] and paired t-test, considering order effect. Cohen d statistic was used to show the magnitudes of differences between two modes. Cohen's d was interpreted as , 0.20 < d <= 0.50 indicated a ''small effect'', 0.50 < d <= 0.80 a ''medium effect'', and d > 0.80 a ''large effect''.[168] Mann-Whitney U test with Bonferroni correction were used to assess differences between groups for clinical and US examinations. Graded Loading Challenge values were analysed with Repeated Measures. Reliability was determined with Intraclass Correlation Coefficients (ICC, two-way random, absolute agreement), classified as <0.5, 0.5 to 0.75, 0.75 to 0.9, and >0.90 being poor, moderate, good, and excellent reliability, respectively.[169] Outliers were removed if they were not within three standard deviations ($\mu \pm 3\sigma$).(170) All data were analysed using Microsoft Excel Version 2013 (Microsoft, California, USA) and SPSS Version 24.0 (SPSS, Chicago, IL).

5.3 Results

5.3.1 Sample Characterisation

Recruitment continued until there were the required numbers for the study arms (figure 1). Forty-eight participants were eligible and consented to join the study, half beginning with the face-to-face questionnaire and half online. All face-to-face questionnaires were completed. Three did not complete the initial online questionnaire and 9 did not complete it in the second round giving 66 complete questionnaire battery responses out of 78, a completion rate of 94% (45 of 48) in round 1 and 80% of online questionnaires in round 2 (36 of 45). The data for the 36 people (19 females & 17 males) who completed both rounds were analysed with equal numbers in each of the three groups: people with PHP (PwPHP), other foot pain (PwOP) and healthy (H) controls. Participants both groups had similar sample characteristics (table 1 and table 2).

Table 16. **Sample characteristics**

Demographics	Plantar Heel Pain (n=12)	Other Foot Problems (n=12)	Healthy Controls (n=12)
Gender (female:male)	6:6	6:6	7:5
Age, years (mean ± SD)	41 ± 16*	38 ± 13	28 ± 2.7
BMI, kg/m^2 (mean ± SD)	27 ± 5.2$*$	24 ± 3.9	23 ± 3.1
Morning Pain Severity, VAS (mean ± SD)	43 ± 20	54± 14	NA
Morning Pain Duration, mins. (mean ± SD)	24 ± 18	25± 19	NA
FAOS (mean ± SD)	55± 28$^{\$*}$	80± 17	99± 1
Occupation, (n, (%))			
Blue-collar	0 (0%)	0 (0%)	2 (17%)
White collar	10 (83%)	9 (75%)	6 (50%)
Unemployment & students	2 (17%)	3 (25%)	4 (33%)
Exercising regularly, (yes:no)	(9:3)	(9:3)	(7:5)

*P-values for differences in means between groups calculated using Kruskal Wallis. *p < 0.05 compared to healthy controls, $p < 0.05 compared to other foot problems. Key = n: number of participants; kg= kilogram; m= metre; BMI: Body Mass Index; mins. =minutes; VAS= Visual analogue scale; FAOS: Foot and Ankle Outcome Score).*

5.3.2 Validity

5.3.2.1 Online survey

Mean values for all PROMs between online and face-to-face did not differ significantly, (all p-values ranged from 0.07 to 0.79; Table 2, Figure 2, Figure 3). There were no systematic differences between face-to-face and online methods in terms of administration modes and order (Figure 3 and Table 2).

5.3.2.2 Clinical examination & ultrasound assessment validity

Clinical assessment showed PwPHP have less active ankle dorsiflexion ROM and hip internal rotation compared to healthy controls (Table 2). In terms of ultrasound findings, both plantar fascia thickness insertion from calcaneus (p-value: 0.02) and 0.5 cm away from calcaneal insertion (p-value: 0.03) were significantly higher in PwPHP compare to others.

5.3.2.3 Biomechanical validity

Biomechanical assessment demonstrated the GLC shows increases in maximum (p-value < 0.01) and second peak (p-value < 0.01) of GRFs with no progressive change in kinematics. (Figure 4 & Table 2).

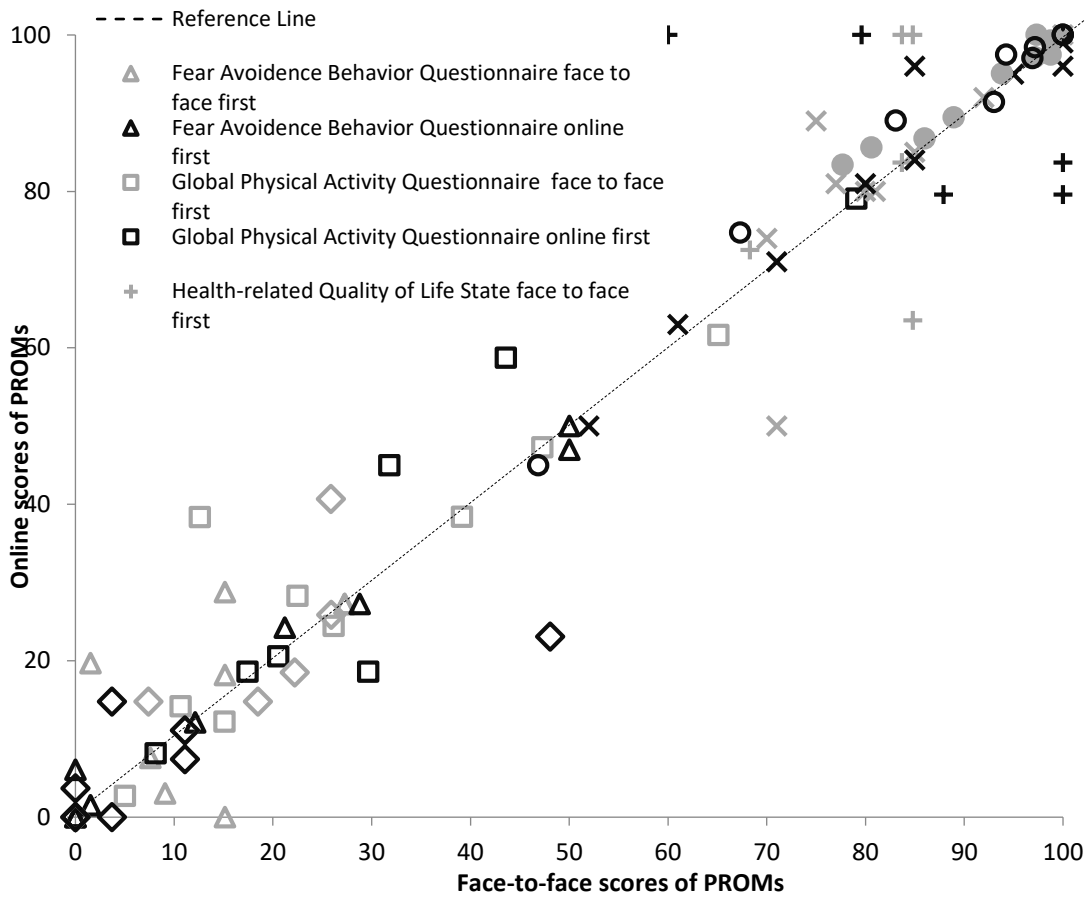

Figure 17. Systematic differences between face to face and online administrations. Two methods of data collections as face to face and online with a systematic difference from Table 1. All values are normalized with in a 100-total score. Broken dash line represent line of identity. Key= FAOS: The Foot and Ankle Outcome Score; PCS: Pain Catastrophizing Scale; FABQ: Fear-Avoidance Belief Questionnaire; GPAQ: Global Physical Activity Questionnaire; EQ-5D-5L: Health-related Quality of Life.

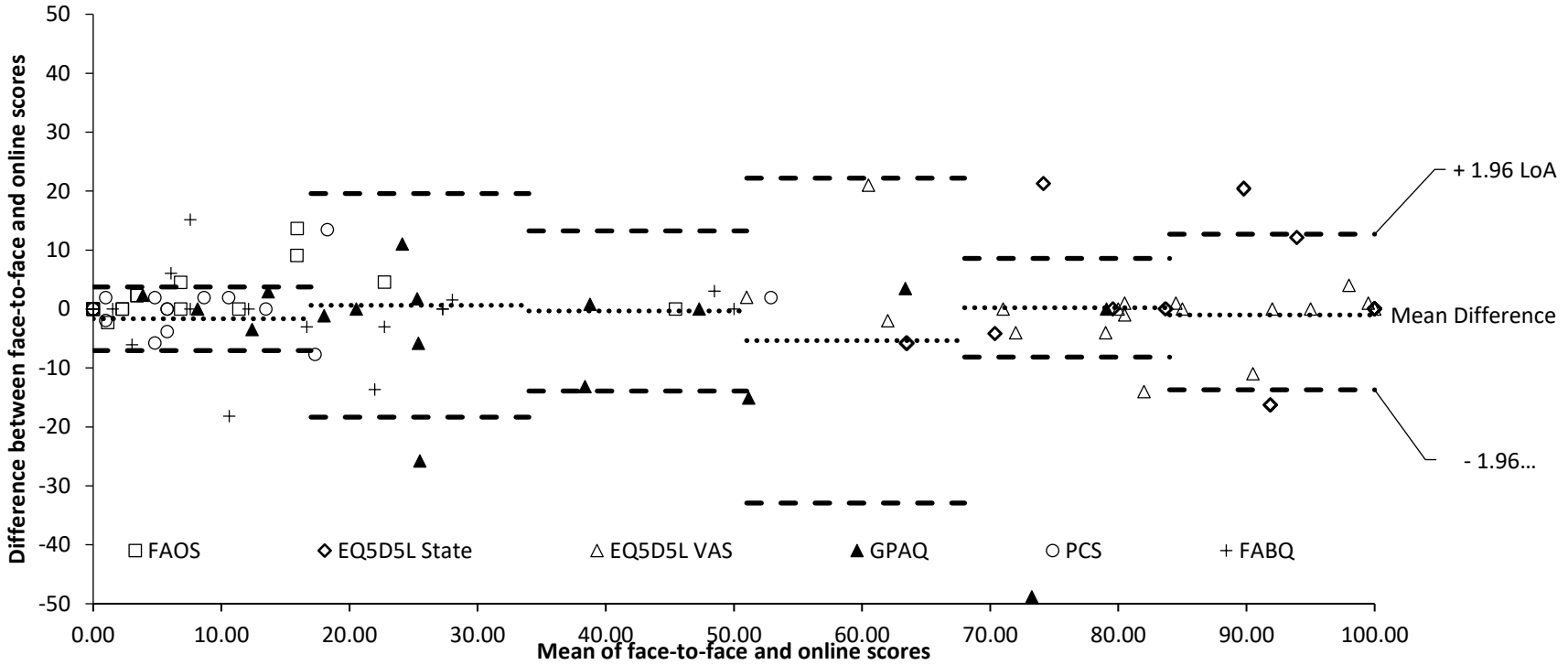

Figure 18. Bland–Altman plot of the relation between face to face and online scores of 5 PROMs and 2 subscales. The combined plots is based on the data presented in table 1. Dashed lines present 95% limits of agreement, where upper limits of agreement (LOA) is +1.96 SD and lower LOA is -1.96 SD from mean difference of methods. Here, the mean differences are between -5.3 and 0.6, whereas the highest limits of agreement are –32.9 and 22.2 out of 100 total score of GPAQ, indicating that 95% of the differences between these two measurements are within this range. Key= FAOS: The Foot and Ankle Outcome Score; PCS: Pain Catastrophizing Scale; FABQ: Fear-Avoidance Belief Questionnaire; GPAQ: Global Physical Activity Questionnaire; EQ-5D-5L: Health-related Quality of Life.

5.3.3 Reliability

5.3.3.1 Online survey

Questionnaire reliability was good to excellent (ICC 0.86-0.99) except for two subscales. The quality of life subscale (QoL) of Foot & Ankle Survey (FAOS) had an ICC of 0.73 [-0.21-0.91] and Fear Avoidance Behaviour Questionnaire (FABQ) work subscale had an ICC of 0.39 [-0.03-0.77] (Table 2 and Figure 3). Pain maps were 98% matched between first and second assessments, with eight PwPHP clearly indicating the usual inferior-medial area as painful. Pain map analysis showed the central dorsal rear-foot was the most common painful area with 25% among of all points on the plantar aspect of the foot. Additionally, 66% of participants with PHP identified the medial dorsal rear and mid-foot as a region to which pain spread.

5.3.3.2 Biomechanical reliability

Biomechanical assessment reliability was typically moderate to excellent (ICC 0.60-0.92) except for the MLA within the walking-with-weight task (Table 2).

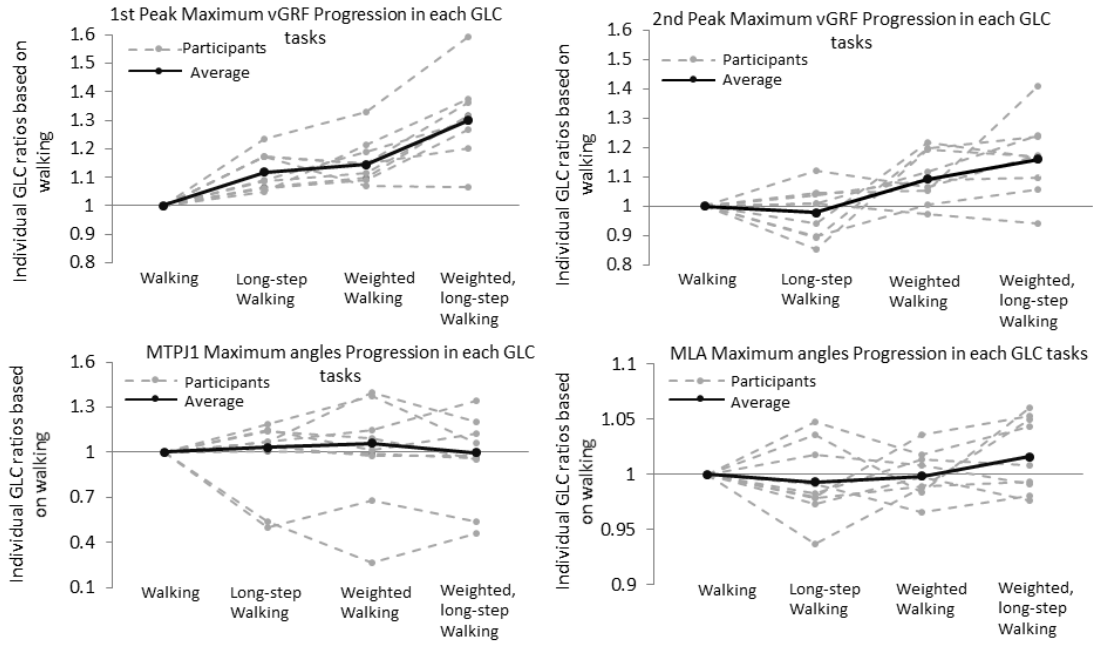

Figure 19. Individual ratio values of 9 participants for biomechanics measures progression in order of GLC tasks— the values in each tasks are divided results of walking by assuming walking values as baseline. Dashed grey lines are presented individual ratios of each participants; Thick black line is the ratio of mean values; Horizontal grey line at 1 is showing reference line. Key=vGRF: vertical Ground Reaction Forces; MLA: Medial Longitudinal Arch Angle; 1MTPJ: First metatarsal phalangeal joint; GLC: Graded Loading Challenge.

5.3.4 Feasibility

5.3.4.1 Online survey

Completion rate was 73% and completion time was 26±14 minutes. Participants reported the survey to be too long and have some repetition, particularly questions about psychosocial factors. It has been recognized that some terminological words such as "Plantar Heel Pain" need to be well-defined for participant understanding. Moreover, some participants had technical difficulties with the online survey system and were reluctant to share some personal details such as date of birth. Participant feedback details is presented in the supplement

5.3.4.2 Clinical examination & US assessment

Clinical assessment took average of 1 hour and 25 minutes. The measures have been streamlined by further practice to improve efficiency.

5.3.4.3 Biomechanics

The kinetic and kinematic motion capture system was found to be a feasible method for measuring of the foot and ankle during walking. No subjects reported any discomfort or undesirable effects associated with the use of the sensors.

Table 17. Values for all measures are reported with validity, reliability and feasibility outcomes

MEASUREMENTS	DOMAIN	PURPOSE	RESULTS	OUTCOMES
Patient Reported Outcome Measures (n = 36)				
Pain Catastrophizing Scale (PCS)	Psychosocial factors	V R F	LoA=0.2±8.5; d=0.01; p=0.83 Excellent (ICC = 0.97) Patients reported psychosocial questions duplication	Online use valid Reliable measure Redesign order
Global Physical Activity Questionnaire (GPAQ)	Activity level	V R F	LoA= -5.3±22.2 d=-0.22; p=0.51 Good (ICC = 0.81) Designed logic between relevant question to avoid time wasting and make GPAQ appropriate for online use	Online use valid Reliable measure Time burden Reduction needed
Fear-Avoidance Belief Questionnaire subscale (FABQ)	Psychosocial factors	V R V R F	*PA:* LoA= 1.6±15.9; d=-0.06; p=0.55 *PA* Excellent (ICC = 0.92) *W:* LoA= -0.5 ±8.5; d=0.25; p=0.77 *W:* Poor (ICC=0.39) Patients reported psychosocial questions duplication	Online use valid Reliable measure Online use valid Poor reliability Redesign order
Health-related Quality of Life (EQ5D-5L)	Quality of Life	V RV R F	*VAS:* LoA= -0.3±13.6; d=-0.26; p=0.07 *VAS:* Excellent (ICC = 0.94) *State:* LoA = -1.1±8.5; 0.16; p=0.55 *State:* Moderate (ICC = 0.64) Easy to report & understandable	Online use valid Reliable measure Online use valid Moderate reliability Easy to use

Table 17. Values for all measures are reported with validity, reliability and feasibility outcomes (continued)

Foot and Ankle Outcome Score (FAOS)	Physical factors	V R F F	LoA= 1.3±10 - 2.5 ±18.2; d=0.11-0.16 p=0.49-.08 Excellent to moderate (ICC = 0.99-0.73) Patient answers inconsistent for last subscale. Patients reported many questions in physical factors	Online use valid Reliable measure Redesign look Reduce repetition
Key miscellaneous questions	Morning pain duration (mins) Morning pain severity (VAS)	V R V R F	LoA= 2.2 ±18.7; d=0.10; p: 0.34 Excellent (ICC = 0.94) LoA= -2.1 ±19.0; d=-0.10; p: 0.33 Excellent (ICC = 0.94) Both measures easy to report & understandable	Overall: Online use valid, reliable measures that are feasible.
Pain map	Foot pain map	V R F	Pain-spreading region with 66% agreement. %98 matched; the medial aspect of RF clumsy system	Valid Use Reliable measure Navigate Pain
Clinic Examination (N = 18)				
Foot mobility	Navicular drift Navicular drops MLA angle	V F V F V F	PHP=6±3; OP=8±1; H=7±3 mm; difficult to control medial movement PHP=10±4; OP=9±4; H=12±9 mm; Difficult to determine the change PHP=160°±7; OP=156°±11; H=155°±5 difficult to position and maintain set-up	Overall: a new measurement procedure is required.
Range of motion	Hip IR Ankle active DF 1MTPJ DF	V F V F V F	PHP=†43°±4; OP=45°±9; H=57°±12 Difficult to estimate centre of rotation PHP=27°±6; OP=25°±3; H=27°±3 Difficult to estimate true vertical and horizontal positions PHP=36°±4; OP=38°±10; H=37°±7 The test was affected by instrumentation,	Overall: valid measure but binary outcomes needed and amended procedure.
Strength (oxford scale)	H. ER Ankle PF Inversion Intrinsic muscle	V F V F V F V F	PHP=4.7±4; OP=4.8±4; H=5 Difficulty to detect difference between grades PHP=4.9±2; OP=4.9±2; H=5 assesses muscles when contracting concentrically PHP=†3.5±5; OP=5; H=5 No difficulty is detected PHP=4,8±4; OP=5; H=4.8±6 Difficulty to control participation of other muscle groups	Overall: valid measure but binary outcome needed and more practical test.
Modified knee to wall	ADROM before NP DFROM in full	V V F	PHP=20°±8; OP=21°±9; H=21°±7 PHP=†14°±6; OP=18°±8; H=28°±10 Navicular drop not clear	Overall: sensible values but test needs modified
Ultrasound Assessment (N = 18)				
Thickness measures	PF origin Mid PF Heel pad	V V V F	PHP=†‡3.7±0.4; OP=2.6±0.8; H=2.9±0.4 mm. PHP=†‡3.7±0.4; OP=2.6±0.7; H=2.8±0.4 mm. PHP=8.4±0.2; OP=7.8±0.2; H=9.3±1.9 mm. Difficult to control pressure	Overall: sensible values but practice needed.
Biomechanical Assessment (N=9)				
Graded loading challenge (GLC)	First vGRF peak (N/BW)	V R F	NW= 7626±1565; LS= 8866 ± 1822; NWW= 9445 ± 1564; LSW= 10825±1320 Excellent (ICC = 0.92-0.95) Easy to measure & high-quality data	Overall: valid and reliable measure which is feasible to collect.
	Second vGRF Peak (N/BW)	V R F	NW= 7826± 1656; LS= 8598±1859; WW = 9569± 1541; LSW = 10919±1805 Good to excellent (ICC = 0.81 - 0.92) Easy to measure & high-quality data	Overall: valid and reliable measure which is feasible to collect.
	Rate of force development ($N.s^{-1}$)	V R F	NW=4741±1307; LS=5949±1671; WW =5235±1518; LSW =7356±1799 Excellent (ICC = 0.91-0.96) Easy to measure & high-quality data	Overall: valid and reliable measure which is feasible to collect.
	1.MTPJ DF on Toe off phase of gait cycle	V R F	NW=14°±6; LS=15°±7; WW =15°±8; LSW =14°±6 Moderate (ICC = 0.60-0.71) Time consuming	Sensible values Moderate reliability Discard measure.

Table 17. Values for all measures are reported with validity, reliability and feasibility outcomes (continued)

	MLA during midstance	V R F	NW=139°±15; LS=139°±15; WW=140°±13; LSW=143°±14 Poor to Good (ICC = 0.53-0.78) Time consuming	Sensible values. Moderate reliability Discard measure.

All measurements, their contents, purpose, relative results and outcomes are presented. Results of the clinical, biomechanical and miscellaneous questions are given in three groups to demonstrate differences as mean ±SD. Key: V=Validity, R=Reliability, F=Feasibility, SD=Standard deviation of mean values; n=Number of participants; LoA= Limits of Agreement (mean bias ± 1.96*SD); ICC= Intra-Class Correlation Coefficients; d= Cohen's d; BMI=Body Mass Index; N=Newton; BW=Body Weight min= minutes; VAS= visual analogue scale. ROM= Range of motion; H.ER= Hip external rotation ROM; DFROM= Dorsiflexion Range of Motion; A=Ankle; ND: Navicular Drop; 1MTPJ= First metatarsophalangeal joint; PF= Plantar Fascia; MLA=Medial Longitudinal arch angle; NW= Normal Walking; LS=Long-Step walking; WW=Walking with Weight. LSW=Long-Step walking with Weight.

†p < .05 compared to control: ‡ p < .05 compared to other foot pain.

5.4 Discussion

This was a comprehensive validity, reliability and feasibility study designed in order to optimise a large planned prospective cohort study. Importantly, some of the questionnaires had not previously been tested for remote use, but we found the online approach was valid and suitable. A novel grade loading challenge test progressively increased kinetic load and may represent a potentially useful assessment tool for plantar heel pain severity. The validity of clinical, ultrasound and biomechanical measures was confirmed. Reliability of measures was also typically good or excellent. Overall, the measures included in this feasibility study, and the protocols developed, are feasible for the planned cohort study. Key lessons included improving explanation of technical words but otherwise feasibility was acceptable.

5.4.1 Interpretation of outcomes

5.4.1.1 Validity

Patient-reported outcome measures (PROMs) are becoming more commonly applied[171] for research health care evaluation purposes, with technology enabling easier access to more participants at lower cost. These advantages are central to maximising cohort study recruitment, but different administration modes require validation compared to the original.[172] In a recent meta-analysis concerning PROMs equivalence between computer and paper versions, the average correlation of 278 PROMs was excellent[173] similar to responses to a comparison across 16 health-related measures.[174] None of the current foot and ankle or more generic PROMS had been previously evaluated,[173] but the demonstrated limits of agreement[175] identified no systematic bias and compared well to previously reported questionnaire properties.[176] For example, our FAOS results (LoA = 9.13) compared

favourably with published minimally important subscale differences ranging from 5.8 to 11.1,[177] giving confidence about online use. The consistent agreement between methods means that researchers and clinicians can be confident using these methods with similar populations although they may need to consider the particular population of interest and their e-Health literacy level in study or evaluation design.[178]

Clinical validity was important to consider, despite established procedures being used that have face validity.[13, 107, 179, 180] We assessed whether between-group differences were of similar direction and magnitude to published work, accepting that we had powered the study primarily to assess questionnaire measure validity and the clinical aspects were relatively underpowered meaning differences, or their absence, would have to be interpreted with caution. As expected, PwPHP have less ankle dorsiflexion ROM and hip internal rotation compared to healthy controls (Table 1) which compares favourably with published data [181]. However, our measured differences in first metatarsophalangeal joint movement (36±4° versus 37±7°) were of the same direction but smaller than reported values (46.2±7.3◦ versus 68.5±13.0◦)[181] between PwPHP and control group. Similar to Wearing et al., our plantar fascia thickness measures agreed well. Control group insertion and 0.5 cm away from calcaneal insertion were higher in PwPHP.[182] Overall, the clinical comparison of PwPHP and controls shows expected directions and magnitudes of differences supporting deployment of this protocol.

Considering that mechanical overload is thought to be a causal reason for PHP, and instrumented gait analysis the gold standard , we attempted to construct a graded loading challenge based on previous work to progressively challenge the load-bearing capacity of the plantar fascia by manipulating stride length and carried load.[183] If compressive or tensile load are aggravating factors for PHP, our results suggest the graded loaded challenge tasks may be a useful indicator of severity, particularly as the kinetic values show a graduated increase with task (Figure 4).

5.4.1.2 Reliability

The ICC calculated for the overall risk factor scores such as pain duration and severity were excellent (ICC 0.92-0.94), which again suggests equivalence.[147] Previously

validated questionnaire reliability was typically good to excellent (ICC 0.86-0.99), except one subscale of the FABQ (work) and FAOS (QoL). However, FAOS comparisons have previously shown remote use suitability.[184] This may indicate that our online questionnaire order, design and burden led to problems and requires further consideration. Finally, the biomechanical measures were repeated and demonstrated similar (Table 2) reliability to published work for kinetics.[185] Kinematic re-test reliability was not as comparable necessitating particular care with marker placement.

5.4.2 Limitations

The questionnaire design was kept as close to original as possible. However, some wording and layout had to be changed for the online mode; these 'faithful migrations' (173) are acceptable but required the comprehensive testing detailed here. The Patient specific function scale (PSFS) had to be removed as the technology does not yet allow the responses from one questionnaire to be carried forward to follow-ups.(186) An open-ended question will be utilized instead of PSFS in the cohort study. We did not collect data on previous treatment in the feasibility study but have added this for the cohort study. This feasibility study did not implement or evaluate the follow-up process.

Finally, it is important to acknowledge that we only focussed on validation of online administration type of patients reported outcome measures in the feasibility study. Validation of both eCRF platforms (Survey Monkey and SmartTrial) were not the main issue because these platforms were already validated in previous studies. For Smart Trial as noted in SMART-TRIALs quality assurance is based on and in compliance with the PIC/S Guidance, PI-011-3 Good Practices for Computerized Systems in Regulated "GxP" Environments, and the software validation process is based on IEC 62304. SMART-TRIAL simplifies regulatory compliance for ISO 14155 (GCP), FDA 21 CFR Part 11, GDPR, and HIPAA by offering ready-to-use QA templates, system modules, and guidance documents. Hence, SMART-TRIAL is a documented software system and has been validated and verified for every publicly available release, which means SMART-TRIAL clients do not have to perform any validation on the software.

5.4.3 Feasibility lessons

In order to optimise questionnaire design, maximise data security, facilitate automated follow-up and enable eligibility screening we redesigned the survey to work on a different platform (SmartTrial 15005-ST-0021, MEDEI ApS, Aalborg, Denmark) and pain mapping was moved to a high-resolution and detailed digital-body chart using the NavigatePain application Version 1 (Aalborg University, Aalborg, Denmark). In doing so, the repetition from the original survey was removed, without compromising questionnaire validity, and the process streamlined to reduce time and inconvenience. The streamlining included the addition of logic functions that enabled respondents to skip to a future question or page in the survey based on their answer to a previous close-ended question. Additionally, in the new versions participants will be able to resume and complete a survey having taken a break. Participants who are struggling with the initial questionnaires will also be offered support with completion if required. A decision to add health literacy assessment was taken in order to ensure population characteristics and data credibility. The clinical, ultrasound and biomechanical examinations were streamlined to reduce contact time, and improve ease of collection.

5.5 Conclusion

Questionnaire administration by online methods is valid and reliable, therefore it could be ideal for remote monitoring of patients for clinical and research purposes, including our planned cohort study. A graded loading challenge designed to progressively increase kinetic load was shown to be a potentially useful assessment tool for plantar heel pain severity and worthy of further research. Hence, the questionnaire and graded loading challenge results in particular could be utilized by clinicians and researchers for a wide range of purposes. The cohort study is feasible.

CHAPTER 6 THE ASSOCIATION OF DEMOGRAPHIC, PSYCHOLOGICAL, SOCIAL AND ACTIVITY FACTORS WITH FOOT HEALTH IN PEOPLE WITH PLANTAR HEEL PAIN: AN INTERNATIONAL CASE-CONTROL STUDY

The systematic review presented in chapter 3 identified that pain related variables such as longer pain duration, multiple painful area in lower extremity are associated with recovery of PHP. Hence, it may be that baseline severity is the main driver of compromised recovery. Furthermore, in the previous chapter (chapter 5), I concluded that the cohort study plan is feasible. Therefore, as a next step, I specifically focus on identifying associated factors for severity of PHP and how PwPHP present and differ from people with other foot problems. These explanatory models presented in this chapter were from the baseline data of the cohort study, which enables us to better understand the consecutive model for recovery of PHP.

Preliminary results from this study were presented at LASEM student showcase in Latrobe University at October 2020. This study was submitted for publication in BMC Musculoskeletal disorders Journal and currently was under-review (appendix).

6.1 Introduction

Plantar heel pain (PHP) is one of the common musculoskeletal pain conditions among adults. PHP accounts for approximately 11%–15% of all foot complaints requiring professional care in adults and for 8%–10% of all running-related injuries (13, 187). It is characterised by pain in the inferior-medial regions of rearfoot during weight-bearing that is usually exacerbated by prolonged periods of standing and walking (2). Hence, PHP has a detrimental impact on health-related quality of life due to limited daily life activities for people with PHP (PwPHP).

There are a variety of management strategies for PHP but none which give satisfactory results. According to a recent comprehensive systematic review, current

conservative management strategies include stretching, footwear modification, taping and patient education in first-line management with interventions such as shock wave therapy and orthoses increasingly available for those who fail to improve (4). To date, nearly all observational studies have been based on the physical impairments of the condition and extensively researched biomedical factors. Height, weight, BMI, age (37), decreased first MTPJ flexion (181), increased plantar fascia and heel pad thickness (188, 189), and decreased calf strength(190) have been found to be associated with PHP. However, improved outcomes are not always associated with biomedical factors. It seems unlikely that fifty percent of individuals would continue to have the same symptoms or 30% of people would have recurrence if the problem were purely biomedical (8). Multiple treatment options with unsatisfactory results may arise from the lack of tailoring management strategies with limited understanding of the full range of biopsychosocial factors associated with PHP.

Increasingly, psychosocial factors have been considered alongside physical factors in other musculoskeletal pain conditions (191-193). A systematic review of low back pain treatment showed that patients with associated psychosocial problems who receiving a psychosocial component in their rehabilitation were likely to experience less pain/disability than those receiving usual care (194). While there are several observational studies that have evaluated the biomedical factors (107, 195) and a few psychological variables (121, 134, 143) for PHP, there is no research that has specifically evaluated the wide range of plausible biopsychosocial factors that is required to inform more nuanced intervention development.

The overarching aim of this study was to improve understanding of PHP by constructing explanatory models from the baseline data of a large international cohort study of PwPHP which comprises a comprehensive range of self-reported biopsychosocial factors. The objectives were to better understand severity of compromised foot health in PwPHP and explore what combination of self-reported factors distinguish PwPHP from people with OP.

6.2 Materials and methods

The study procedures were ethically approved by QMERC ethics committee (approval No. QMREC2014/24/153), National Health Service (NHS) (approval No: 264615) and Hospitalo-Facultaire Universitaire de liege ethics committee (approval No: 2019/182) from France. Electronic informed consent was sought from each recruited participant prior to completion of the online questionnaire. The STROBE (**St**rengthening the **R**eporting of **Ob**servational Studies in **E**pidemiology) statement was followed as a guideline for the design and reporting of this case-control study.

6.2.1 Participants and Screening process

The sample included 235 people (PHP 136 (age 44±12 years, 65% ♀) and OFP 99 (age 38±11 years, 54% ♀) who were recruited via advertising in hospitals and physiotherapy clinics, posters in public areas, and social media outlets over a year in 2019/20.

The inclusion criteria were having a clinical diagnosis of PHP or another clinically diagnosed ankle or foot musculoskeletal condition within the last 6 months. A podiatrist with over 30 years' clinic experience (TP) and a clinician's (DC) team diagnosed 72 percent of both groups of conditions based on reported symptoms and clinical examination. Subjects with early morning and first step pain for more than one month, and pain on palpation of the plantar medial tubercle of the calcaneus were classified as people with PHP compared to other foot problems. The rest of the sample were recruited by GPs and physiotherapist from other clinics (10%), NHS (%13) and social media (5%). Additionally, six further questions were asked to confirm diagnosis of patients in the questionnaire battery. The questions were; (1) Please describe your main problem? ; (2) What was your diagnosis in right/left foot? ; (3) Who diagnosed your condition? ; (4) Which investigations did you have for your conditions? ; (5) How many visits have you made to the clinician for your problem? ; (6) How long have you had this condition? Participants who did not provide diagnosis details and medical history were excluded from the study (5 and 45 participants from PHP and OFP groups, respectively). People under 18 years of age were not eligible to attend the study. The eligibility and screening process is demonstrated in Figure 20 and the survey questions are presented in the appendix.

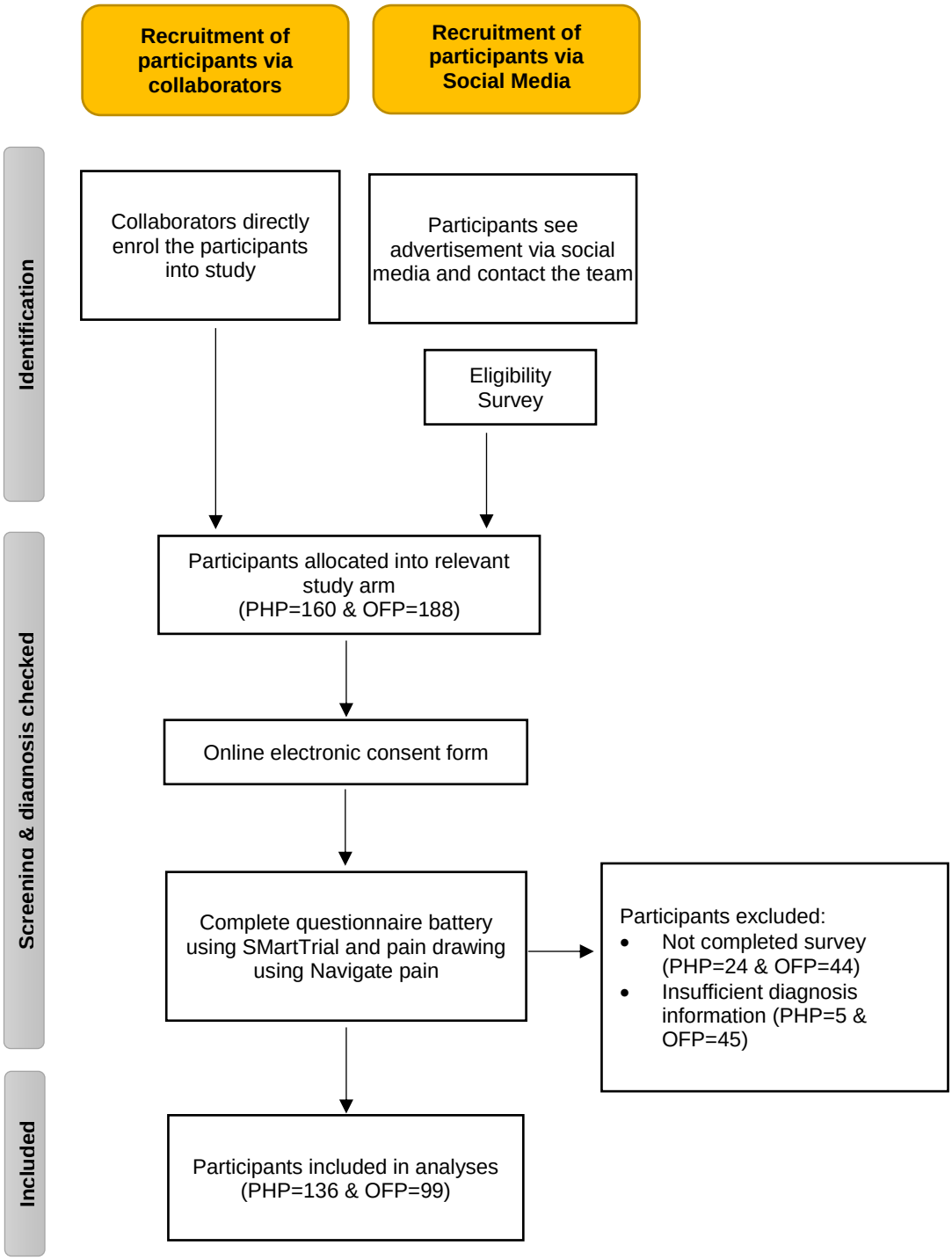

Figure 20. Participant screening and enrolment process

6.2.2 Measures

The online survey was constructed and administered using 'SmartTrial' https://www.smart-trial.com. Validity and reliability of this online questionnaire battery was determined with a previously published feasibility study (196) before implementation. Translation, cross-cultural adaptation and validation of self-

reported outcome measures in different languages were considered during design of the study. To assess the area and distribution of pain, participants completed pain drawings using the Navigate Pain app (version 1.0; Aalborg University, Denmark) (197, 198). All measures were completed by both groups.

6.2.2.1 Main patient reported outcome measure

Foot health was measured by the General Foot Health subscale of the Foot Health Status Questionnaire (FHSQ). There are 4 subscales and 13 questions in total: foot pain (4 questions), foot function (4 questions), footwear (3 questions), and general foot health (2 questions) (199). The total score ranges from 0 to 100 points, with 0 representing worst foot health and 100 best in each subscale (200). The FHSQ subscales have demonstrated high test-retest reliability and content, construct, and criterion validity (199).

6.2.2.2 Quality of life

The Euro quality of life (Euroqol) 5 dimension 5 level questionnaire (EQ-5D-5L), measures generic health status classification defining health in terms of five dimensions; mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The respondent's response can be converted into a single preference-based index anchored on a scale where -1 and 1 represent being dead and full health, respectively (158).

6.2.2.3 Biomedical Measures

A range of characteristics was recorded including medical history, duration of symptoms, side affected (left, right, or bilateral), and the duration/severity of pain beneath the heel over the previous week. A comorbidity was defined as any medical condition reported by a participant for which she or he was taking medication in FHSQ.

6.2.2.4 Psychological Measures

The Pain Catastrophizing Scale (PCS) was used to measure pain-related catastrophizing (132). It has 13 items that yield an overall score and three subscale scores (rumination, magnification and helplessness), with higher total scores indicating more catastrophic behaviour (150). Reliability and validity of the PCS have

been established (201). The Fear-Avoidance Belief Questionnaire (FABQ) is designed to assess fear of avoidance beliefs on movement for use in patients with the musculoskeletal condition and chronic pain (153). Items are scored on a 7-point Likert scale, with higher values indicating greater fear of movement. The FABQ demonstrates high levels of internal consistency and test-retest reliability (154, 155), therefore being a useful screening tool for identifying patients at risk of a poor outcome (156). The Central Sensitization Inventory (CSI) is a 25-item questionnaire (two parts) developed to detect central sensitisation symptoms in clinical settings. The CSI has high levels of internal consistency and test-retest reliability (202). Finally, we assumed that participants' beliefs about future condition status can be associated with severity; hence, three questions were asked to understand participant predictions about condition progress, time to recover, and prediction confidence.

6.2.2.5 Social related Measures

The occupational category combined information on occupation and employment status to yield six separate classifications: white-collar professional, white-collar other, blue-collar, retired, homemakers and other (203). Classification of education status was based on information about the highest education level completed. From this standard, the following categories were created: did not attend, primary school, secondary school, and college/high school, bachelor, Master of Science and PhD. The eHealth Literacy Scale (eHEALS) evaluate use of digital sources on a 5-point Likert scale (1-strongly disagree, 5-strongly agree), and the total ranges from 8 to 40, with a higher score indicating higher literacy. Reliability and validity of the eHEALS have been confirmed (204).

6.2.2.6 Activity Related Measures

The Global Physical Activity Questionnaire (GPAQ) is comprised of 16 items that measure physical activity in work, transport, leisure activities, and time spent in inactivity and covers several components of physical activity (intensity, duration, and frequency). The GPAQ showed acceptable evidence of short- and long-term test-retest reliability by activity category and modest validity evidence (157). Hours Standing was measured with an arbitrary question that "How much time did you spend on your feet in a typical day?" Answers were recorded as minutes and hours.

Footwear comfort, fit, and the choice was assessed using the footwear domain of Foot Health Status Questionnaire (FHSQ) (FHSQ version 1.03). Specific questions relating to sports participation, running history, which included running miles run per week, frequency and training surface were also constructed.

6.2.3 Data Analysis

Height and weight measures were expressed as centimetres and kilograms and Body mass index (BMI) calculated. Categorical and ordinal data were electronically transcribed from SmartTrial and recoded for calculations in STATA (version 16.0, StataCorp LP, College Station, TX, USA). Comorbidity, education and ethnicity factors were combined to eliminate sparse categories by retaining a ratio of ≥10 participants per estimated model parameter. We treated categorical factors as continuous if linearity with outcome could be assumed after visual examination using scatter plots. Missing values were not imputed, and models were developed using only participants with complete data. Data cleaning was completed using Excel (Microsoft Excel 2016 MSO, (16.0.4266.1001)) and STATA.

To assess the area and distribution of pain, the total area drawn expressed as the total number of pixels was extracted for each pain map. The Navigate Pain system also provided average usual and current pain level for each drawing. Further, the total number of independent non-contiguous pain sites was manually recorded.

6.2.4 Statistical Analysis

Group data were reported as mean (SD) with a 95% confidence interval and frequency count as appropriate. All analyses were performed using STATA (version 16.0, StataCorp LP, College Station, TX, USA). All variables were explored for normality using the skewness and kurtosis statistic and inspection of histograms and de-trended Q-Q plots prior to statistical analysis. Continuous data were assessed with a parametric test of one-way ANOVA. Ordinal and categorical data were assessed with chi-square to compare prevalence between groups and differences described using effect size measures (205). Prior to multivariable linear and logistic regression, correlations between explanatory variables were evaluated to detect levels of association and avoid issues relating to multi-collinearity by calculating variance inflation factors (VIFs). The level of collinearity was considered problematic, and one

of the two independent variables was not included in the model, if the mean VIF was ≥5 and individual VIFs were ≥10 (206).

For objective 1, Multivariable linear regression was used to develop a model of PHP severity with the FHSQ general foot health subscale as the dependent variable. To facilitate variable selection, we used univariate analyses to assess crude associations with correlation coefficients (significance level was set P>0.01). A final model was developed hierarchically by manually entering significant variables from the univariate analysis and comparing models using the likelihood ratio test. For objective 2, comparison between groups, we first used univariate logistic regression to assess crude associations between variables and conditions (0= PwOP and 1= PwPHP). The same model building approach was uses as for objective one. Model fit was tested with Hosmer-Lemeshow. Accuracy, specificity and sensitivity of the model were also assessed.

6.3 Results

6.3.1 Sample Characteristics

All participants were deemed eligible (Figure 1) and completed pain, psychological, social and other contextual measures. There were 234 participants, including 135 PwPHP (age 44±12 years, 65% ♀, BMI 26±4, weekly activity levels (expressed in MET-minutes) of 5393±6557) and 99 PwOFP (age 38±11 years, 54% ♀, BMI 25±4, weekly activity levels of 5498±6983). Worst pain over the last week for the PHP and OP groups were 29±2 and 25±3, respectively. There was statistically significant difference regarding all psychological factors apart from depression. No between-group mean differences were found for activity related factors. All biopsychosocial variables were presented in Table 18.

Table 18. Population Characteristics and groups comparison between PwPHP and PwOFP.

Population Characteristics			
	PHP (n=135)	OFP (n=99)	
VARIABLES	Mean ± SD or n (%)	Mean ± SD or n (%)	Effect size
Quality of Life EQ5D5L-index, (0-1)	§0.67 ± 0.2	0.76 ± 0.1	0.41
Demographics			
Age, years	§44.1 ± 12.1	38.1 ± 11.5	-0.47
BMI, kg/m^2	§26.9 ± 4.4	25.1 ± 4.6	-0.38
Sex, (female: male)	88:47	53:37	0.11

Ethnicity (White: Asian: Other: PNTS)	99:26:4:7	112:14:6:10	0.14
Dominant Leg (right: left: not sure)	112:16:7	79:14:6	0.04
Biomedical			
General Foot Health, FHSQ, (0-100)	§35.1 ± 25	49.1 ± 24	0.57
Foot Pain, FHSQ, (0-100)	§49.9 ± 24	64.9 ± 22	0.62
Foot Function, FHSQ, (0-100)	§56.2 ± 30	74.3 ± 24	0.64
Morning Pain duration, mins.	29.4 ± 67	25.8 ± 64	-0.54
Morning Pain Severity, VAS	§58.4 ± 25	42.2 ± 23	-0.65
Disease duration			
0-6 months	37 (28%)	30 (32%)	
6-12 months	18 (13%)	16 (16%)	
1-2 years	29 (21%)	14 (14%)	0.18
2-3 years	17 (13%)	12 (12%)	
More than 3 years	34 (25%)	26 (26%)	
Onset of Pain (Sudden: Gradual: Other)	92:40:3	98:1:0	0.39
Co-morbidities			
MSK (Back pain, Osteoarthritis, **RA**)	15 (18%)	7 (7%)	
Systemic (Cholesterol. Diabetes, **HT, HD, LD**)	30 (35%)	9 (9%)	
Psychological disease (Depression, anxiety)	15 (17%)	11 (11%)	0.44
None	25 (29%)	72 (73%)	
Number of co-morbidities	§1.3 ± 0.7	1.1± 0.4	-0.37
Back pain presence, n (%)			
Yes (Current, recurrent)	67 (49%)	39 (39%)	
Yes (Previously)	38 (28%)	27 (27%)	0.13
No	30 (22%)	33 (34%)	
Back Pain spreading to;			
Thigh and knee, n (%)	17 (41%)	12 (50%)	
Shank, n (%)	6 (14%)	2 (8%)	0.10
Foot, n (%)	18 (43%)	10 (41%)	
Back pain association with leg pain, yes, n (%)	41 (39%)	24 (36%)	-0.03
First Symptoms noticed (Pain: Stiffness: swelling: other)	124:7:3:1	84:8:4:3	0.12
Pain in walking (worse: better: no change)	76:48:11	35:43:21	0.23
Pain in standing (worse: better: no change)	102:7:26	49:10:40	0.26
Pain in sitting (worse: better: no change)	40:64:31	15:54:30	0.17
Having previous injury (yes: no)	43:92	42:57	0.10
Investigation types (Ultrasound: Physical examination: MRI: xRAY: Blood tests: other)	37:52:12:15:3:16	23:28:6:8:30:3	0.42
Number of investigations	5.9 ± 5.3	4.6± 6.3	-0.25
Number of visits to health professional	§1.3 ± 0.7	1.1± 0.4	-0.22
Sleeping Duration, hours	6.9 ± 1.1	7.2± 1.0	0.26
Sleeping Difficulties (yes : no)	77:58	23:76	0.20
Reason Sleep Difficulties (Foot pain: Other pain: Depression: Anxiety: Other)	33:14:27:2:1	6:2:2:7:6	0.65
Feeling Rested (Yes: Partially: No)	33:75:27	35:52:12	0.13
Smoking			
Yes (Active, social smokers)	25(18%)	17 (17%)	
No (Passive, ex-smokers)	46(34%)	25 (25%)	0.10
Never Smoked	64(47%)	57 (56%)	
Family History (Tendon disorders: Psoriasis: Connective tissue disease: Ankylosing spondylitis: Rheumatoid arthritis: None : other)	88:11:3:13:2:7:11	7:8:2:3:7:68:4	0.75

Table 18. Population Characteristics and groups comparison between PwPHP and PwOFP (continued)

Psychological			
Catastrophization, PCS (0-52)	§15.0 ± 12.3	9.6 ± 9.6	-0.48
Sensitization, CSI, (0-100)	§32.2 ± 17	26.4 ± 14.5	-0.35
Fear avoidance- work, FABQ	§10.5 ± 9.7	7.1 ± 8.5	-0.47
Fear avoidance- PA, FABQ	§14.2 ± 5.6	11.5 ± 5.5	-0.37
Depression diagnosis, (yes : no)	11:124	5:95	0.06
Condition Prediction (Get better: get worse: no change: don't know)	64:21:11:39	53:16:11:19	0.11

Condition confidence, (out of 100)	77.2 ± 20.0	84.4± 0.5	0.33
Time Prediction, months	73.1 ± 5.3	76.4± 6.3	0.13
Social			
Educational Level, n (%)			
Elementary school	16 (12%)	4 (4%)	
High school	26 (19%)	15 (15%)	
Bachelor	62 (46%)	50 (50%)	0.22
Master's degree	20 (15%)	26 (26%)	
PhD	11 (8%)	4 (4%)	
Occupation n (%)			
Blue-collar	16 (12%)	7 (7%)	
White collar	55 (40%)	61 (62%)	
Professionals & Athlete	22 (16%)	15 (15%)	0.34
Unemployment & students	20 (15%)	12 (12%)	
Homemakers & retired	22(16%)	4 (4%)	
Health Literacy, eHEALS	28 ± 6	28 ± 6	0.16
Activity			
Activity Level, GPAQ	5363 ± 6187	5498 ± 6983	0.12
Hours Standing	6.5 ± 3	6.1 ± 3	-0.01
Sports Participation, yes n (%)	57(42%)	64(64%)	-0.22
Type of sports (Running: Yoga : Rugby: Football: Basketball: Climbing: others)	21:19:5:4:1:7	1:28:6:3:2:24	0.54
Number of Sports Participated in	0.64 ± 0.8	1.46 ± 0.7	1.00
Sports age, years	14.3 ± 14.2	13.2 ± 10.3	-.08
Footwear, FHSQ footwear	§*51.9 ± 25	43.1 ± 26	-0.34
Running Distance	18.1 ± 13.1	21.3 ± 15.0	0.22
Pain map (PHP:57, OP:46 – n=103 in total)			
Total area drawn (pixel number)	3870	4108	0.11
Current pain level (out of 10)	5.30	4.62	-0.34
Usual pain level (out of 10)	5.12	4.42	-0.13
Total number of painful sites	3.5	3.2	

All measurements, their contents, relative results and outcomes are presented at columns. Results are given in two groups to demonstrate differences as mean ±SD or total number with percentage in the group. Effect size measured with Cohen's d. Key: SD=Standard deviation of mean values; n=Number of participants; PHP: Plantar heel pain; OFP=other foot problems BMI=Body Mass Index; PNTS= Prefer not to say; min= minutes; VAS= visual analogue scale; EQ5D5L= The Euro quality of life (Euroqol) five dimension five level; MSK= Musculoskeletal; RA= Rheumatoid arthritis; HT= Hypertension; HD= Heart diseases ; LD= Lung disease; GPAQ= Global Physical activity questionnaire; FHSQ= Foot Health Status Questionnaire; PCS: Pain Catastrophization Scale; CSI: Central Sensitization Inventory; FABQ: Fear avoidance behavior; Global Physical Activity Questionnaire; § p < .05 compared to other foot pain.

Table 19. Correlation matrix between independent variables

Correlations between explanatory factors													
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Age	–												
(2) BMI	0.1055	–											
(3) Catastrophization	0.0488	0.0916	–										
(4) Sensitization	0.0716	0.1951	0.4934	–									
(5) Fear avoidance-work	-0.0039	0.0615	0.4200	0.2972	–								

(6) Fear avoidance-PA	0.0591	0.0886	0.4965	0.2944	0.1429	–						
(7) EQ5D5L-index	-0.0982	-0.1543	-0.5579	-0.5028	-0.2892	-0.2740	–					
(8) Pain Duration	0.0184	-0.0648	0.1741	0.1009	0.1190	0.0717	-0.1298	–				
(9) Pain Severity	0.0233	0.2242	0.3965	0.1507	0.2220	0.1129	-0.2995	0.1147	–			
(10) Num. of Comorbidity	0.1584	-0.0261	0.3201	0.4047	0.0914	0.1556	-0.3091	0.0703	0.1362	–		
(11) Hours Standing	-0.0405	-0.0446	-0.0291	0.0326	0.0948	-0.0382	0.0891	-0.0447	0.0449	0.0295	–	
(12) Activity Level	-0.1687	-0.2437	0.0620	-0.0406	0.2050	0.0884	0.0074	0.1742	0.1737	-0.0329	0.3401	–
(13) Health literacy	-0.1182	0.0022	-0.0133	-0.0179	-0.0429	-0.1061	0.0461	0.0665	-0.0988	-0.0003	-0.0783	0.0947
(14) Footwear	-0.0597	0.1192	0.0592	0.1968	0.0638	0.0615	-0.1726	-0.0389	0.0633	0.0865	0.0765	0.0113

Table 20. Univariate analyses results for linear regression (n=135, PwPHP)

Potential Predictors	R^2	Beta-coefficient		P > I t I
Quality of Life	**0.15 15**	**0.38**		**<0.000***
Demographics				
Age	0.01	-.12		0.15
BMI	0.01	-.11		0.17
Sex (ref: male)	**0.03**	**-.20**		**0.01**
Ethnicity (ref others and PNTS)	0.008			
White		.09		0.31
Asian		-.01		0.89
Biomedical				
Morning Pain duration, mins.	**0.02**	**-.16**		**0.05**
Morning Pain Severity, VAS	**0.09**	**-.30**	**0.06**	**<0.000***
Disease duration	**0.04**	**-.20**	**1.01**	**0.01**
Onset of Pain (Sudden: Gradual: Other)	0.008	.09	4.69	0.27
Comorbidity (ref: none)	**0.07**			
Musculoskeletal d.		**-.25**	**6.65**	**0.005**
Systemic d.		.04	5.39	0.64
Psychological d.		-.10	5.70	0.24
Number of Comorbidity	0.003	-.06	2.81	0.47
Back pain presence, (ref: no)	**0.06**			
Yes (Current, recurrent)		**-.31**	**5.45**	**0.004**
Yes (Previously)		**-.20**	**6.06**	**0.05**
Pain in walking (ref: no change)	0.004			
Worse		-.11	8.24	0.48
Better		-.06	8.54	0.66
Pain in standing (ref: no change)	0.01			
Worse		-.06	5.59	0.52
Better		.06	10.84	0.47
Pain in sitting (ref: no change)	0.03			
Worse		**-.23**	**6.08**	**0.03**
Better		-.07	5.49	0.48
Number of investigations	0.01	-.12	2.21	0.16
Number of visit to health professional	**0.02**	**-.14**	**0.40**	**0.09**
Sleeping Duration	0.01	.11	1.97	0.17

Table 20. Univariate analyses results for linear regression (n=135, PwPHP) (continued)

Sleeping Difficulties, (yes)	**0.01**	**-.10**	**4.41**	**0.21**
Reason Sleep Difficulties (Ref: Foot pain)	0.01			
Any other Pain		-.05	5.38	0.59
Depression and anxiety		-.13	6.41	0.21
Feeling Rested (Ref: Yes)	0.01			
Partially		-.04	5.30	0.69

No		-.14	6.59	0.16
Smoking (ref: never smoked)	0.01			
Yes (Active, social smokers)		-.10	5.99	0.24
No (Passive, ex-smokers)		.03	4.91	0.72
Family History (Ref : None)	0.01			
Tendon disorders		-.01	7.16	0.92
Psoriasis & Connective tissue disease		-.06	9.53	0.55
Ankylosing spondylitis & RA		-.06	9.36	0.58
Other		.06	16.22	0.46
Psychological				
PCS	**0.09**	**-.31**	**0.16**	**<0.001***
CSI	**0.10**	**-.31**	**0.12**	**<0.001***
FABQ-W	**0.03**	**-.18**	**0.22**	**0.03**
FABQ-PA	0.01	-.11	0.39	0.19
Depression				
Condition Prediction (ref: don't know)	0.05			
Get better		.11	5.08	0.26
No change		.01	6.77	0.91
Get worse		**-.17**	**8.54**	**0.06**
SOCIAL				
Education (ref: PhD and Msc)	0.07			
Bachelor		.09	5.43	0.37
High school		.03	6.57	0.76
Elementary school		**-.22**	**7.60**	**0.02**
Occupation (ref: Unemployment, students, homemakers , retired)	0.02			**0.01***
Blue-collar		.10	**7.60**	0.26
White collar & Professionals		.16	**5.05**	**0.09**
eHealth	0.001	-.08	0.31	0.35
ACTIVITY				
GPAQ	0.002	-.04	0.01	0.61
Hours Standing	0.002	-.04	0.59	0.58
Footwear	**0.02**	**-.15**	**0.08**	**0.07***
Sport Participation	**0.03**	**.19**	**4.36**	**0.02***
Pain map (PHP:57, OP:46 – n=103 in total)				
Total area drawn, (pixel)				
Current pain level, (out of 10)				
Usual pain level, (out of 10)				
Total number of painful site (n)				

Table 21. Univariate analyses for logistic regression

Potential Predictors	**Odds ratio**	Std. Error	**Confidence int.**	P > I t I
Increased Quality of Life	**1.02 15**	**0.007**	**1.00 – 1.03**	**0.004**
Demographics				
Age	**1.03**	**.01**	**1.01 – 1.06**	**0.001**
BMI	**1.09**	**.03**	**1.02 – 1.16**	**0.005**
Sex (ref: male)	**1.62**	**.43**	**.95 – 2.76**	**0.07**

Ethnicity (ref: others and PNTS)	0.008			
White	**2.11**	**.91**	**.90 – 4.93**	**0.08**
Asian	1.64	.52	.87 – 3.06	0.11
Biomedical				
Morning Pain duration, mins.	1.00	.002	0.99 – 1.00	0.31
Morning Pain Severity, VAS	**1.02**	**.004**	**1.01 – 1.03**	**<0.001**
Disease duration	1.05	.006	0.94 – 1.18	0.33
Comorbidity (ref: none)	0.07			
Musculoskeletal d.		-.25	6.65	0.005
Systemic d.		.04	5.39	0.64
Number of Comorbidity	**2.02**	**.54**	**1.20 – 3.43**	**0.008**
Back pain presence, (ref: no)				
Yes (Current, recurrent)	1.54	.55	0.76 – 3.11	0.22
Yes (Previously)	**1.88**	**.61**	**1.00 – 3.55**	**0.04**
Pain in walking (ref: no change)				
Worse	**0.51**	**-.15**	**.28 – .91**	**0.02**
Better	**0.24**	**-.10**	**.10 – .55**	**0.001**
Pain in standing (ref: no change)				
Worse	**.33**	**.17**	**.12 - .93**	**0.03**
Better	**.31**	**.09**	**.17 - .56**	**<0.001**
Pain in sitting (ref: no change)				
Worse	**.44**	**.15**	**.22 - .89**	**0.02**
Better	**.38**	**.15**	**.17 - .84**	**0.01**
Having previous injury (ref: yes)	**1.57**	**.43**	**.92 - 2.70**	**0.09**
Number of investigations	**1.34**	**.20**	**.99 – 1.81**	**0.05**
Number of visit to health professional	**1.04**	**.02**	**.99 – 1.09**	**0.09**
Sleeping Duration	**0.77**	**.09**	**.60 – .99**	**0.04**
Sleeping Difficulties, (yes)	**2.48**	**.73**	**1.39 – 4.43**	**0.002**
Feeling Rested (Ref: Yes)				
Partially	1.52	.46	.84 – 2.76	0.16
No	**2.38**	**1.01**	**1.04 – 5.47**	**0.04**
Smoking (ref: never smoked)				
Yes (Active, social smokers)	1.25	.50	.57 – 2.74	0.57
No (Passive, ex-smokers)	.76	.27	.37 – 1.55	0.45
Psychological				
PCS	**1.04**	**.01**	**1.01 – 1.07**	**0.001**
CSI	**1.02**	**.009**	**1.01 – 1.04**	**0.009**
FABQ-W	**1.04**	**.01**	**1.01 – 1.07**	**0.007**
FABQ-PA	**1.08**	**.02**	**1.03 – 1.14**	**0.001**
Depression	1.66	.92	0.56 – 4.96	0.35
Condition Prediction (ref: don't know)				
Get better	.58	.19	0.30 – 1.13	0.11
No change	.63	.27	0.27 – 1.49	0.30
Get worse	.48	.24	0.17 – 1.32	0.15
SOCIAL				
Education (ref: PhD and Msc)				
Bachelor	1.2	.38	0.64 – 2.24	0.56
High school	1.67	.69	0.74 – 3.77	0.21
Elementary school	3.87	2.38	0.15 – 12.91	0.20

Table 21. Univariate analyses for logistic regression (continued)

Occupation (ref: Unemployment, students, homemakers , retired)				
White collar & Professionals	0.76	.42	0.25 – 2.29	0.62
Blue-collar	**0.34**	**.12**	**0.16 – .71**	**0.004**
eHealth	1.01	.01	0.97 – 1.05	0.40
ACTIVITY				
GPAQ	0.99	0.000	0.99-1.00	0.36

Hours Standing	1.01	0.03	0.94 – 1.09	0.92
Footwear	**1.01**	**0.005**	**1.00 – 1.02**	**0.01**
Sport Participation	**0.39**	**0.11**	**0.23 – 0.62**	**0.001**
Pain map (PHP:57, OP:46 – n=103 in total)				
Total area drawn, (pixel)				
Current pain level, (out of 10)				
Usual pain level, (out of 10)				
Total number of painful site (n)				

6.3.2 Multiple Linear regression for severity of PHP

Correlations between a range of biopsychosocial factors and dependent variable were seen in univariate analyses. Quality of Life, sensitization and catastrophization showed the largest correlations (r^2= 0.15, r^2= 0.10 and r^2= 0.09, respectively). Various biomedical, physiological and activity related factors held small correlations to foot health constructs (ranging from r^2= 0.10 to r^2 = 0.02). The only statistically important correlation was education in social subgroups of variables (r^2= 0.07). All univariate analysis results are reported in.

The multivariate regression revealed that Quality of life (β=35.4, 95% CI, 19.4-51.4), education [β (95% CI), -17.8 (-29.3 to -6.3)], sex [β (95% CI), -11.1 (-19.1 to -3.1)], disease duration [β (95% CI), -1.8 (-3.5 to -0.8)], and morning pain duration [−0.07 (−0.13 to −0.01)] were the only constructs significantly contributing to the overall severity of PHP measured by general foot health; meaning higher PHP severity was associated with lower quality of life, lower education level, being female, longer morning pain and longer disease duration. The model [F (5,129) 10.94, p ≤ 0.001] explained 29% of the total variance (Table 2).

Table 22. Multivariate/univariate linear regression analysis for condition severity of people with PHP (n=135)

	Univariate analysis		**Multivariate analysis (R^2=0.29 Adjusted R^2=0.27)**	
VARIABLES	Coef. (95% CI)	Coef. (95% CI)	β coef.	P value
Higher quality of Life, EQ5D5L-index	41.5 (24.5 to 58.3)	35.4 (19.4 to 51.4)	0.35	<0.001
Social				
Stopping **Education** earlier	-21.1 (-34.2 to -7.8)	-17.8 (-29.3 to -6.3)	-0.22	0.003

Biomedical				
Being **female**	-10.9 (-19.8 to -2.1)	-11.0 (-19.1 to -3.1)	-0.20	0.007
Longer Morning Pain Duration, mins.	-0.06 (-0.13 to 0.001)	-0.07 (-0.13 to -0.01)	-0.18	0.01
Longer PHP Duration, years	-2.5 (-4.5 to -0.6)	-1.8 (-3.5 to 0.08)	-0.15	0.04

R2: statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model. The dependent variable is general foot health subscale of FHSQ, which is 0-100 scale, indicating worse to better foot health score. Negative values in standardized beta coefficient means increases the possibility of severe PHP condition while positive values means decreases the possibility of severe PHP condition. Key: mins= minutes, CI: Confidence Interval, β=Beta, Coef= coefficient.

6.3.3 Multiple Logistic regression comparing people with PHP and OP

In univariate analyses, people with plantar heel pain are older (OR: 1.03; 95% CI, 1.01 – 1.06), and have a higher BMI (OR: 1.09; 95% CI, 1.02 – 1.16), compared to people who have another foot and ankle musculoskeletal condition. The plantar heel pain group had greater levels of psychological conditions (ranging from OR = 1.02 – 1.08; 95% CI, 1.01 – 1.14). Similarly, there were notably different biomedical factors. All univariate analyses result in.

A model including 5 independent accounted for 21% of the variance in the presence of heel pain. The results reveal that people with plantar heel pain tend to have a systematic disease (OR = 3.34; 95% CI, 1.53 – 7.76), express more fear avoidance (OR = 1.02; 95% CI, 1.01 – 1.14), have worse morning pain (OR = 1.02 ; 95% CI, 1.01 – 1.03) and worse pain when standing (OR = 2.60; 95% CI, 1.39 – 4.87) while they were less likely to have a unilateral previous injury (OR = 0.40; 95% CI, 0.19 – 0.81). (Table 3). Model fit was good (Hosmer-Lemeshow test= 0.75, p<0.001) with acceptable accuracy (AUC=0.78), specificity (69.8%) and sensitivity (70.1%).

Table 23. Multivariate/univariate logistic regression analysis by comparing people with PHP (n=135) and people with other foot problems (n=99).

$Model_{differentiation}$ (Sensitivity=0.70, specificity=0.69, AUC=0.78)					
	Univariate analyse		Multivariate analyse		
VARIABLES	Odd Ratio	95% CI	Odds Ratio	95% CI	P value
Biomedical					
Severe morning pain	1.02	1.01 – 1.03	1.02	1.01 – 1.03	<0.001
Having pain during standing	3.15	1.80 – 5.50	2.60	1.39 – 4.87	0.003
Having a systemic disease	3.74	1.76 – 7.93	3.34	1.53 – 7.76	0.005
Having unilateral previous injury	0.49	0.27 – 0.91	0.40	0.19 – 0.81	0.01
Psychological					
More fear avoidance behaviour	1.04	1.01 – 1.06	1.02	1.01 – 1.04	0.03

The dependent variable is having PHP versus having other foot and ankle related musculoskeletal conditions. Odd ratio were the likelihood of having PHP, meaning greater than 1 increases the possibility of having PHP, while less than 1 decreases the possibility of having PHP. Key: mins= minutes, CI: Confidence Interval, Std= standard.

6.4 Discussion

The aim of this study was to evaluate the association between self-reported biopsychosocial factors with the severity of PHP and improve understanding of PwPHP by determining what combination of these factors distinguished PwPHP from people with OP. The multivariate regression revealed that quality of life, education, sex, disease duration and morning pain duration were significantly contributing to the overall severity of PHP. We found also those with PHP have higher levels of biomedical and psychological impairments such as severe morning pain, having systemic disease, standing pain and fear avoidance than people with other foot problems. These findings highlights; (1) quality of life is one of the most significant factors for PHP, but not BMI, contrary to what was thought so far, (2) the importance of considering psychosocial component of PHP next to biomedical impairments during assessment, diagnosis and management processes.

6.4.1 Severity of plantar heel pain

The variables with the highest coefficient values that quality of life (QoL), education, sex, disease duration and morning pain duration, were those most strongly associated with the severity of plantar heel pain in the multivariable model. The strongest associations between all variables investigated and severity of PHP was QoL score from EQ5D5L the model after controlling for education, sex, morning pain and symptom duration. The plausible explanation is that the EQ5D5L questionnaire consisted varies components of well-being such as psychology, pain, function, and daily activities. Given the broad impact of pain on enjoyment of life in general, emotional well-being, fatigue and weakness (207, 208), the result is not surprising but also powerful support suggestions regarding the importance of assessing QoL of PwPHP in usual care. It should be noted, also, that the QoL included psychological domain and this is the reason why any other psychological factors is not in multivariable model. Therefore, QoL measured by EQ5D5L could be useful assessment to help explain and understand psychological aspect of a patient presentation.

Education level was the second most significant correlate of foot health in this sample, with lower education level being associated with poorer foot health in

PwPHP when controlling for QoL, sex, morning pain and symptom duration. This provides additional support for the findings of Kamaleri Y. et al (2009) (209) and makes intuitive sense, because individuals who dropped out of school in their elementary or junior-high years are very likely to have been employed in jobs requiring physical strength and fitness, such as manual labor jobs. This required physical demand, which is predisposing factor for PHP (210). Also, individuals with lower education levels are likely to be more have difficulties with the most fundamental school-based knowledge, which may lead them to be more concrete in their reasoning, and/or may be less flexible in considering coping options (122).

The finding in this study is in line with a similar study (121) that found being female explained an additional 7% of the variance in foot health scores in PwPHP, beyond a model including QoL, education, morning pain and symptom duration, which explained 29% of foot health scores in total. Several studies reported that it is well established that sex differences in pain and function but the reason of the association is still unknown. Explanations can roughly be that women can be more exposed to some factors such as physical (211), shoe wear, or environmental (8).

The significant relation between morning pain and foot health in this sample indicated that longer pain in the morning was associated with poorer foot health in PwPHP the model after controlling QoL, sex and education. Considering morning pain and stiffness are important for the diagnosis of PHP (212), the duration of morning pain could be intuitively related to severity of PHP. Similarly, it has been well established that patients with longer duration of symptoms are less likely to respond to treatment and increased possibility of chronicity due to changes peripheral pain processing and psychological responses to pain (213, 214) . In this study, we found significant correlation between disease duration and severity of PHP provides additional support for the findings of Klein S. et al (2012), which reported that PwPHP with symptoms for a longer duration related to poor functionality (215).

6.4.2 Comparison between people with PHP and OP

Because PHP and other foot problems (OP) may share very similar symptoms but they need different assessment and management to optimise outcomes. Hence, understanding differences can guide those different approaches. When we

compared PHP with OP, severe morning pain and increase in pain during prolonged standing beneath heel tended to indicate PHP in the model that when controlling after systemic disease, unilateral previous injury and fear avoidance behaviour. This provides additional support for the previous published researches about typical presentation of PHP (216, 217).

The results from the current study identified that people who having previous injury in one side are tend to be have more likely to have PHP when controlling after morning pain, pain during standing, systemic disease and fear avoidance behaviour. Unilateral previous injury was significantly less likely to indicate PHP than OP (odds ratio=0.49). This could be explained by that mechanical reasoning is also higher in PwPHP. If there is an injury in one sides, the other sides compensates, which eventually could result in plantar heel pain in this sides. The reason of this could be the biomechanical faults in long-term mechanism of PHP. A foot and ankle related musculoskeletal problem develop in a single foot initially (105-107), symptoms may becoming present in the contralateral foot as severity increases, possibly due to altered gait or because intrinsic and extrinsic risk factors apply to both limbs. Eventually, PHP can be developed as secondary injury after other foot and ankle related musculoskeletal conditions.

Having a systemic disease was the most significant odd ratio in multivariable model for distinguishing PHP and OP in this sample, which indicated PwPHP have most likely to have a systemic disease compare to people other foot problems. Our results in current study is supporting findings from previous researches. For example, it is know that the seronegative spondyloarthropathies may produce heel pain. Similarly, rheumatoid arthritis can affect the calcaneus and other adjacent structures (216). Also some mechanisms between inflammation process and increased BMI with subsequent reduced activity level can play an important.

An association between kinesiophobia and PHP has previously been shown a recent meta-analysis and cross-sectional study that found a moderate positive relationship between kinesiophobia and disability in PwPHP (134, 218). Further, the finding that kinesiophobia was not significantly associated with pain severity in other populations (219, 220). Consequently, we should not make a diagnosis based on only couple of

symptoms, and should consider other symptoms, participant's medical history and psychology aspect of the disease. In case of mixed characteristics of PHP and other foot problems.

6.4.3 Strengths, limitations and future Directions

Our study needs to be viewed in light of its limitations. First is the absence of clinical examination, which meaning that an evaluation of the model suggests that other variables not included might influence the severity of PHP, including the thickness of the plantar fascia (221), radiographic evidence of a calcaneal spur (221), variations in foot posture (106), income (222) and other several biomechanical variables. In addition, when other potential factors are added to the model, those factors which are currently in the model may not still contribute significantly to an association with PHP. Finally, due to study design, establishing causal relationships and the directionality of associations between variables is not appropriate.

Despite the view range of limitation in this research, the strengths of this study include that we: (a) recruited a comprehensive international sampled PHP cohort from general public; (b) encompass a broad range of biomedical, psychological, social and activity domains of health; (c) used accessible and easy to administer self-reported measures, which have been used extensively in clinical practice and musculoskeletal pain research. Additionally, important consideration before interpreting the results of the present study was the extent to which our participants could be considered representative of the population. For both groups, the level of pain (6, 106, 223), duration of symptoms (6, 223, 224), BMI (6, 106, 223, 224), age (6, 106, 223, 224), and percentage of females (106, 223) were similar to other studies that have evaluated risk factors and interventions for PHP and foot pain.

There are several potential avenues for further research into the biopsychosocial features of PHP. One research direction involves the study of biomechanical factors pertaining to kinetic, kinematic and neuromusculoskeletal impairment of PHP. These factors have been found to influence the experience of musculoskeletal pain and will add further depth to our understanding of PHP subgroups. A second research approach should investigate the causal aspects of these factors in PHP. This would require prospective cohort studies that are more likely to validate temporal

relationships. If high levels of severity of symptoms are an indicator of biopsychosocial problems, then early intervention aimed at reducing the severity of PHP may prevent the development of chronicity and impact on overall well-being. Thus, a third research direction could explore the prognostic capabilities of biopsychosocial factors in PHP and how attending to these might impact on treatment outcomes.

6.5 Conclusion

Biopsychosocial variables are related to severity of PHP including QoL, education, sex, morning pain duration and disease duration in the context of a comprehensive model. These findings show that severity of in PwPHP is more than just a mechanical or biomedical problem. Diverse psychological, social and activity-related factors are present and influence foot health. Additionally, those with PHP have higher levels of biomedical and psychological impairments such as severe morning pain, having systemic disease, standing pain and fear avoidance than people with other foot problems. Although causality cannot be determined in this study and the relations among these variables are not fully understood, this information may be helpful in optimising management of plantar heel pain, clinicians should consider the presence and potential role of these variables in the overall care of their participants. Prospective cohort studies are needed to confirm these associations and establish temporal relationships.

CHAPTER 7 PREDICTING OUTCOME FOR ADULTS WITH PLANTAR HEEL PAIN: A ONE YEAR PROSPECTIVE COHORT STUDY

The systematic review presented in chapter 3 identified that pain related variables such as longer pain duration, multiple painful area in lower extremity are associated with recovery of PHP. In case-control chapter, I aim to provide an evidence about prognosis of PHP within a multivariable model. The findings from from the longitudinal prospective cohort study are presented in this chapter.

7.1 Introduction

Plantar heel pain (PHP) is the most common musculoskeletal condition in adults, with an estimated prevalence between 4% and 10% in the community (68-70, 225) It is characterised by pain in the inferior-medial regions of the rearfoot during weight-bearing and is usually exacerbated by prolonged periods of standing and walking (2). People with PHP have a reduced health-related quality of life due to limitations on daily life activities.

There are multiple treatment options for PHP, but none give satisfactory results (3). Current conservative treatment options, include stretching, footwear modification, taping and patient education, in the first-line management with interventions such as shock wave therapy and orthoses increasingly available for those who do not improve after first attempt treatment (12). However, PHP can still remain resistant to recovery and approximately 50% of individuals continue to have some symptoms up to fifteen years (8). A variety of management strategies with poor outcomes may arise from the lack of tailoring management approaches due to limited understanding of the biopsychosocial variables that affect PHP prognosis.

In healthcare, prognosis often refers to the likelihood of an individual experiencing a particular outcome over time, based on demographic, biomedical, psychological and psychosocial characteristics (226-228). Identification of clinically meaningful prognostic factors for PHP would be useful to clinicians judging prognosis,

researchers who want to understand causal relationships and perhaps for sufferers seeking to understand their condition and set the outcome expectations (229). Given the number of factors that may influence outcome, a multivariate approach considering a wide range of variables is necessary to gain the most accurate prognostic information, (227).

Studies have utilised multivariate regression modelling for PHP, identifying being female and having bilateral heel pain, immediate effect of low-dye taping, symptom duration, number of painful sites and several ankle and hip related clinical associations such as increased ankle plantar flexion, hip internal and external rotation range as prognostic indicators (8, 66, 92-94). However, only one of these studies is prospective cohort, which are considered as the most informative design and, all the studies performed poorly on risk of bias and quality assessments, mainly due to inadequate reporting standards for study participants and methodological issues. Furthermore, none of these studies investigated the psychosocial component of PHP. On the basis of this, a high-quality prospective cohort study that evaluate the prognostic value of a range of variables, including psychosocial factors is warranted.

Therefore, the aim of this study was to improve the understanding of PHP by constructing a prognostic model from a large international prospective cohort of people. The objectives of this study were (1) describe the proportion of individuals with PHP who experience an unfavourable recovery over 12 months and, (2) develop and internally validate a prognostic model to predict recovery of plantar heel pain, using a wide range of biopsychosocial self-reported variables derived from the baseline characteristics of a cohort with a 12 month follow-up. The impact is to inform clinical care, assist decision making and treatment decisions for this troublesome, common, recalcitrant condition.

7.2 Methods

The study procedures were ethically approved by QMERC ethics committee (approval No. QMREC2014/24/153), National Health Service (NHS) (approval No: 264615) and Hospitalo-Facultaire Universitaire de liege ethics committee (approval No: 2019/182) from France. Electronic informed consent was sought from each

recruited participant prior to completion of the online questionnaire. The feasibility of the proposed study and validation of online questionnaire battery have been described in a published paper (196). This study is reported according to the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement (230, 231).

7.2.1 Study design and participants

A prospective longitudinal cohort design was conducted. The sample included 136 people with PHP (age 44±12 years, 65% female) who were recruited via advertising in hospitals and physiotherapy clinics, posters in public areas, and social media outlets from April 2018 to February 2020 based on a set of prespecified eligibility criteria. The follow-up of the last participant was completed in March 2021.

The inclusion criteria were having a clinical diagnosis of PHP within the last 6 months. A podiatrist with over 30 years' clinic experience (TP) and a clinician's (DC) team diagnosed 72 percent of both groups of conditions based on reported symptoms and clinical examination. Subjects with early morning and first step pain for more than one month, and pain on palpation of the plantar medial tubercle of the calcaneus were classified as people with PHP compared to other foot problems. The rest of population were recruited by GPs and physiotherapist from other clinics (10%), NHS (Mile End hospital) (%13) and social media (5%) (Figure 1). Additionally, an eligibility survey was implemented with six questions to confirm each patient's diagnosis (Table 1). Participants who did not provide diagnosis details and medical history were excluded from the study (n=5). People under 18 years of age were not eligible.

Table 24. The list of eligibility questions for the study

1. Please describe your main problem?
2. What was your diagnosis in right/left foot?
3. Who diagnosed your condition?
4. Which investigations did you have for your conditions?
5. How many visits have you made to the clinician for your problem?
6. How long have you had this condition?

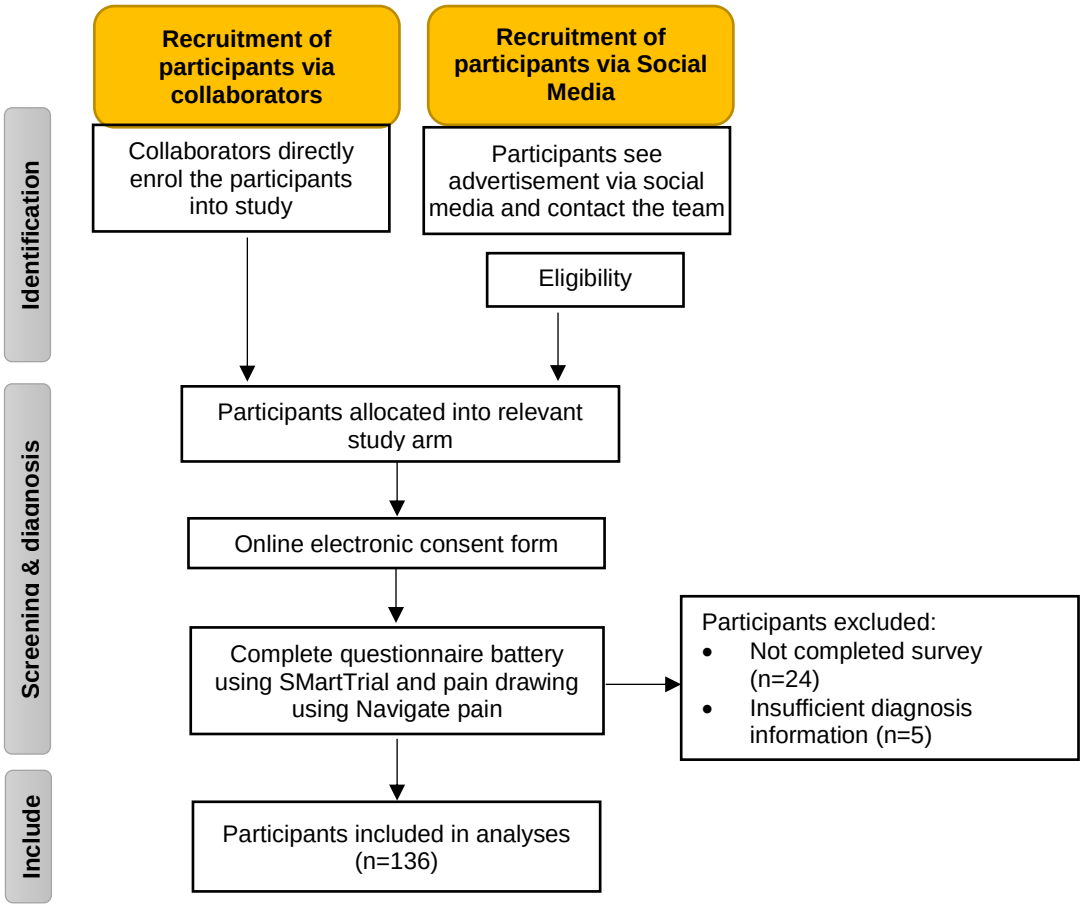

Figure 21. Participant enrolment and screening process.

7.2.3 Definition of the outcome

A prognostic model was developed to predict 'recovery', which was defined as is the state top two categories of the Global Rating of Change (GROC) at any time point. The GROC is a 11-point (-5~+5), self-rated measure used to measure the participants' impression of the change over 12 months. There are two main question in the questionnaire, firstly, participants are asked to rate their perceived change. This has previously been demonstrated to be clinically relevant and stable concept (232). The scale ranges from -5 (very much worse) through 0 (no change) to +5 (very much better) with the score of +4 (much better) or more representing being recovered.

7.2.4 Baseline candidate predictors

Thirty-six self-reported baseline variables were considered plausible candidate predictors of poor outcome of PHP. This initial selection was made internally by the research team, taking into account the results from our systematic review and the conclusions from a consensus group meeting convened for the study, which included

clinicians and medical researchers. The selected candidate predictors measured by patient reported outcome measures (PROMs) and standard miscellaneous questions format was constructed for previously validated online administration using 'SmartTrial' https://www.smart-trial.com (196). The online survey consisted of eight PROMs and miscellaneous questions designed to collect outcome measures, consisting of pain severity, restriction level of some activities, kinesiophobia, and report of pain location with a pain map, physical activity level, quality of life, age and BMI (Table 2), which are all considered as relevant factors for prediction of PHP prognosis. For full details of study measures see feasibility study (196).

Table 25. List of candidate predictor variables from the Baseline assessment datasets.

Demographic variables

1. Age (years)
2. Sex (male / female)
3. Ethnic Group (White / Black-Caribbean / Black-African / Black-Other / Indian / Pakistani / Bangladeshi / Chinese / Other)
4. First language (English / Turkish/ French/Spanish/Danish

Biomedical variables

5. BMI
6. General foot health(FHSQ)
7. Foot pain (FHSQ)
8. Foot function (FHSQ)
9. Disease duration (0-6 months/ 6-12 months/ 1-2 years/ 2-3 years/ >3 years)
10. Morning pain duration
11. Morning pain severity
12. Onset of pain
13. Co-morbidities
14. Number of co-morbidities
15. Back pain, presence
16. Pain during activities(walking/standing/sitting)
17. Having previous injury
18. Number of investigation
19. Number of visit to health professionals
20. Sleeping duration
21. Sleeping difficulties
22. Smoking status

Psychological variables

23. Catastrophisation (PCS)
24. Sensitization (CSI)
25. Fear avoidance behavior (FABQ)
26. Future belief about the conditions
27. Depression

Social variables

28. Education (CSE / O-Level or GCSE / A-level / degree / higher degree / other)
29. Type of employment (open ended)
30. Health literacy

Activity related variables

31. Physical activity level (GPAQ)
32. Time on feet (most of the day / > 4 hours a day / < 4 hours a day / Not much time, mostly sitting)
33. Practice of exercises (yes/no)
34. Sports age
35. Type of sports practicing

7.2.5 Sample size calculation

Sample size was calculated using the receiver operating characteristic (ROC) area under the curve (AUC), and checked with events per variable (EPV). The ROC curve approach, as represented by the single variable of area under the curve (AUC)

enables definition of outcome prediction accuracy (233). AUC can be also used to detect sample size (234). The excellent score (>0.8, Hosmer, Applied Logistic Regression 2nd Edition, Chapter 5; pg160-164) was defined as an indicator of a useful model with a power of 80% and an alpha of 5% in order to provide robust data for clinical approaches. Ratio of sample sizes in negative/positive groups was considered based on recovery rates from previous intervention studies of plantar heel pain. We used highest recovery rate which is 61% in order to cover all population including foot problems and plantar heel pain groups. Computer based MedCalc software (version 18.6) was used to calculate the required sample size. The sample size was 189 participants (115 participants for positive group, 74 is for negative group) (Table 3). Then an estimated drop out of 20% was added, to give a required of 236 participants. It is widely recommended that the data set used to develop a prognostic tool should contain a minimum of 5–10 outcome events per variable (EPV) included as a predictor in the model 14–19.

Table 26. Sample size calculation based on area under the ROC curve (AUC) *chosen sample size

Non-recovery: Recovery		30:70		39:61		40:60	
Alpha		0.05	0.01	0.05	0.01	0.05	0.01
Beta	0.20	140+61	223+92	***115+74**	175+112	114+76	172+114
1-Power	0.10	181+78	262+113	149+96	216+139	147+98	213+141

7.2.6 Data management

All data were electronically transcribed from SmartTrial and recoded for calculations in Microsoft Excel Version 2013 (Microsoft, California, USA) and STATA (version 16.0, StataCorp LP, College Station, TX, USA). Levels/categorizes within comorbidity, education and ethnicity variables were combined to eliminate sparse categories by retaining a ratio of ≥20 participants per estimated model parameter. We treated a categorical factor (i.e. disease duration) as continuous if linearity with outcome could be assumed after visual examination using scatter plots. (BMI) was calculated using height and weight (cm2/kg)

7.2.7 Statistical analysis

Statistical analysis was conducted using STATA (version 16.0, StataCorp LP, College Station, TX, USA). All variables were explored for normality using the histograms and Q-Q plots, prior to statistical analysis. One-way ANOVA or chi-square were used to

compare recovered and non-recovered participants. Differences described using effect size measures with Cohen's d for continuous variables and Cramér's V for categorical variables (205).

A Kaplan-Meier survival analysis was used to estimate the prognosis of PHP. The period between baseline and the month at which recovery was reported, was used to define time to event. Observations were censored at the first completed monthly questionnaire on which recovery was reached.

Multivariable cox proportional hazard regression analysis was used for the prediction model on the baseline characteristics. The first stage of the analysis used univariate regression to assess crude associations with correlation coefficients. A significance level of $p \leq 0.1$ was adopted to ensure that the univariate analyses were sufficiently sensitive to identify potential prognostic factors for entry in the model (ref) as per previous prognostic studies of musculoskeletal conditions. (228, 235). In the second stage, the prognostic factors with significant associations in univariate analyses were further entered into stepwise regression with backward elimination ($p \leq 0.05$) in order to identify a group of factors that were independently associated with recovery of PHP. After constructing final multivariable cox proportional hazard model, proportional- hazard assumptions were checked with Schoenfeld residuals (chi square > 0.05) and observing each variables for people recovered and unrecovered over time.

For the apparent performance of the model, discrimination determines a model's ability to differentiate between participants who have experienced an outcome compared to those who have not (236), and was quantified using the concordance index (C-index). This is equivalent to the area under the receiver operating characteristic (ROC) curve for logistic regression, where 1 demonstrates perfect discrimination, whilst 0.5 indicates that discrimination is no better than chance (237). Calibration determines the agreement between the model's predicted outcome risks and those observed (238). All predicted risks were divided into ten groups defined by tenths of predicted risk. The mean predicted risks for the groups were plotted against the observed group outcome proportions with corresponding 95% confidence intervals (CIs). The degree of over/under fitting was determined using the calibration

slope, where a value of 1 equals perfect calibration on average across the entire range of predicted risks (231).

Prior to cox proportional regression, correlations between explanatory variables were evaluated to detect levels of association, and avoid issues relating to multi-collinearity by calculating variance inflation factors (VIFs). The level of collinearity was considered problematic, and one of the two independent variables was not included in the model, if the mean VIF was ≥5 and individual VIFs were ≥10.(206)

7.3 Results

7.3.1 Participants

The baseline response rate was 100% (n = 136). The estimated median time between study entry and questionnaire response was 17 days. Ninety-five percent (n = 129) of participants returned one or more of the monthly follow-up questionnaires (mean 6.1); 19% of these returned all 12 questionnaires, 20% returned 7–11 questionnaires and the remaining 57% returned 1–6 questionnaires (Figure 2).

The mean age of participants was 44±12 years (65% female, BMI 26±4, weekly activity levels (expressed in MET-minutes) of 5393±6557). Worst pain over the last week for the PHP was 29±2 out of 100 scale. There was a statistically significant difference between people who recovered and un-recovered regarding all psychological factors apart from depression. No between-group mean differences were found for activity related factors. The sociodemographic, physical and psychological profiles of all study participants are presented in Tables 5.

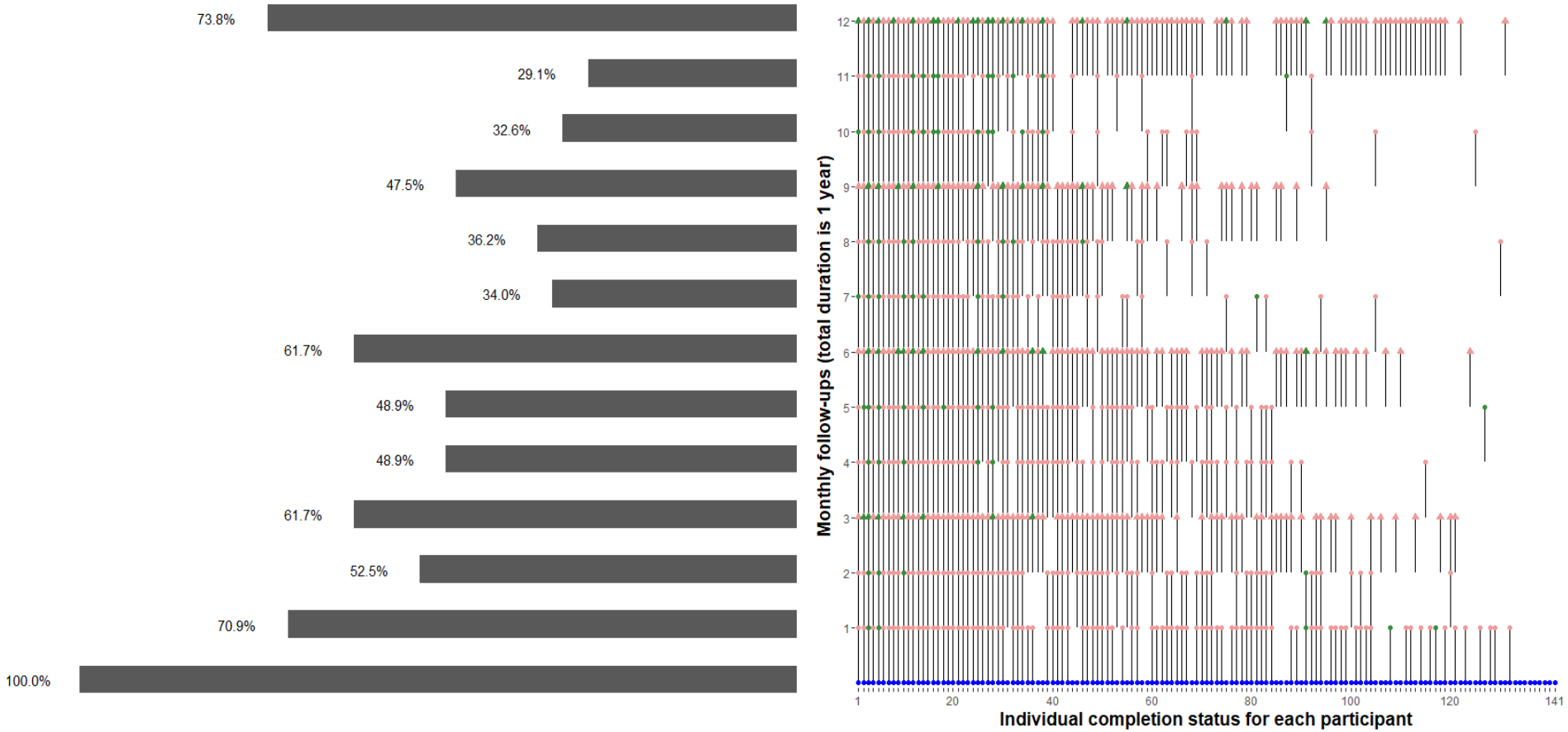

Figure 22. Overall retention rates for each months and individual completion status for each participants

Table 27. Self-reported baseline characteristics of participants who recovered and un-recovered.

Variables	All (n=137)	Recovered (n=72)	Unrecovered (n=65)
Quality of Life EQ5D5L-index, (0-1)	0.67 ± 0.2	0.77 ± 0.11	0.67 ± 0.19
Demographics			
Age, years	44.1 ± 12.1	42.3 ± 8.6	46.6 ± 13.3
BMI, kg/m^2	26.9 ± 4.4	24.1 ± 3.4	27.3 ± 4.8
Sex, (female: male)	88:47	4:2	52:28
Biomedical			
General Foot Health, FHSQ, (0-100)	35.1 ± 25	52 ± 30.7	34.4 ± 25.3
Foot Pain, FHSQ, (0-100)	51.6 ± 24	47.8 ± 23.1	49.1 ± 23.8
Foot Function, FHSQ, (0-100)	56.2 ± 30	65.5 ± 30.5	55.6 ± 29.1
Symptom Duration	2.8 ± 2.3	4.3 ± 2.1	4.2 ± 11.3
Morning Pain duration, mins.	29.4 ± 67	22.5 ± 22.4	25.1 ± 60.9
Morning Pain Severity, VAS	58.4 ± 25	60.1 ± 22.6	59.4 ± 23.5
Psychological			
Catastrophization, PCS (0-52)	15.0 ± 12.3	5.3 ± 4.1	14.9 ± 10.8
Sensitization, CSI, (0-100)	32.2 ± 17	19.1 ± 11.5	33.0 ± 16.1
Fear avoidance- work, FABQ	10.5 ± 9.7	11.5 ± 6.6	13.9 ± 5.1
Fear avoidance- PA, FABQ	14.2 ± 5.6	11.5 ± 5.5	13.9 ± 5.4
Depression diagnosis, (yes : no)	11:124	5:65	6:59
Social			
Educational Level, n (%)			
Elementary school	16 (12%)	4 (3%)	12 (9%)
High school	26 (19%)	11 (8%)	15 (11%)
Bachelor	62 (46%)	43 (33%)	19 (13%)
Master's degree	20 (15%)	13 (10%)	7 (5%)
PhD	11 (8%)	6 (5%)	5 (3%)

7.3.2 Prognosis of Plantar Heel Pain

During follow-up, there were n=72 (54%) patients in the asymptomatic group and n= 64 (46%) in the symptomatic group. The mean duration of the symptoms in the asymptomatic group was nearly 332 days (range, 28-365.25 days) before symptoms disappeared. According to the KM-curve the recovery from PHP was 50.5% (95% CI, 73.5-85.6) in 1 year (Figure 3).

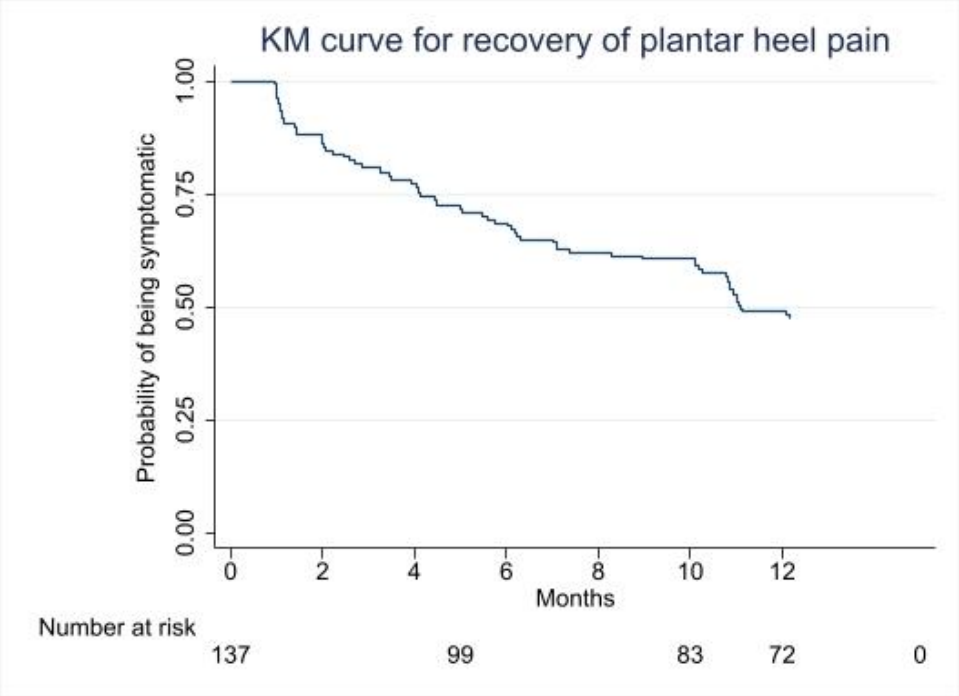

Figure 23. Kaplan Mayer curve for recovery of people with plantar heel pain

7.3.3 Univariate and multivariable cox proportional- hazards regression model

Univariate linear regression revealed that general foot health scores of FHSQ (HR: 1.01, [1.00 – 1.02]), foot pain scores of FHSQ (HR: 1.01, [1.00 – 1.02]), morning pain severity (HR: 0.98, [0.98 – 0.99]), disease duration (HR: 0.81, [0.73 – 0.90]), catastrophization (HR: 0.97, [0.95 – 0.99]), sensitization (HR: 0.97, [0.96 – 0.99]), condition prediction (HR: 2.16, [1.35 – 3.47]), education (HR: 2.35, [0.99 – 5.56]), sports participation (HR: 1.74, [1.09 – 2.77]), having injection (HR: 2.38, [1.37 – 4.14]) were associated with recovery of PHP (Table 29 & Table 28).

Table 28. Univariate cox regression results for candidate predictors

	Cox proportional-Hazards **(n=137)**		
Potential Predictors	Haz. Ratio	P > l t l	Confidence int.
Increased Quality of Life	**8.07**	**0.003**	**2.00 – 32.57**
DEMOGRAPHICS			
Age	1.00	0.69	0.98 – 1.02
BMI	0.96	0.2	0.91 – 1.02
Sex (ref: male)	1.03	0.88	0.63 – 1.69
Ethnicity (ref: others and PNTS)			
White	0.63	0.17	0.32 – 1.22
Asian	0.50	0.02	0.28 – 0.90
BIOMEDICAL			
General foot health, FHSQ	**1.01**	**< 0.001**	**1.00 – 1.02**
Foot pain, FHSQ	**1.01**	**0.001**	**1.01 – 1.02**
Foot function, FHSQ	1.006	0.11	0.99 – 1.01
Morning Pain duration, mins.	0.99	0.53	0.99 – 1.01

Table 28. Univariate cox regression results for candidate predictors (continued)

Morning Pain Severity, VAS	0.98	0.007	0.98 – 0.99
Disease duration	**0.81**	**< 0.001**	**0.73 – 0.90**
Comorbidity (ref: none)			
Musculoskeletal d.	0.69	0.36	0.31 – 1.52
Systemic d.	1.28	0.38	0.73 – 2.26
Psychological d.	1.72	0.08	0.91 – 3.25
Number of Comorbidity	0.90	0.38	0.73 – 1.12
Back pain presence, (ref: no)			
Yes (Previously)	0.80	0.49	0.42 – 1.50
Yes (Current, recurrent)	0.61	0.11	0.34 – 1.11
Pain in walking (ref: Better & No Change)			
Worse	1.22	0.41	0.75 – 2.00
Pain in standing (ref: Better & No Change)			
Worse	0.85	0.55	0.50 - 1.44
Pain in sitting (ref: Better & No Change)			
Worse	0.70	0.13	0.44 - 1.11
Having previous injury (ref: no)	0.64	0.35	0.24 - 1.63
Number of investigations	1.04	0.66	0.84 – 1.30
Number of visit to health professional	0.99	0.73	0.94 – 1.03
Sleeping Duration	1.09	0.33	0.90 – 1.32
Sleeping Difficulties, (ref : no)	0.80	0.36	0.49 – 1.29
Feeling Rested (Ref: Yes)			
Partially	0.64	0.10	0.37 – 1.09
No	0.57	0.11	0.29 – 1.12
Smoking (ref: never smoked)			
Yes (Active, social smokers)	0.81	0.61	0.54 – 3.01
No (Passive, ex-smokers)	1.59	0.49	0.41 – 1.56
Psychological			
PCS	**0.97**	**0.01**	**0.95 – 0.99**
CSI	**0.97**	**0.02**	**0.96 – 0.99**
FABQ-W	0.98	0.21	0.95 – 1.00
FABQ-PA	0.97	0.33	0.93 – 1.02
Depression	0.79	0.74	0.18 – 3.21
Condition Prediction (ref: don't know & No change& worse : Get better)	**2.16**	**0.001**	**1.35 – 3.47**
SOCIAL			
Education (ref: Elementary)			
High school	1.48	0.41	0.56 – 3.86
Bachelor	**2.35**	**0.05**	**0.99 – 5.56**
MSc &PhD	1.00	0.98	0.37 – 2.68
Occupation (ref: Unemployment, students, homemakers , retired)			
Blue-collar	1.39	0.44	0.59 – 3.28
White collar & Professionals	1.19	0.58	0.62 – 2.30
eHealth	0.98	0.46	0.95 – 1.02
ACTIVITY			
GPAQ	1.00	0.76	0.99 - 1.00
Hours Standing	1.01	0.81	0.94 – 1.07
Sport Participation (ref: no)	**1.74**	**0.01**	**1.09 – 2.77**
TREATMENT			
Treatment (ref: no)	1.16	0.55	0.70 - 1.90
Footwear changes	1.44	0.10	0.90 - 2.28
Self- education	0.90	0.80	0.39 - 2.07
Education check	1.17	0.55	0.68 - 2.01
Exercises*	1.27	0.30	0.80 - 2.02
Orthoses	0.56	0.22	0.20 - 1.54
Injection	**2.38**	**0.002**	**1.37 – 4.14**
Medication	1.15	0.57	0.69 - 1.93
Stretching	1.27	0.61	0.79 - 2.05

Table 28. Univariate cox regression results for candidate predictors (continued)

Taping	**0.67**	**0.58**	**0.16 - 2.75**
Foot insole	0.56	0.26	0.20 - 1.54
ESWT	1.12	0.72	0.58 – 2.13

The multivariable regression revealed that general foot health (HR: 1.02, 95% CI 1.00 to 1.02, p = 0.02), longer duration of disease (HR: 0.84, 95% CI, 0.74 to 0.94, p= 0.003), condition prediction (HR: 1.69, 95% CI, 1.03 to 2.77 p=0.03) and having had an injection prior to joining the study (HR: 2.61, 95% CI, 1.47 to 4.63 p=0.001) remained significantly associated with recovery of PHP in the multivariate model. It means recovery in PHP was associated with the combination of a higher general foot health score of FHSQ, shorter disease duration and belief about recovery and having injection. Model fit was good as the proportional hazards assumption has not been violated (estat phtest=0.95, p value < 0.001).

Table 29. Multivariable proportional cox-hazard regression

Model$_{recovery}$					
	Univariate analyse		Multivariate analyse		
VARIABLES	HR	95% CI	HR	95% CI	P value
Biomedical & Treatment					
General foot health	1.02	1.00 – 1.03	1.02	1.00 – 1.02	0.02
Symptom duration	0.84	0.64 – 0.91	0.84	0.74 – 0.94	0.003
Condition prediction	1.69	1.35 – 3.47	1.69	1.03 – 2.77	0.03
Having Injection	2.61	1.29 – 8.96	2.61	1.47 – 4.63	0.001

7.3.4 Model Performance

Overall, discrimination of baseline model was fair, with C-statistics of 0.69 (95% CI, 0.63 to 0.75). The prognostic model has perfect apparent overall calibration in the large and calibration slope, which was more variable around the 45 degree line between expected risk ranges of 28 to 94%. The apparent overall model fit was acceptable, indicated by Nagelkerke R2 values of 0.288. The table30 shows the optimism-adjusted performance statistics for the model. After adjustment for the optimisation, the overall model fit and the model's discrimination performance deteriorated (Nagelkerke R2 = 0.064; C-index = 0.014 (0.52 to 0.65)). Furthermore, bootstrapping suggested the model would be fitted in new data (calibration slope= 1.00 (95%= 0.67 to 1.32)) (Figure 24).

Table 30. Model Performance statistics

Measure	Apparent	Boot sample	Average optimism	Optimism-corrected
C-index	0.691	0.698	0.014	0.684
Calibration slope	0.990	1	0.076	0.924

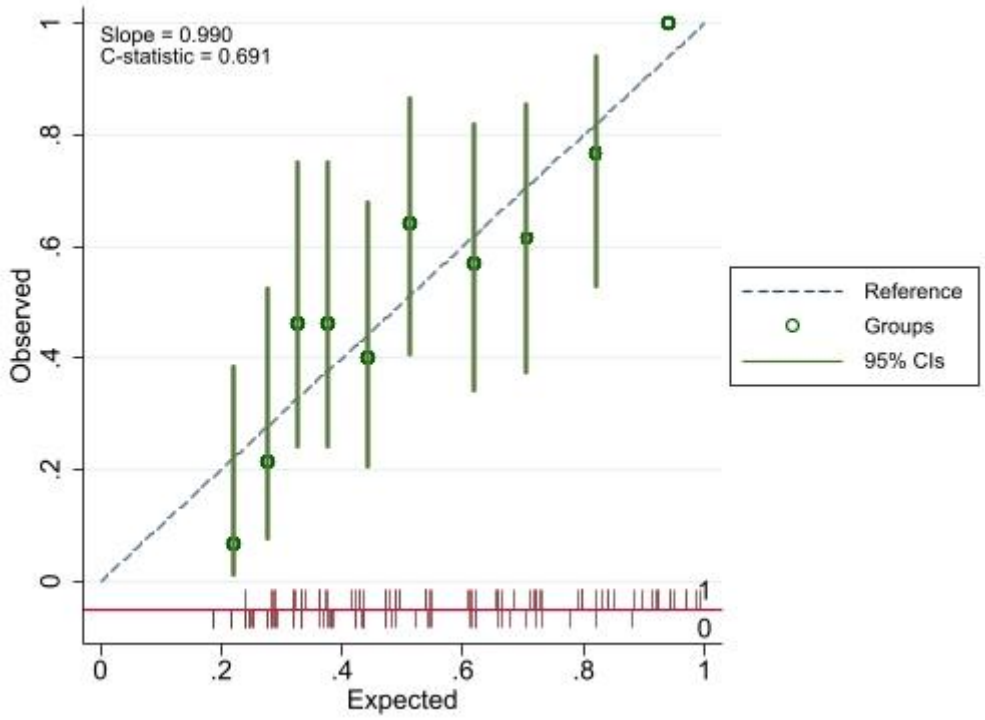

Figure 24. Calibration Plot

7.4 Discussion

The aim of this study was to investigate a range of self-reported factors associated with plantar heel pain (PHP) prognosis at 1 year in order to develop and validate a multivariable prognostic model of recovery. I found that the risk of still having PHP after 1 year from study entry was 49.1%. The multivariable cox regression revealed that condition severity, disease duration, future condition prediction and having had a recent injection were significantly associated – alone and in combination - with PHP recovery. The model presented acceptable discriminatory ability and good calibration. The model is therefore composed of easy to assess predictors which provide reasonable predictions of recovery for people with PHP. These findings highlight; (1) resolution of PHP is not self-limited, (2) baseline condition severity might be one of the main driver of PHP recovery (3) indicate the importance of considering the psychosocial components of PHP alongside biomedical impairments during assessment, diagnosis and management processes.

7.4.1 Prognosis of Plantar Heel Pain

The survival analysis in my study showed that the risk of still having PHP after 3 months was 80.1%, 77.2% after 6 months, and 49.1% after 1 year from the study entry. Patients had a mean duration of symptoms at baseline of 257.7 days (range, 29.3 – 365.25 days). There is currently only one study that investigated PHP prognosis in the literature (8). Hansen et al (2018) reported that the possibility of being symptomatic was 80.5% after 1 year and 50.0% after 5 years from the onset of PHP, indicating that the prognosis of PHP was worse than our results. On the other hand, these findings should be considered with particular caution as patients in the study (8) belong to a subgroup with the most severe conditions and 93% of the patients were treated with a US-guided corticosteroid injection, which is not a first line of treatment, and thus an indication that it was a "difficult-to-treat" cohort. However, patients in present study could be considered representative of the population as the level of pain (6, 106, 223), duration of symptoms (6, 223, 224), BMI (6, 106, 223, 224), age (6, 106, 223, 224), and percentage of females (106, 223) were similar to other studies that have evaluated risk factors and interventions for PHP (12). Furthermore, variety between sample characteristics such as country of research and quality of the study could be one of the reason of the differences.

7.4.2 Predictors of plantar heel pain recovery

The multivariable proportional hazard cox regression revealed that 4 of 36 measured biomedical, psychological, social and activity related factors predicted recovery. The strongest associations with the recovery of PHP was general foot health score of foot health status questionnaire (FHSQ), in the multivariable model which included for symptom duration, patient belief about future and having injection. This is unsurprising if one considers compromised foot health a valid marker of condition severity. It has also been reported in previous studies that if we can better estimate baseline severity, we can better estimate outcome (104). It should also be noted that general foot health is a measure that interacts with multiple aspects of wellbeing such as enjoyment of life, emotional well-being, fatigue and weakness (239). Hence, it is likely that baseline severity is the main driver of compromised recovery, and therefore important to consider for management planning.

Longer symptom duration was found to be predictive of plantar heel pain non-recovery. Similarly, higher pain severity at baseline and longer pain duration have also shown an association with a poor prognosis in other musculoskeletal pain conditions (104). A study investigating the effects of different symptom durations on musculoskeletal pain prognosis revealed that there are significant trends between recalled length of episode duration and pain and psychological status at consultation, and outcome over the subsequent year (240). Furthermore, about one-fifth of those who recall that their back pain episode is longer than 3 year duration will fail to improve in the following year, likely because of that longer duration (240). These findings highlight the clinical importance of implementing an effective pain intervention programme as early as possible after onset in order to increase the likelihood of intervention success.

Our results show that patients' belief that the condition will be persistent or deterioration of her/his plantar heel pain predicted poor outcome alongside general foot health, symptom duration and having an injection. A recent review on psychosocial predictors for musculoskeletal pain reported that expectations about recovery conferred a more consistent prognostic factor than other psychological factors in predicting outcome up to 12 months (241). Taken together with my findings, this strengthens the conclusion that patients' beliefs about condition progress are important and robust prognostic markers. Therefore, assessment of such beliefs could constitute meaningful predictors of use to clinicians, which merit further evaluation of their usefulness and impact in medical care.

Corticosteroid injections into the heel to treat PHP have been used frequently. In the present study, cox hazard proportional regression revealed that having an injection could predict the recovery of PHP controlled by general foot health, symptom duration and condition prediction. One possible explanation is that having injection have highly positive effect on the plantar fascia thickness, hypoechogenicity of the fascia and VAS values following the treatment strategy, considering the mechanism of corticosteroid injection as a part of management strategy of PHP. Additionally, according multivariable results, it could be said that having injection would provide better results once patients have poor general foot health, longer symptom duration

and pessimistic future belief about condition. However, it could be important to note that our observational study does not allow us to determine the efficacy of any treatment strategies.

7.4.3 Limitations, strengths and future Directions

The largest limitation is the absence of a clinical examination. An evaluation of the model suggests that variables not included in this study might influence the prognosis of PHP, including the thickness of the plantar fascia (221), muscle strength in lower limb, radiographic evidence of a calcaneal spur (221), variations in foot posture (106), income (222) and other biomechanical variables. The addition of other clinical or imaging variables to the current model may alter the significance of the associations identified in this study to PHP. Additionally, notwithstanding the fact that the current study contains a large number of participants, our sample size was inadequate when considering the number of potential predictors evaluated.

Despite the limitations of this study, the strengths include that we: (a) recruited a comprehensive international sample PHP cohort from the general public; (b) encompassed a broad range of biomedical, psychological, social and activity domains of health; (c) and used accessible, easily-administered self-reported measures, which have been used extensively in clinical practice and musculoskeletal pain research.

There are several potential avenues for further research into the biopsychosocial features of PHP. One involves the study of biomechanical factors pertaining to kinetic, kinematic and neuromusculoskeletal impairment of PHP. These factors have been found to influence the experience of musculoskeletal pain and will add further depth to our understanding of PHP subgroups. A second research approach should investigate external validation of the developed model. This would require further prospective cohort studies. Then early intervention aimed at reducing the severity of PHP may prevent the development of chronicity and impact on overall well-being. Thus, a third research direction could explore the impact of these factors, namely general foot health, symptom duration, patient's belief, having injection treatment outcomes of PHP.

7.5 Conclusion

This is the second study investigating outcome predictors for PHP recovery. The risk of still having PHP was 49.1 % after 1 year. The developmental models showed recovery is not just determined by physical features of the presentation as shown in previous literature. Patients presenting with PHP of long duration who score worse on the foot health of FHSQ have a poorer prognosis, irrespective of age, sex and other demographic variables. The results suggest that strategies aimed at preventing chronicity of more severe PHP may optimise prognosis.

CHAPTER 8 DISCUSSION

As discussed in the introduction to this thesis, plantar heel pain is a common condition that predominantly affects middle aged and overweight but also athletic individuals. Plantar heel pain can cause significant pain and is associated with poorer health-related quality of life. An example of the effects of this condition on individuals was personified in the introduction to Chapter 1 by telling a patient's history; that of Fatma. Ironically, there are thousands of published studies considering how to fix the problem, and clinicians have been innovating for more than 200 years. Despite the fact that much effort, time, and money has been invested, we are still dealing with the same issue – non-recovery of PHP. To effectively reduce Fatma's pain, health professionals must understand why some people get better while others have a poor prognosis. This requires knowledge about prognosis. However, there is only one prospective cohort study in this field with a poor study design and various limitations in the methodology, so there is limited high-quality evidence. Therefore, this PhD thesis aimed to investigate the prognosis of PHP and identify the outcome predictors using multivariable prediction model to bridge the gap in the literature. To achieve the aim of this thesis, four main study with specific hypothesis were outlined in Chapter 2. A visual summary of the research question, key findings and outcome for each study is displayed in Figure 25.

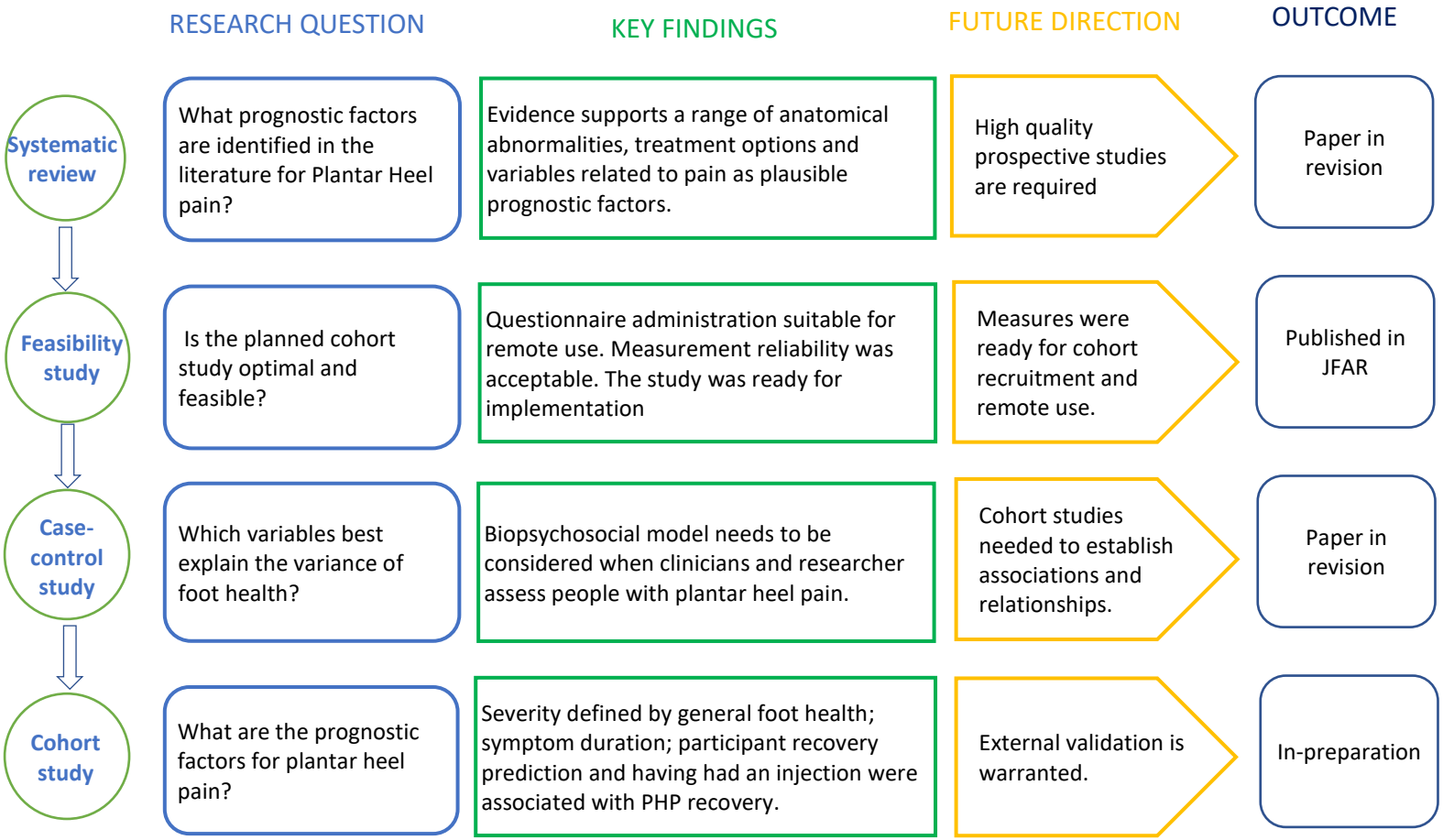

Figure 25: Thesis overview

As presented in chapter 3, in the systematic review of prognostic factors for PHP, the hypothesis were that there would be an extended range of variables but less strength of evidence, for potentially prognostic factors for PHP. In addition, these prognostic factors would be of relevance to clinicians treating people with PHP. The systematic review found that the existence literature is currently insufficient for robust recommendations in usual with the clinical tentative clinical guidance and causal relationship are scare due to absence of prospective cohort studies, there being only one cohort with a problematically small sample size. Therefore, the current literature is likely to change when future research is published. Accordingly, the hypothesis for this objective was supported by this systematic review. This systematic review has an impact to help researchers generate better hypotheses and direct their efforts more effectively, perhaps with prospective cohort studies.

As presented in chapter 5, the hypothesis for feasibility study was that the planned cohort study's data collection procedures are valid, reliable and feasible. Overall, the cohort study plan could be implemented with few modifications, and the alternative hypothesis was accepted. The protocol was reduced to lessen the time burden and improve data quality in order to increase overall viability. The key drawback was that the online questionnaire battery's follow-up process could not be tested, which meant that the issue of retention could not be addressed. The feasibility study had the effect of giving researchers with useful information about data collection processes, including comprehensive measurements, particularly for online use versus traditional administration.

As presented in chapter 6, the third study evaluated associated factors with severity of PHP and explored what combination of self-reported factors distinguish PwPHP from people with OP. The hypothesis for this study were a range biopsychosocial factors will explain the variance of condition severity and there will be specific variables to PHP distinguished from other foot problem. The findings show that severity of in PwPHP is more than just a mechanical or biomedical problem and there are various variables only specific to PHP. Accordingly, the hypothesis of this study was supported by case-control study. The case-control study has an impact of

explaining the variance of PHP severity and informing clinical profiling that leads to a better understanding of presentation of PHP.

As presented in chapter 7, the cohort study investigated what combination of self-reported factors predicts PHP recovery in order to improve the understanding of PHP prognosis. The hypothesis for this study was that (1) there will be range of biopsychosocial variables predicting recovery of PHP with the biggest contribution condition severity; (2) the PHP is not self-limiting condition, which resolved in a year. The alternative hypotheses were the supported by this study. The main contribution of this study to existing literature is that recovery of PHP is not just determined by physical features of the presentation as shown in previous literature. The results suggest that strategies aimed at preventing chronicity of more severe PHP may optimise prognosis. Thus, cohort study will have the impact of providing an approach that predicts PHP recovery, hence better understanding of PHP prognosis and management of PHP. Therefore, output from this cohort could support clinical decision making by helping to clarify who gets better, why they get better and when they get better.

8.1 Contributions of findings and clinical implications

In below paragraphs, I will discuss what this PhD adds to the current literature with regards to study design, impact, resources of the previous studies in other musculoskeletal conditions and different research fields such as biomechanics and digital health.

8.1.1 Remote use of Patient Reported Outcome Measures

One of the main contribution of these studies is to provide evidence about the validity and reliability of Patient Reported Outcome Measures (PROMs) in digital platforms. Increasing mobile technology availability offers the potential to collect PROMs more easily. Particularly, to reduce the burden and cost of data collection in large population-based epidemiology research, it is critical to collect valid and reliable data remotely. As impacts, the study can be proof of a number of benefits of ePROMS over paper and pencil administration; (1) missing data within an assessment can be reduced by requiring completion of an item before the patient

can move on to the subsequent question; 2) computerized assessments can handle complex skip patterns, which often confound patients and result in incomplete or invalid data; 3) eliminate out of range and ambiguous data by allowing the patient to only select one of the on-screen response options and 4) reduce the effort and error involved in entering paper PRO data. Thus, we made a contribution to literature addressing why clinicians and researchers may prefer computerized administration to paper and pencil PRO measures, particularly when conducting a large cohort study.

8.1.2. A novel approach of Graded Loaded Challenge

I presented a novel graded loaded challenge (GLC) in the feasibility study that could be a valid and reliable clinical measure, but more research is needed to establish its utility. Musculoskeletal foot and ankle pain is common and typically aggravated by weight-bearing activity. Examination is usually based on a patient's symptom description, physical examination and imaging findings with severity graded subjectively in the clinical setting using patient reported outcome measures (PROMs). Objective severity grading is challenging to obtain. There are few studies which measure severity with a biomechanical testing protocol for other musculoskeletal conditions. For example; Tayfur A. et al (2020) developed a progressive testing protocol for patellar tendinopathy (242). Similarly, there are a couple of papers measuring Achilles tendon loading during progressive exercise challenges (243). The contribution of GLC is that providing to grade foot pain severity with an objective measure of potential use in the clinical setting. Specific clinical tests for assessing patients with foot pain facilitate the clinician’s understanding of the patient's status, response to intervention, which provide determining of the best treatment option. With the GLC, we provided easily applied functional tests to elicit the level of the patient's foot function and pain, thus ascertaining a valid clinical assessment. Considering that mechanical overload is thought to be a causal reason for foot pain, and instrumented gait analysis the gold standard, we attempted to construct a graded loading challenge with progressive load-bearing activity by manipulating stride length and carried load. The impact of these tests may be to

evaluate changes in the patient's status over time or after therapeutic intervention but recommendations about use and utility are dependent on further evaluation.

8.1.3. Psychosocial aspects of Plantar Heel Pain

Another contribution of this thesis is providing evidence about psychosocial roles of PHP. Our systematic review showed there is an absence of research of prognosis or successful outcome prediction related to the psychosocial aspect of PHP. Historically, management strategies for musculoskeletal disorders have focused on physical improvements. Symptoms and injuries are thought to be caused by tissue incapacity, which can be avoided through better ergonomic design of occupational tasks to limit mechanical loading. In the last few years, the role of psychosocial elements in several musculoskeletal conditions' development and symptom maintenance (73, 120) has received increasing attention within several case-control and cross sectional studies (121-124). The most relevant psychosocial correlations of debilitating musculoskeletal pain have been identified by several meta-analyses and reviews (244). Low back pain has been examined the most, although the findings are comparable for spinal cord injury and limb pain. Furthermore, the psychosocial correlates of disabling musculoskeletal pain are comparable to those found in patients with headaches, fibromyalgia, and irritable bowel syndrome, among other illnesses that cause disabling pain. Chronic musculoskeletal pain is highly linked to depression, insufficient coping abilities, stress, low socioeconomic position, unemployment, and the perception of a demanding employer.

8.1.3.1. Emotional variables

Across almost all musculoskeletal diseases, depression is one of the biggest predictors of health status (245). Secondly, anxiety is also associated with chronic pain and disability (246). Anger is the third biggest factor associated with debilitating pain, and has the potential to alter pain through known biological mechanisms (increased arousal) as well as impede pain acceptance and treatment adherence (247). In our case-control study, we didn't find any association between plantar heel pain severity and depression. In our case-control study (chapter 6), we only assessed who people got diagnosis from a medical practitioner. However, other musculoskeletal studies are generally use a self-reported outcome measures to

assess depression. These methodological differences make it difficult to compare the results of the respective studies but the trend of increasing recognition of such factors is increasingly clear.

Frustrations about the persistence of symptoms, the absence of a known aetiology or other features of uncertainty, therapy failures or other disability claims, and financial and family relationship issues have been shown as predictors or associated factors for musculoskeletal pain (248). Additionally, our cohort study revealed that the future beliefs of participants about their prognosis were also important.

8.1.3.2. Cognitive variables

The most common cognitive variables assessed in musculoskeletal pain states are pain sensitization and catastrophisation. This aligns with our results from the univariate analyses in case-control and cohort studies. A cognitive error is a misguided unfavourable perception of the condition. Pain perception, affective distress, and disability are all affected by a same set of cognitive errors (249). The most common pain-related cognitive errors include an intuitive tendency to misinterpret or over-interpret the nociception (e.g., “This pain in my arm means that my entire body is degenerating and falling apart” or “I can't enjoy anything until I am completely pain-free.”), negative predictions (e.g., “I know that learning coping techniques will not work for me.”), and a lack of understanding of pain (249). These thoughts could affect the neuromuscular process of the pain and lead chronicity.

8.1.3.3. Behavioural Variables

Pain-avoidance practises can aggravate the severity of pain and disability associated with it (24-26). Avoiding action causes anticipatory concern about pain (muscle tension and other symptoms associated with fight or flight or sympathetic activation), which may operate as a conditioned stimulus for pain that persists after healing. More activities are seen as risky or unpleasant with time, and they are avoided. This may result in deconditioning and ineffective coping mechanisms.

Overall, disabling musculoskeletal pain has major psychosocial consequences that can and need to be understood and addressed. Interventions focused on psychosocial factors have also shown favourable outcomes in other musculoskeletal

conditions (125). By working in multidisciplinary teams with psychologists and other health-care providers, orthopaedic surgeons can reduce pain intensity and disability. Surgery, injections, medication, exercises, and other biomedical treatments are only one part of the treatment for debilitating musculoskeletal pain. Therefore, our study results have contributed to literature by identifying of such predictors which has the potential to significantly increase understanding of outcomes of PHP and treatment efficacy as well.

8.1.4. Prospective cohort studies in other musculoskeletal conditions

Although observational research on chronic musculoskeletal pain is currently limited, there is still some useful information that enhances our understanding and guides musculoskeletal pain prognosis. For example, a prospective study with a cohort of 4977 Danish people working in the health industry looked at how different levels of physical effort perception during work affect the long-term prognosis of recovery of those with pain in different parts of the body (lumbar area, neck/shoulder, and knees) in the adult population. They revealed that a light physical effort was related with a favourable long-term prognosis for low back pain, but not for knee pain. For all locations with reported pain, a feeling of moderate physical exertion is linked to a poor long-term prognosis (250).

Depression, psychological distress, passive coping mechanisms, and high levels of fear related to pain were found to be predictors of poor evolution in individuals with chronic low bac pain in another study (251). Another risk factor they identified was being aware of the likelihood of chronicity developing at the start of discomfort.

A Swedish study tracked a cohort of 3938 men and 5056 women for four years to see if a healthy lifestyle was a predictive factor for lower back pain. They were categorised into five categories based on the amount of healthy lifestyle characteristics they demonstrated (0–4), with healthy elements defined as non-smoking, no alcohol risk consumption, a suggested level of recreational physical activity, and a recommended weekly intake of fruits and vegetables. The study determined cut-off points (healthy/unhealthy) based on the World Health Organization's guidelines for a healthy lifestyle (WHO). Women with just occasional lower back pain had a reduced chance of having chronic lower back pain, with the

risk falling by a higher percentage as more healthy variables were present. As a result, leading a healthy lifestyle is a reliable indicator of a better prognosis (252).

In recent UK longitudinal research, risk variables for chronic impairment in acute whiplash disorders were measured and analysed. The study included 430 patients with a history of whiplash who were assessed for risk variables on average 32 days after injury, with a 12-month follow-up. They discovered that having one risk factor raised the chance of chronic impairment by 3.5 times, while having four or five risk factors increased the risk by 16 times. As a result, it is likely that psychological variables, behavioural factors, and the presence of an initial impairment have a cumulative impact on disability (253).

8.3 Directions for future research

Research on plantar heel pain is relatively abundant, but it is still evolving, particularly from the perspective of methodological consistency and rigour. As such, there are several issues that have been mentioned in this thesis that require further research. The key areas for future research are discussed below.

As mentioned in section 7.3 above, this study could be re-implemented with a large number of people increase the number of EPV, which will provide more robust results. Additionally, future study could include confirmatory diagnosis and clinical examination such as the thickness of the plantar fascia (221), radiographic evidence of a calcaneal spur (221), variations in foot posture (106), income (222) and other various biomechanical variables.

The second area of future research is to understand the long-term effect of biopsychosocial variables on PHP prognosis. The systematic review presented in Chapter 3 highlighted that there is only one prospective cohort study that have investigated PHP prognosis, in this case over 15 years with a limited number of variables - 9 prognostic factors being investigated in total (8). Therefore, it is important to understand long term prognostic factors so that the most appropriate intervention can be recommended for people with chronic PHP. Also, future prospective cohort studies could investigate PHP recurrence, as an explanation for PHP re-injury is still lacking, despite its high occurrence.

The third area of future research is to investigate external validity of the current and previous models. Developing prognostic models is a process with several steps; starting from evaluation of prognostic factors, followed by development of model and validation of it (126, 127). It should be emphasised that the current evidence base is relevant only to the initial stage of prognostic research (model development), none of them followed the next steps of this process to validate a prognostic model. Therefore, second and third phase prognostic studies from the derivation stage of design are clearly needed for the validity and incorporating these outcome predictors to be reliably included into a targeted intervention strategy. Finally, future research could focus on model usability via websites or mobile applications to make the screening, monitoring and managing easier.

8.4 Conclusion

This thesis found that prognostic factors for recovery of plantar heel pain are mainly reported as being physical in the previous literature. Also, there was a noticeable gap that no study investigated psychosocial variables for PHP prognosis. My online questionnaire considering a wide range of biopsychosocial variables and was valid for remote monitoring of patients for clinical and research purposes, including the cohort study. The developmental models showed severity and recovery are not just determined by physical features of the presentation.

Patients presenting with PHP of long duration who score worse on the foot health section of the FHSQ have a poorer prognosis, irrespective of age, sex and other demographic variables and, should therefore be included in any assessment of a new patient diagnosed with PHP. It may be that strategies designed to prevent chronicity, or the development of more severe PHP, may optimise prognosis. When recommending interventions to patients, health professionals should consider patients' conditions from a broad of psychosocial as well as biomedical perspective. Finally, it is important to note that PHP is not a self-limiting condition as previously claimed. Therefore, early intervention considering the factors (such as severity, disease duration, education level and future condition belief) may be essential to prevent chronicity and detrimental effect of PHP on quality of life. Most importantly,

my work has provided the only robust prognostic evidence about any biopsychosocial factors for PHP.

REFERENCES

1. Thomas MJ, Whittle R, Menz HB, Rathod-Mistry T, Marshall M, Roddy E. Plantar heel pain in middle-aged and older adults: population prevalence, associations with health status and lifestyle factors, and frequency of healthcare use. BMC musculoskeletal disorders. 2019;20(1):337.
2. McPoil TG, Martin RL, Cornwall MW, Wukich DK, Irrgang JJ, Godges JJ. Heel pain—plantar fasciitis. journal of orthopaedic & sports physical therapy. 2008;38(4):A1-A18.
3. Cotchett M, Rathleff MS, Dilnot M, Landorf KB, Morrissey D, Barton C. Lived experience and attitudes of people with plantar heel pain: a qualitative exploration. Journal of foot and ankle research. 2020;13(1):1-9.
4. Morrissey D, Cotchett M, J'Bari AS, Prior T, Vicenzino B, Griffiths I, et al. Management of plantar heel pain: a best practice guide synthesising systematic review with expert clinical reasoning and patient values. 2020.
5. Landorf B, Menz B. Plantar heel pain and fasciitis. BMJ Clinical Evidence. 2008;2008.
6. Radford JA, Landorf KB, Buchbinder R, Cook C. Effectiveness of calf muscle stretching for the short-term treatment of plantar heel pain: a randomised trial. BMC musculoskeletal disorders. 2007;8(1):1-8.
7. Salvioli S, Guidi M, Marcotulli G. The effectiveness of conservative, non-pharmacological treatment, of plantar heel pain: A systematic review with meta-analysis. The Foot. 2017;33:57-67.
8. Hansen L, Krogh TP, Ellingsen T, Bolvig L, Fredberg U. Long-term prognosis of plantar fasciitis: a 5-to 15-year follow-up study of 174 patients with ultrasound examination. Orthopaedic journal of sports medicine. 2018;6(3):2325967118757983.
9. Excellence NIfC. Principles for best practice in clinical audit: Radcliffe publishing; 2002.
10. Iorio A, Spencer FA, Falavigna M, Alba C, Lang E, Burnand B, et al. Use of GRADE for assessment of evidence about prognosis: rating confidence in estimates of event rates in broad categories of patients. bmj. 2015;350:h870.
11. Riel H, Cotchett M, Delahunt E, Rathleff MS, Vicenzino B, Weir A, et al. Is 'plantar heel pain'a more appropriate term than 'plantar fasciitis'? Time to move on. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine; 2017. p. 1576-7.
12. Morrissey D, Cotchett M, Said J'Bari A, Prior T, Griffiths IB, Rathleff MS, et al. Management of plantar heel pain: a best practice guide informed by a systematic review, expert clinical reasoning and patient values. British Journal of Sports Medicine. 2021:bjsports-2019-101970.
13. Martin RL, Davenport TE, Reischl SF, McPoil TG, Matheson JW, Wukich DK, et al. Heel pain—plantar fasciitis: revision 2014. Journal of Orthopaedic & Sports Physical Therapy. 2014;44(11):A1-A33.
14. Wearing SC, Smeathers JE, Urry SR, Hennig EM, Hills AP. The pathomechanics of plantar fasciitis. Sports Medicine. 2006;36(7):585-611.
15. Bhogal G. Plantar fasciitis in a Professional Boxer. 2012.

16. Viel E, Esnault M. The effect of increased tension in the plantar fascia: a biomechanical analysis. Physiother Pract. 1989;5:69-73.
17. Cralley J, Schuberth J, Fitch K. The deep band of the plantar aponeurosis of the human foot. Anatomischer Anzeiger. 1982;152(2):189-97.
18. Kelikian AS, Sarrafian SK. Sarrafian's anatomy of the foot and ankle: descriptive, topographic, functional: Lippincott Williams & Wilkins; 2011.
19. Stecco C, Corradin M, Macchi V, Morra A, Porzionato A, Biz C, et al. Plantar fascia anatomy and its relationship with A chilles tendon and paratenon. Journal of anatomy. 2013;223(6):665-76.
20. Zhang J, Nie D, Rocha JL, Hogan MV, Wang JH. Characterization of the structure, cells, and cellular mechanobiological response of human plantar fascia. Journal of tissue engineering. 2018;9:2041731418801103.
21. Snow SW, Bohne WH, DiCarlo E, Chang VK. Anatomy of the Achilles tendon and plantar fascia in relation to the calcaneus in various age groups. Foot & ankle international. 1995;16(7):418-21.
22. Mann RA, Haskell A. Biomechanics of the foot and ankle. Surgery of the foot and ankle 6th ed St Louis: Mosby. 1993;1993:29.
23. Hicks J. The mechanics of the foot: II. The plantar aponeurosis and the arch. Journal of anatomy. 1954;88(Pt 1):25.
24. Pohl MB, Hamill J, Davis IS. Biomechanical and anatomic factors associated with a history of plantar fasciitis in female runners. Clinical Journal of Sport Medicine. 2009;19(5):372-6.
25. Ker R, Bennett M, Bibby S, Kester R, Alexander RM. The spring in the arch of the human foot. Nature. 1987;325(6100):147-9.
26. Erdemir A, Hamel AJ, Fauth AR, Piazza SJ, Sharkey NA. Dynamic loading of the plantar aponeurosis in walking. JBJS. 2004;86(3):546-52.
27. Simkin A, Leichter I. Role of the calcaneal inclination in the energy storage capacity of the human foot—a biomechanical model. Medical and Biological Engineering and Computing. 1990;28(2):149-52.
28. Warren BL. Plantar fasciitis in runners. Sports Medicine. 1990;10(5):338-45.
29. Jacques P, Lambrecht S, Verheugen E, Pauwels E, Kollias G, Armaka M, et al. Proof of concept: enthesitis and new bone formation in spondyloarthritis are driven by mechanical strain and stromal cells. Annals of the rheumatic diseases. 2014;73(2):437-45.
30. MacAuley D, Best TM. Evidence-based sports medicine: Wiley Online Library; 2007.
31. Newell SG, Miller SJ. Conservative treatment of plantar fascial strain. The Physician and sportsmedicine. 1977;5(11):68-73.
32. Kumar V, Abbas A, Fausto N, Aster J. Robbins and cotran pathologic basis of disease. 8th. Philadelphia: Ed Saunders Elsevier. 2010:1-12.
33. Chuckpaiwong B, Berkson EM, Theodore GH. Extracorporeal shock wave for chronic proximal plantar fasciitis: 225 patients with results and outcome predictors. The journal of foot and ankle surgery. 2009;48(2):148-55.
34. DiGiovanni BF, Nawoczenski DA, Lintal ME, Moore EA, Murray JC, Wilding GE, et al. Tissue-specific plantar fascia-stretching exercise enhances outcomes in patients with chronic heel pain: a prospective, randomized study. JBJS. 2003;85(7):1270-7.

35. Lynch DM, Goforth W, Martin J, Odom R, Preece C, Kotter M. Conservative treatment of plantar fasciitis. A prospective study. Journal of the American Podiatric Medical Association. 1998;88(8):375-80.
36. Gerdesmeyer L, Frey C, Vester J, Maier M, Lowell Jr W, Weil Sr L, et al. Radial extracorporeal shock wave therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis: results of a confirmatory randomized placebo-controlled multicenter study. The American journal of sports medicine. 2008;36(11):2100-9.
37. McClinton SM, Cleland JA, Flynn TW. Predictors of response to physical therapy intervention for plantar heel pain. Foot & Ankle International. 2015;36(4):408-16.
38. Landorf KB, Keenan AM, Herbert RD. Effectiveness of foot orthoses to treat plantar fasciitis: a randomized trial. Archives of Internal Medicine. 2006;166(12):1305-10.
39. Bishop C, Thewlis D, Hillier S. Custom foot orthoses improve first-step pain in individuals with unilateral plantar fasciopathy: a pragmatic randomised controlled trial. BMC Musculoskeletal Disorders 2018;19(222).
40. Oliveira HA, Jones A, Moreira E, Jennings F, Natour J. Effectiveness of total contact insoles in patients with plantar fasciitis. Journal of Rheumatology. 2015;42(5):870-8.
41. Wrobel JS, Fleischer AE, Crews RT, Jarrett B, Najafi B. A randomized controlled trial of custom foot orthoses for the treatment of plantar heel pain. Journal of the American Podiatric Medical Association. 2015;105(4):281-94.
42. Baldassin V, Gomes CR, Beraldo PS. Effectiveness of prefabricated and customized foot orthoses made from low-cost foam for noncomplicated plantar fasciitis: a randomized controlled trial. Archives of Physical Medicine & Rehabilitation. 2009;90(4):701-6.
43. Winemiller MH, Billow RG, Laskowski ER, Harmsen WS. Effect of magnetic vs sham-magnetic insoles on plantar heel pain: a randomized controlled trial. Journal of the American Medical Association. 2003;290(11):1474-8.
44. Gerdesmeyer L, Frey C, Vester J, Maier M, Weil L, Jr., Weil L, Sr., et al. Radial extracorporeal shock wave therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis: results of a confirmatory randomized placebo-controlled multicenter study. American Journal of Sports Medicine. 2008;36(11):2100-9.
45. Ibrahim MI, Donatelli RA, Hellman M, Hussein AZ, Furia JP, Schmitz C. Long-term results of radial extracorporeal shock wave treatment for chronic plantar fasciopathy: A prospective, randomized, placebo-controlled trial with two years follow-up. Journal of Orthopaedic Research. 2017;35(7):1532-8.
46. Hocaoglu S, Vurdem UE, Cebicci MA, Sutbeyaz ST, Guldeste Z, Yunsuroglu SG. Comparative effectiveness of radial extracorporeal shockwave therapy and ultrasound-guided local corticosteroid injection treatment for plantar fasciitis. Journal of the American Podiatric Medical Association. 2017;107(3):192-9.
47. Lohrer H, Nauck T, Dorn-Lange NV, Scholl J, Vester JC. Comparison of radial versus focused extracorporeal shock waves in plantar fasciitis using functional measures. Foot & Ankle International. 2010;31(1):1-9.

48. Rompe JD, Cacchio A, Weil L, Jr., Furia JP, Haist J, Reiners V, et al. Plantar fascia-specific stretching versus radial shock-wave therapy as initial treatment of plantar fasciopathy. Journal of Bone & Joint Surgery - American Volume. 2010;92(15):2514-22.
49. Gollwitzer H, Saxena A, DiDomenico LA, Galli L, Bouche RT, Caminear DS, et al. Clinically relevant effectiveness of focused extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis: a randomized, controlled multicenter study. Journal of Bone & Joint Surgery - American Volume. 2015;97(9):701-8.
50. Speed CA, Nichols D, Wies J, Humphreys H, Richards C, Burnet S, et al. Extracorporeal shock wave therapy for plantar fasciitis. A double blind randomised controlled trial. Journal of Orthopaedic Research. 2003;21(5):937-40.
51. Gollwitzer H, Diehl P, von Korff A, Rahlfs VW, Gerdesmeyer L. Extracorporeal shock wave therapy for chronic painful heel syndrome: a prospective, double blind, randomized trial assessing the efficacy of a new electromagnetic shock wave device. Journal of Foot & Ankle Surgery. 2007;46(5):348-57.
52. Rompe JD, Decking J, Schoellner C, Nafe B. Shock wave application for chronic plantar fasciitis in running athletes. A prospective, randomized, placebo-controlled trial. American Journal of Sports Medicine. 2003;31(2):268-75.
53. Kudo P, Dainty K, Clarfield M, Coughlin L, Lavoie P, Lebrun C. Randomized, placebo-controlled, double-blind clinical trial evaluating the treatment of plantar fasciitis with an extracoporeal shockwave therapy (ESWT) device: a North American confirmatory study. Journal of Orthopaedic Research. 2006;24(2):115-23.
54. Rompe JD, Meurer A, Nafe B, Hofmann A, Gerdesmeyer L. Repetitive low-energy shock wave application without local anesthesia is more efficient than repetitive low-energy shock wave application with local anesthesia in the treatment of chronic plantar fasciitis. Journal of Orthopaedic Research. 2005;23(4):931-41.
55. Cotchett MP, Munteanu SE, Landorf KB. Effectiveness of trigger point dry needling for plantar heel pain: a randomized controlled trial. Phys Ther. 2014;94(8):1083-94.
56. Young MA, Cook JL, Webster KE. The effect of topical wheatgrass cream on chronic plantar fasciitis: a randomized, double-blind, placebo-controlled trial. Complementary Therapies in Medicine. 2006;14(1):3-9.
57. Radford JA, Landorf KB, Buchbinder R, Cook C. Effectiveness of calf muscle stretching for the short-term treatment of plantar heel pain: a randomised trial. BMC Musculoskeletal Disorders. 2007;8:36.
58. Radford JA, Landorf KB, Buchbinder R, Cook C. Effectiveness of low-Dye taping for the short-term treatment of plantar heel pain: a randomised trial. BMC Musculoskeletal Disorders. 2006;7:64.
59. Elston CW, Ellis IO. Pathological prognostic factors in breast cancer. I. The value of histological grade in breast cancer: experience from a large study with long-term follow-up. CW Elston & IO Ellis. Histopathology 1991; 19; 403–410: AUTHOR COMMENTARY. Histopathology. 2002;41(3a):151-.
60. Peul WC, Brand R, Thomeer RT, Koes BW. Influence of gender and other prognostic factors on outcome of sciatica. Pain. 2008;138(1):180-91.
61. Coste J, Delecoeuillerie G, De Lara AC, LeParc J, Paolaggi J. Clinical course and prognostic factors in acute low back pain: an inception cohort study in primary care practice. Bmj. 1994;308(6928):577-80.

62. Borghouts JA, Koes BW, Bouter LM. The clinical course and prognostic factors of non-specific neck pain: a systematic review. Pain. 1998;77(1):1-13.
63. Carroll LJ, Hogg-Johnson S, van der Velde G, Haldeman S, Holm LW, Carragee EJ, et al. Course and prognostic factors for neck pain in the general population: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. Journal of manipulative and physiological therapeutics. 2009;32(2):S87-S96.
64. Irving DB, Cook JL, Menz HB. Factors associated with chronic plantar heel pain: a systematic review. Journal of science and medicine in sport. 2006;9(1-2):11-22.
65. Irving DB, Cook JL, Young MA, Menz HB. Obesity and pronated foot type may increase the risk of chronic plantar heel pain: a matched case-control study. BMC musculoskeletal disorders. 2007;8(1):41.
66. Wu F-L, Shih Y-F, Lee S-H, Luo H-J, Wang WT-J. Development of a clinical prediction rule to identify patients with plantar heel pain likely to benefit from biomechanical anti-pronation taping: A prospective cohort study. Physical Therapy in Sport. 2018;31:58-67.
67. Moore SD. Predictors of Outcome Following Standardized Rehabilitation for Patients with Shoulder Pain. 2013.
68. Dunn J, Link C, Felson D, Crincoli M, Keysor J, McKinlay J. Prevalence of foot and ankle conditions in a multiethnic community sample of older adults. American journal of epidemiology. 2004;159(5):491-8.
69. Hill CL, Gill TK, Menz HB, Taylor AW. Prevalence and correlates of foot pain in a population-based study: the North West Adelaide health study. Journal of foot and ankle research. 2008;1(1):2.
70. Menz HB, Tiedemann A, Kwan M, Plumb K, Lord SR. Foot pain in community-dwelling older people: an evaluation of the Manchester Foot Pain and Disability Index. Rheumatology. 2006;45(7):863-7.
71. Irving DB, Cook JL, Young MA, Menz HB. Impact of chronic plantar heel pain on health-related quality of life. Journal of the American Podiatric Medical Association. 2008;98(4):283-9.
72. Matthews M, Rathleff MS, Claus A, McPoil T, Nee R, Crossley K, et al. Can we predict the outcome for people with patellofemoral pain? A systematic review on prognostic factors and treatment effect modifiers. British Journal of Sports Medicine. 2017;51(23):1650-60.
73. Mallows A, Debenham J, Walker T, Littlewood C. Association of psychological variables and outcome in tendinopathy: a systematic review. British journal of sports medicine. 2017;51(9):743-8.
74. Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Annals of internal medicine. 2015;162(11):777-84.
75. Riley RD, Moons KG, Snell KI, Ensor J, Hooft L, Altman DG, et al. A guide to systematic review and meta-analysis of prognostic factor studies. Bmj. 2019;364.
76. Van Leeuwen K, Rogers J, Winzenberg T, van Middelkoop M. Higher body mass index is associated with plantar fasciopathy/'plantar fasciitis': systematic

review and meta-analysis of various clinical and imaging risk factors. Br J Sports Med. 2016;50(16):972-81.
77. Cook C, Brismée J-M, Pietrobon R, Sizer Jr P, Hegedus E, Riddle DL. Development of a quality checklist using Delphi methods for prescriptive clinical prediction rules: the QUADCPR. Journal of manipulative and physiological therapeutics. 2010;33(1):29-41.
78. Genaidy A, Lemasters G, Lockey J, Succop P, Deddens J, Sobeih T, et al. An epidemiological appraisal instrument–a tool for evaluation of epidemiological studies. Ergonomics. 2007;50(6):920-60.
79. Hayden JA, van der Windt DA, Cartwright JL, Côté P, Bombardier C. Assessing bias in studies of prognostic factors. Annals of internal medicine. 2013;158(4):280-6.
80. Büttner F, Winters M, Delahunt E, Elbers R, Lura CB, Khan KM, et al. Identifying the 'incredible'! Part 2: Spot the difference-a rigorous risk of bias assessment can alter the main findings of a systematic review. British journal of sports medicine. 2020;54(13):801-8.
81. Moons KG, de Groot JA, Bouwmeester W, Vergouwe Y, Mallett S, Altman DG, et al. Critical appraisal and data extraction for systematic reviews of prediction modelling studies: the CHARMS checklist. PLoS Med. 2014;11(10):e1001744.
82. Rubinstein ML, Kraft CS, Parrott JS. Determining qualitative effect size ratings using a likelihood ratio scatter matrix in diagnostic test accuracy systematic reviews. Diagnosis. 2018;5(4):205-14.
83. Menard S. Applied logistic regression analysis: Sage; 2002.
84. Azuero A. A note on the magnitude of hazard ratios. Cancer. 2016;122(8):1298-9.
85. Huguet A, Hayden JA, Stinson J, McGrath PJ, Chambers CT, Tougas ME, et al. Judging the quality of evidence in reviews of prognostic factor research: adapting the GRADE framework. Systematic reviews. 2013;2(1):71.
86. Scheuer R, Friedrich M, Hahne J, Holzapfel J, Machacek P, Ogon M, et al. Approaches to optimize focused extracorporeal shockwave therapy (ESWT) based on an observational study of 363 feet with recalcitrant plantar fasciitis. International Journal of surgery. 2016;27:1-7.
87. Micke O, Seegenschmiedt MH, Diseases GCGoRfB. Radiotherapy in painful heel spurs (plantar fasciitis)—results of a national patterns of care study. International Journal of Radiation Oncology* Biology* Physics. 2004;58(3):828-43.
88. Martin RL, Irrgang JJ, Conti SF. Outcome study of subjects with insertional plantar fasciitis. Foot & ankle international. 1998;19(12):803-11.
89. Muecke R, Micke O, Reichl B, Heyder R, Prott F-J, Seegenschmiedt MH, et al. Demographic, clinical and treatment related predictors for event-free probability following low-dose radiotherapy for painful heel spurs–a retrospective multicenter study of 502 patients. Acta oncologica. 2007;46(2):239-46.
90. Wolgin M, Cook C, Graham C, Mauldin D. Conservative treatment of plantar heel pain: long-term follow-up. Foot & ankle international. 1994;15(3):97-102.
91. Koca T, Aydın A, Sezen D, Başaran H, Karaca S. Painful plantar heel spur treatment with Co-60 teletherapy: factors influencing treatment outcome. Springerplus. 2014;3(1):1-4.

92. Wu F-L, Shih Y-F, Lee S-H, Luo H-J, Wang WT-J. Can short-term effectiveness of anti-pronation taping predict the long-term outcomes of customized foot orthoses: developing predictors to identify characteristics of patients with plantar heel pain likely to benefit from customized foot orthoses. BMC musculoskeletal disorders. 2019;20(1):264.
93. Yin M, Ma J, Xu J, Li L, Chen G, Sun Z, et al. Use of artificial neural networks to identify the predictive factors of extracorporeal shock wave therapy treating patients with chronic plantar fasciitis. Scientific reports. 2019;9(1):1-8.
94. Yin M, Chen N, Huang Q, Marla AS, Ma J, Ye J, et al. New and accurate predictive model for the efficacy of extracorporeal shock wave therapy in managing patients with chronic plantar fasciitis. Archives of physical medicine and rehabilitation. 2017;98(12):2371-7.
95. Wrobel JS, Fleischer AE, Matzkin-Bridger J, Fascione J, Crews RT, Bruning N, et al. Physical examination variables predict response to conservative treatment of nonchronic plantar fasciitis: secondary analysis of a randomized, placebo-controlled footwear study. PM&R. 2016;8(5):436-44.
96. Liang H-W, Wang T-G, Chen W-S, Hou S-M. Thinner plantar fascia predicts decreased pain after extracorporeal shock wave therapy. Clinical Orthopaedics and Related Research (1976-2007). 2007;460:219-25.
97. Roca B, Mendoza MA, Roca M. Comparison of extracorporeal shock wave therapy with botulinum toxin type A in the treatment of plantar fasciitis. Disability and rehabilitation. 2016;38(21):2114-21.
98. Fleischer AE, Albright RH, Crews RT, Kelil T, Wrobel JS. Prognostic value of diagnostic sonography in patients with plantar fasciitis. Journal of Ultrasound in Medicine. 2015;34(10):1729-35.
99. Canyilmaz E, Canyilmaz F, Aynaci O, Colak F, Serdar L, Uslu GH, et al. Prospective randomized comparison of the effectiveness of radiation therapy and local steroid injection for the treatment of plantar fasciitis. International Journal of Radiation Oncology* Biology* Physics. 2015;92(3):659-66.
100. Schneider O, Stückle CA, Bosch E, Gott C, Adamietz IA. Effectiveness and prognostic factors of radiotherapy for painful plantar heel spurs. Strahlentherapie und Onkologie. 2004;180(8):502-9.
101. Macaluso A, De Vito G. Muscle strength, power and adaptations to resistance training in older people. European journal of applied physiology. 2004;91(4):450-72.
102. Mitchell WK, Atherton PJ, Williams J, Larvin M, Lund JN, Narici M. Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. Frontiers in physiology. 2012;3:260.
103. Bartley EJ, Fillingim RB. Sex differences in pain: a brief review of clinical and experimental findings. British journal of anaesthesia. 2013;111(1):52-8.
104. Artus M, Campbell P, Mallen CD, Dunn KM, van der Windt DA. Generic prognostic factors for musculoskeletal pain in primary care: a systematic review. BMJ open. 2017;7(1).
105. Beeson P. Plantar fasciopathy: revisiting the risk factors. Foot and ankle surgery. 2014;20(3):160-5.

106. Irving DB, Cook JL, Young MA, Menz HB. Obesity and pronated foot type may increase the risk of chronic plantar heel pain: a matched case-control study. BMC musculoskeletal disorders. 2007;8(1):1-8.
107. Irving D, Cook J, Menz H. Factors associated with chronic plantar heel pain: A matched case–control study. Journal of Science and Medicine in Sport. 2006;9:7.
108. Phillips A, McClinton S. Gait deviations associated with plantar heel pain: a systematic review. Clinical Biomechanics. 2017;42:55-64.
109. Hossain M, Makwana N. "Not Plantar Fasciitis": the differential diagnosis and management of heel pain syndrome. Orthopaedics and trauma. 2011;25(3):198-206.
110. O'Leary H, Smart KM, Moloney NA, Doody CM. Nervous system sensitization as a predictor of outcome in the treatment of peripheral musculoskeletal conditions: a systematic review. Pain practice. 2017;17(2):249-66.
111. Meier K, McPoil TG, Cornwall MW, Lyle T. Use of antipronation taping to determine foot orthoses prescription: a case series. Research in sports medicine. 2008;16(4):257-71.
112. Vicenzino B. Foot orthotics in the treatment of lower limb conditions: a musculoskeletal physiotherapy perspective. Manual therapy. 2004;9(4):185-96.
113. Martin RL, Irrgang JJ. A survey of self-reported outcome instruments for the foot and ankle. Journal of Orthopaedic & Sports Physical Therapy. 2007;37(2):72-84.
114. Yates B, White S. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. The American journal of sports medicine. 2004;32(3):772-80.
115. Resende RA, Deluzio KJ, Kirkwood RN, Hassan EA, Fonseca ST. Increased unilateral foot pronation affects lower limbs and pelvic biomechanics during walking. Gait & posture. 2015;41(2):395-401.
116. Lee MS, Vanore JV, Thomas JL, Catanzariti AR, Kogler G, Kravitz SR, et al. Diagnosis and treatment of adult flatfoot. The Journal of Foot and Ankle Surgery. 2005;44(2):78-113.
117. Hollman JH, Kolbeck KE, Hitchcock JL, Koverman JW, Krause DA. Correlations between hip strength and static foot and knee posture. Journal of Sport Rehabilitation. 2006;15(1):12-23.
118. Cheung RT, Chung RC, Ng GY. Efficacies of different external controls for excessive foot pronation: a meta-analysis. British journal of sports medicine. 2011;45(9):743-51.
119. Turner DE, Helliwell PS, Siegel KL, Woodburn J. Biomechanics of the foot in rheumatoid arthritis: identifying abnormal function and the factors associated with localised disease 'impact'. Clinical Biomechanics. 2008;23(1):93-100.
120. Truong LK, Mosewich AD, Holt CJ, Le CY, Miciak M, Whittaker JL. Psychological, social and contextual factors across recovery stages following a sport-related knee injury: a scoping review. British journal of sports medicine. 2020;54(19):1149-56.
121. Cotchett MP, Whittaker G, Erbas B. Psychological variables associated with foot function and foot pain in patients with plantar heel pain. Clinical rheumatology. 2015;34(5):957-64.

122. Averill PM, Novy DM, Nelson DV, Berry LA. Correlates of depression in chronic pain patients: a comprehensive examination. Pain. 1996;65(1):93-100.
123. Foster NE, Delitto A. Embedding psychosocial perspectives within clinical management of low back pain: integration of psychosocially informed management principles into physical therapist practice—challenges and opportunities. Physical therapy. 2011;91(5):790-803.
124. Fritz JM, George SZ. Identifying psychosocial variables in patients with acute work-related low back pain: the importance of fear-avoidance beliefs. Physical therapy. 2002;82(10):973-83.
125. Priore LB, Lack S, Garcia C, Azevedo FM, de Oliveira Silva D. Two weeks of wearing a knee brace compared with minimal intervention on kinesiophobia at 2 and 6 weeks in people with patellofemoral pain: a randomized controlled trial. Archives of physical medicine and rehabilitation. 2020;101(4):613-23.
126. Steyerberg EW, Moons KG, van der Windt DA, Hayden JA, Perel P, Schroter S, et al. Prognosis Research Strategy (PROGRESS) 3: prognostic model research. PLoS Med. 2013;10(2):e1001381.
127. Riley RD, Hayden JA, Steyerberg EW, Moons KG, Abrams K, Kyzas PA, et al. Prognosis Research Strategy (PROGRESS) 2: prognostic factor research. PLoS Med. 2013;10(2):e1001380.
128. Ritchie J, Spencer L. Qualitative data analysis for applied policy research. The qualitative researcher's companion. 2002;573(2002):305-29.
129. Draghi F, Gitto S, Bortolotto C, Draghi AG, Belometti GO. Imaging of plantar fascia disorders: findings on plain radiography, ultrasound and magnetic resonance imaging. Insights into imaging. 2017;8(1):69-78.
130. Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC medical research methodology. 2008;8(1):1-10.
131. Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot & Ankle International. 2001;22(10):788-94.
132. Sullivan MJ, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. Psychological assessment. 1995;7(4):524.
133. George SZ, Stryker SE. Fear-avoidance beliefs and clinical outcomes for patients seeking outpatient physical therapy for musculoskeletal pain conditions. journal of orthopaedic & sports physical therapy. 2011;41(4):249-59.
134. Cotchett M, Lennecke A, Medica VG, Whittaker GA, Bonanno DR. The association between pain catastrophising and kinesiophobia with pain and function in people with plantar heel pain. The Foot. 2017;32:8-14.
135. Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). Journal of Public Health. 2006;14(2):66-70.
136. Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Quality of life research. 2011;20(10):1727-36.
137. Kvien TK, Heiberg T, Hagen KB. Minimal clinically important improvement/difference (MCII/MCID) and patient acceptable symptom state (PASS): what do these concepts mean? Annals of the rheumatic diseases. 2007;66(suppl 3):iii40-iii1.

138. Williams GN, Taylor DC, Gangel TJ, Uhorchak JM, Arciero RA. Comparison of the single assessment numeric evaluation method and the Lysholm score. Clinical Orthopaedics and Related Research®. 2000;373:184-92.
139. Sengkerij PM, de Vos R-J, Weir A, van Weelde BJ, Tol JL. Interobserver reliability of neovascularization score using power Doppler ultrasonography in midportion achilles tendinopathy. The American journal of sports medicine. 2009;37(8):1627-31.
140. Buchbinder R. Plantar fasciitis. New England Journal of Medicine. 2004;350(21):2159-66.
141. Babatunde OO, Legha A, Littlewood C, Chesterton LS, Thomas MJ, Menz HB, et al. Comparative effectiveness of treatment options for plantar heel pain: a systematic review with network meta-analysis. British journal of sports medicine. 2019;53(3):182-94.
142. Whittaker GA, Munteanu SE, Menz HB, Tan JM, Rabusin CL, Landorf KB. Foot orthoses for plantar heel pain: a systematic review and meta-analysis. Br J Sports Med. 2018;52(5):322-8.
143. Cotchett M, Munteanu SE, Landorf KB. Depression, anxiety, and stress in people with and without plantar heel pain. Foot & ankle international. 2016;37(8):816-21.
144. Harutaichun P, Boonyong S, Pensri P. Predictors of plantar fasciitis in Thai novice conscripts after 10-week military training: A prospective study. Physical Therapy in Sport. 2019;35:29-35.
145. Drake C, Mallows A, Littlewood C. Psychosocial variables and presence, severity and prognosis of plantar heel pain: A systematic review of cross-sectional and prognostic associations. Musculoskeletal care. 2018;16(3):329-38.
146. Hill JC, Whitehurst DG, Lewis M, Bryan S, Dunn KM, Foster NE, et al. Comparison of stratified primary care management for low back pain with current best practice (STarT Back): a randomised controlled trial. The Lancet. 2011;378(9802):1560-71.
147. Coons SJ, Gwaltney CJ, Hays RD, Lundy JJ, Sloan JA, Revicki DA, et al. Recommendations on evidence needed to support measurement equivalence between electronic and paper-based patient-reported outcome (PRO) measures: ISPOR ePRO Good Research Practices Task Force report. Value in Health. 2009;12(4):419-29.
148. Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. Pilot and feasibility studies. 2016;2(1):64.
149. Negahban H, Mazaheri M, Salavati M, Sohani SM, Askari M, Fanian H, et al. Reliability and validity of the foot and ankle outcome score: a validation study from Iran. Clinical rheumatology. 2010;29(5):479-86.
150. Scott W, Wideman TH, Sullivan MJ. Clinically meaningful scores on pain catastrophizing before and after multidisciplinary rehabilitation: a prospective study of individuals with subacute pain after whiplash injury. The Clinical journal of pain. 2014;30(3):183-90.
151. Osman A, Barrios FX, Gutierrez PM, Kopper BA, Merrifield T, Grittmann L. The Pain Catastrophizing Scale: further psychometric evaluation with adult samples. Journal of behavioral medicine. 2000;23(4):351-65.

152. Osman A, Barrios FX, Kopper BA, Hauptmann W, Jones J, O'Neill E. Factor structure, reliability, and validity of the Pain Catastrophizing Scale. Journal of behavioral medicine. 1997;20(6):589-605.
153. Mccracken LM, Gross RT, Aikens J, Carnrike Jr C. The assessment of anxiety and fear in persons with chronic pain: a comparison of instruments. Behaviour research and therapy. 1996;34(11-12):927-33.
154. Jacob T, Baras M, Zeev A, Epstein L. Low back pain: reliability of a set of pain measurement tools. Archives of physical medicine and rehabilitation. 2001;82(6):735-42.
155. Swinkels-Meewisse E, Swinkels R, Verbeek A, Vlaeyen J, Oostendorp R. Psychometric properties of the Tampa Scale for kinesiophobia and the fear-avoidance beliefs questionnaire in acute low back pain. Manual therapy. 2003;8(1):29-36.
156. Cleland JA, Fritz JM, Brennan GP. Predictive validity of initial fear avoidance beliefs in patients with low back pain receiving physical therapy: is the FABQ a useful screening tool for identifying patients at risk for a poor recovery? European Spine Journal. 2008;17(1):70-9.
157. Herrmann SD, Heumann KJ, Der Ananian CA, Ainsworth BE. Validity and reliability of the global physical activity questionnaire (GPAQ). Measurement in Physical Education and Exercise Science. 2013;17(3):221-35.
158. Dolan P. Modeling valuations for EuroQol health states. Medical care. 1997:1095-108.
159. Simoneau GG, Hoenig KJ, Lepley JE, Papanek PE. Influence of hip position and gender on active hip internal and external rotation. Journal of Orthopaedic & Sports Physical Therapy. 1998;28(3):158-64.
160. Brukner P. Brukner & Khan's clinical sports medicine: McGraw-Hill North Ryde; 2012.
161. Wrobel JS, Connolly JE, Beach ML. Associations between static and functional measures of joint function in the foot and ankle. Journal of the American Podiatric Medical Association. 2004;94(6):535-41.
162. Chimenti R, Forenza A, Previte E, Tome J, Nawoczenski D. Forefoot and rearfoot contributions to the lunge position in individuals with and without insertional Achilles tendinopathy. Clinical Biomechanics. 2016;36:40-5.
163. Williams DS, McClay IS. Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. Physical therapy. 2000;80(9):864-71.
164. Leardini A, Benedetti MG, Berti L, Bettinelli D, Nativo R, Giannini S. Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. Gait & posture. 2007;25(3):453-62.
165. López-López D, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, Palomo-López P, Rodríguez-Sanz D, Brandariz-Pereira JM, et al. Evaluation of foot health related quality of life in individuals with foot problems by gender: a cross-sectional comparative analysis study. BMJ open. 2018;8(10):e023980.
166. Zou G. Sample size formulas for estimating intraclass correlation coefficients with precision and assurance. Statistics in medicine. 2012;31(29):3972-81.

167. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. International journal of nursing studies. 2010;47(8):931-6.
168. Cohen J. Statistical power analysis for the behavioral sciences: Routledge; 2013.
169. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of chiropractic medicine. 2016;15(2):155-63.
170. Bakker M, Wicherts JM. Outlier removal, sum scores, and the inflation of the type I error rate in independent samples t tests: The power of alternatives and recommendations. Psychological methods. 2014;19(3):409.
171. Stankevitz D, Larkins L, Baker R. Electronic Patient-Reported Outcome Validation: Disablement in the Physically Active Scale. Journal of athletic training. 2019.
172. Muehlhausen W, Doll H, Quadri N, Fordham B, O'Donohoe P, Dogar N, et al. Equivalence of electronic and paper administration of patient-reported outcome measures: a systematic review and meta-analysis of studies conducted between 2007 and 2013. Health and quality of life outcomes. 2015;13(1):167.
173. Gwaltney CJ, Shields AL, Shiffman S. Equivalence of electronic and paper-and-pencil administration of patient-reported outcome measures: a meta-analytic review. Value in health. 2008;11(2):322-33.
174. Ritter P, Lorig K, Laurent D, Matthews K. Internet versus mailed questionnaires: a randomized comparison. Journal of Medical Internet Research. 2004;6(3).
175. Bishop FL, Lewis G, Harris S, McKay N, Prentice P, Thiel H, et al. A within-subjects trial to test the equivalence of online and paper outcome measures: the Roland Morris disability questionnaire. BMC musculoskeletal disorders. 2010;11(1):113.
176. Giavarina D. Understanding bland altman analysis. Biochemia medica: Biochemia medica. 2015;25(2):141-51.
177. Desai S, Peterson AC, Wing K, Younger A, Crump T, Liu G, et al. Minimally Important Difference in the Foot and Ankle Outcome Score Among Patients Undergoing Hallux Valgus Surgery. Foot & ankle international. 2019;40(6):694-701.
178. Xie B. Older adults, e-health literacy, and collaborative learning: An experimental study. Journal of the American Society for Information Science and Technology. 2011;62(5):933-46.
179. Wrobel JS, Armstrong DG. Reliability and validity of current physical examination techniques of the foot and ankle. Journal of the American Podiatric Medical Association. 2008;98(3):197-206.
180. Riddle DL, Pulisic M, Pidcoe P, Johnson RE. Risk factors for plantar fasciitis: a matched case-control study. JBJS. 2003;85(5):872-7.
181. Creighton DS, Olson VL. Evaluation of range of motion of the first metatarsophalangeal joint in runners with plantar faciitis. Journal of Orthopaedic & Sports Physical Therapy. 1987;8(7):357-61.
182. Wearing SC, Smeathers JE, Sullivan PM, Yates B, Urry SR, Dubois P. Plantar fasciitis: are pain and fascial thickness associated with arch shape and loading? Physical therapy. 2007;87(8):1002-8.

183. Schulz BW, Ashton-Miller JA, Alexander NB. The effects of age and step length on joint kinematics and kinetics of large out-and-back steps. Clinical Biomechanics. 2008;23(5):609-18.
184. Neto NCT, Lima YL, Almeida GPL, Bezerra MA, Lima PODP, de Oliveira RR. Physiotherapy questionnaires app to deliver main musculoskeletal assessment questionnaires: Development and validation study. JMIR rehabilitation and assistive technologies. 2018;5(1):e1.
185. Hyslop E, Woodburn J, McInnes IB, Semple R, Newcombe L, Hendry G, et al. A reliability study of biomechanical foot function in psoriatic arthritis based on a novel multi-segmented foot model. Gait & posture. 2010;32(4):619-26.
186. Horn KK, Jennings S, Richardson G, van Vliet D, Hefford C, Abbott JH. The patient-specific functional scale: psychometrics, clinimetrics, and application as a clinical outcome measure. journal of orthopaedic & sports physical therapy. 2012;42(1):30-42.
187. Taunton JE, Ryan MB, Clement D, McKenzie DC, Lloyd-Smith D, Zumbo B. A retrospective case-control analysis of 2002 running injuries. British journal of sports medicine. 2002;36(2):95-101.
188. Wearing SC, Smeathers JE, Yates B, Sullivan PM, Urry SR, Dubois P. Sagittal movement of the medial longitudinal arch is unchanged in plantar fasciitis. Medicine and science in sports and exercise. 2004;36(10):1761-7.
189. Ozdemir H, Yilmaz E, Murat A, Karakurt L, Poyraz AK, Ogur E. Sonographic evaluation of plantar fasciitis and relation to body mass index. European journal of radiology. 2005;54(3):443-7.
190. Kibler WB, Goldberg C, Chandler TJ. Functional biomechanical deficits in running athletes with plantar fasciitis. The American Journal of Sports Medicine. 1991;19(1):66-71.
191. Bumann A, Banzer W, Fleckenstein J. Prevalence of Biopsychosocial Factors of Pain in 865 Sports Students of the Dach (Germany, Austria, Switzerland) Region–A Cross-Sectional Survey. Journal of sports science & medicine. 2020;19(2):323.
192. Caneiro J, O'Sullivan PB, Roos EM, Smith AJ, Choong P, Dowsey M, et al. Three steps to changing the narrative about knee osteoarthritis care: a call to action. BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine; 2020.
193. Mitchell T, O'Sullivan PB, Smith A, Burnett AF, Straker L, Thornton J, et al. Biopsychosocial factors are associated with low back pain in female nursing students: a cross-sectional study. International journal of nursing studies. 2009;46(5):678-88.
194. Kamper SJ, Apeldoorn AT, Chiarotto A, Smeets RJ, Ostelo RW, Guzman J, et al. Multidisciplinary biopsychosocial rehabilitation for chronic low back pain. Cochrane Database of Systematic Reviews. 2014(9).
195. Van Leeuwen K, Rogers J, Winzenberg T, van Middelkoop M. Higher body mass index is associated with plantar fasciopathy/'plantar fasciitis': systematic review and meta-analysis of various clinical and imaging risk factors. British journal of sports medicine. 2016;50(16):972-81.
196. Gulle H, Prior T, Miller S, Birn-Jeffery AV, Morrissey D. Online questionnaire, clinical and biomechanical measurements for outcome prediction of plantar heel

pain: feasibility for a cohort study. Journal of Foot and Ankle Research. 2021;14(1):1-13.
197. Boudreau SA, Badsberg S, Christensen SW, Egsgaard LL. Digital pain drawings. The Clinical journal of pain. 2016;32(2):139-45.
198. Boudreau SA, Spence R, Vasov G, Egsgaard LL. Feature extraction APP for pain profiles. Replace, Repair, Restore, Relieve–Bridging Clinical and Engineering Solutions in Neurorehabilitation: Springer; 2014. p. 853-4.
199. Bennett PJ, Patterson C, Wearing S, Baglioni T. Development and validation of a questionnaire designed to measure foot-health status. Journal of the American Podiatric Medical Association. 1998;88(9):419-28.
200. Riskowski JL, Hagedorn TJ, Hannan MT. Measures of foot function, foot health, and foot pain: American Academy of Orthopedic Surgeons Lower Limb Outcomes Assessment: Foot and Ankle Module (AAOS-FAM), Bristol Foot Score (BFS), Revised Foot Function Index (FFI-R), Foot Health Status Questionnaire (FHSQ), Manchester Foot Pain and Disability Index (MFPDI), Podiatric Health Questionnaire (PHQ), and Rowan Foot Pain Assessment (ROFPAQ). Arthritis care & research. 2011;63(S11):S229-S39.
201. . !!! INVALID CITATION !!! [20, 22, 23].
202. Neblett R, Cohen H, Choi Y, Hartzell MM, Williams M, Mayer TG, et al. The Central Sensitization Inventory (CSI): establishing clinically significant values for identifying central sensitivity syndromes in an outpatient chronic pain sample. The Journal of Pain. 2013;14(5):438-45.
203. Crespo CJ, Smit E, Andersen RE, Carter-Pokras O, Ainsworth BE. Race/ethnicity, social class and their relation to physical inactivity during leisure time: results from the Third National Health and Nutrition Examination Survey, 1988–1994. American journal of preventive medicine. 2000;18(1):46-53.
204. Nguyen J, Moorhouse M, Curbow B, Christie J, Walsh-Childers K, Islam S. Construct validity of the eHealth literacy scale (eHEALS) among two adult populations: a Rasch analysis. JMIR public health and surveillance. 2016;2(1):e24.
205. Sullivan GM, Feinn R. Using effect size—or why the P value is not enough. Journal of graduate medical education. 2012;4(3):279.
206. O'brien RM. A caution regarding rules of thumb for variance inflation factors. Quality & quantity. 2007;41(5):673-90.
207. Turk DC, Dworkin RH, Revicki D, Harding G, Burke LB, Cella D, et al. Identifying important outcome domains for chronic pain clinical trials: an IMMPACT survey of people with pain. PAIN®. 2008;137(2):276-85.
208. Katz N. The impact of pain management on quality of life. Journal of pain and symptom management. 2002;24(1):S38-S47.
209. Kamaleri Y, Natvig B, Ihlebaek CM, Benth JS, Bruusgaard D. Change in the number of musculoskeletal pain sites: a 14-year prospective study. PAIN®. 2009;141(1-2):25-30.
210. Werner RA, Gell N, Hartigan A, Wiggerman N, Keyserling WM. Risk factors for plantar fasciitis among assembly plant workers. PM&R. 2010;2(2):110-6.
211. Wijnhoven HA, de Vet HC, Picavet HSJ. Explaining sex differences in chronic musculoskeletal pain in a general population. Pain. 2006;124(1-2):158-66.

212. Kuyucu E, Koçyiğit F, Erdil M. The association of calcaneal spur length and clinical and functional parameters in plantar fasciitis. International Journal of Surgery. 2015;21:28-31.
213. Ong W-Y, Stohler CS, Herr DR. Role of the prefrontal cortex in pain processing. Molecular neurobiology. 2019;56(2):1137-66.
214. Bruehl S, Chung OY. Psychological and behavioral aspects of complex regional pain syndrome management. The Clinical journal of pain. 2006;22(5):430-7.
215. Klein SE, Dale AM, Hayes MH, Johnson JE, McCormick JJ, Racette BA. Clinical presentation and self-reported patterns of pain and function in patients with plantar heel pain. Foot & ankle international. 2012;33(9):693-8.
216. Aldridge T. Diagnosing heel pain in adults. American family physician. 2004;70(2):332-8.
217. Im Yi T, Lee GE, Seo IS, Huh WS, Yoon TH, Kim BR. Clinical characteristics of the causes of plantar heel pain. Annals of rehabilitation medicine. 2011;35(4):507.
218. Zale EL, Lange KL, Fields SA, Ditre JW. The relation between pain-related fear and disability: a meta-analysis. The journal of pain. 2013;14(10):1019-30.
219. Wideman TH, Sullivan MJ. Differential predictors of the long-term levels of pain intensity, work disability, healthcare use, and medication use in a sample of workers' compensation claimants. PAIN®. 2011;152(2):376-83.
220. Domenech J, Sanchis-Alfonso V, López L, Espejo B. Influence of kinesiophobia and catastrophizing on pain and disability in anterior knee pain patients. Knee Surgery, Sports Traumatology, Arthroscopy. 2013;21(7):1562-8.
221. McMillan A, Landorf K, Barrett J, Menz H, Bird A. Diagnostic imaging for chronic plantar heel pain: a systematic review and meta-analysis. Journal of Foot and Ankle Research. 2011;4(1):1-.
222. George SZ, Coronado RA, Beneciuk JM, Valencia C, Werneke MW, Hart DL. Depressive symptoms, anatomical region, and clinical outcomes for patients seeking outpatient physical therapy for musculoskeletal pain. Physical therapy. 2011;91(3):358-72.
223. McMillan AM, Landorf KB, Gilheany MF, Bird AR, Morrow AD, Menz HB. Ultrasound guided corticosteroid injection for plantar fasciitis: randomised controlled trial. BMj. 2012;344.
224. Landorf KB, Keenan A-M, Herbert RD. Effectiveness of foot orthoses to treat plantar fasciitis: a randomized trial. Archives of internal medicine. 2006;166(12):1305-10.
225. Thomas MJ, Whittle R, Menz HB, Rathod-Mistry T, Marshall M, Roddy E. Plantar heel pain in middle-aged and older adults: population prevalence, associations with health status and lifestyle factors, and frequency of healthcare use. BMC musculoskeletal disorders. 2019;20(1):1-8.
226. Jewell DV. Guide to evidence-based physical therapist practice: Jones & Bartlett Publishers; 2014.
227. Moons KG, Royston P, Vergouwe Y, Grobbee DE, Altman DG. Prognosis and prognostic research: what, why, and how? Bmj. 2009;338.
228. Straus SE, Richardson W, Glasziou P, Haynes R. How to practice and teach EBM. Evidence-Based Medicine Third edition Elservier. 2005:13-29.

229. Artus M, Campbell P, Mallen CD, Dunn KM, van der Windt DA. Generic prognostic factors for musculoskeletal pain in primary care: a systematic review. BMJ open. 2017;7(1):e012901.
230. Collins GS, Reitsma JB, Altman DG, Moons KG. Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): the TRIPOD statement. Journal of British Surgery. 2015;102(3):148-58.
231. Moons KG, Altman DG, Reitsma JB, Ioannidis JP, Macaskill P, Steyerberg EW, et al. Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD): explanation and elaboration. Annals of internal medicine. 2015;162(1):W1-W73.
232. Kamper SJ, Maher CG, Mackay G. Global rating of change scales: a review of strengths and weaknesses and considerations for design. Journal of Manual & Manipulative Therapy. 2009;17(3):163-70.
233. Mandrekar JN. Simple Statistical Measures for Diagnostic Accuracy Assessment. Journal of Thoracic Oncology. 2010;5(6):763-4.
234. Bradley AP, Longstaff ID, editors. Sample size estimation using the receiver operating characteristic curve. Pattern Recognition, 2004 ICPR 2004 Proceedings of the 17th International Conference on; 2004: IEEE.
235. Thomas E, van der Windt D, Hay EM, Smidt N, Dziedzic K, Bouter LM, et al. Two pragmatic trials of treatment for shoulder disorders in primary care: generalisability, course, and prognostic indicators. Annals of the rheumatic diseases. 2005;64(7):1056-61.
236. Steyerberg EW, Vergouwe Y. Towards better clinical prediction models: seven steps for development and an ABCD for validation. European heart journal. 2014;35(29):1925-31.
237. Royston P, Moons KG, Altman DG, Vergouwe Y. Prognosis and prognostic research: developing a prognostic model. Bmj. 2009;338.
238. Steyerberg EW, Vickers AJ, Cook NR, Gerds T, Gonen M, Obuchowski N, et al. Assessing the performance of prediction models: a framework for some traditional and novel measures. Epidemiology (Cambridge, Mass). 2010;21(1):128.
239. Palomo-López P, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, Rodríguez-Sanz D, Calvo-Lobo C, López-López D. Impact of plantar fasciitis on the quality of life of male and female patients according to the Foot Health Status Questionnaire. Journal of pain research. 2018;11:875.
240. Dunn KM, Croft PR. The importance of symptom duration in determining prognosis. Pain. 2006;121(1-2):126-32.
241. Campbell P, Foster NE, Thomas E, Dunn KM. Prognostic indicators of low back pain in primary care: five-year prospective study. The journal of pain. 2013;14(8):873-83.
242. Tayfur A, Salles J, Miller S, Screen H, Morrissey D. Patellar tendinopathy outcome predictors in jumping athletes: feasibility of measures for a cohort study. Physical Therapy in Sport. 2020;44:75-84.
243. Gheidi N, Kernozek TW, Willson JD, Revak A, Diers K. Achilles tendon loading during weight bearing exercises. Physical Therapy in Sport. 2018;32:260-8.
244. Buscemi V, Chang W-J, Liston MB, McAuley JH, Schabrun S. The role of psychosocial stress in the development of chronic musculoskeletal pain disorders:

protocol for a systematic review and meta-analysis. Systematic reviews. 2017;6(1):1-5.
245. Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. The Lancet. 2007;370(9590):851-8.
246. Hadjistavropoulos HD, Hadjistavropoulos T. The relevance of health anxiety to chronic pain: research findings and recommendations for assessment and treatment. Current Pain and Headache Reports. 2003;7(2):98-104.
247. Vlaeyen JW, de Jong J, Geilen M, Heuts PH, van Breukelen G. The treatment of fear of movement/(re) injury in chronic low back pain: further evidence on the effectiveness of exposure in vivo. The Clinical journal of pain. 2002;18(4):251-61.
248. Hahn SR, Thompson KS, Wills TA, Stern V, Budner NS. The difficult doctor-patient relationship: somatization, personality and psychopathology. Journal of clinical epidemiology. 1994;47(6):647-57.
249. DeGood DE, Tait RC. Assessment of pain beliefs and pain coping. 2001.
250. Cangussu LM, Nahas-Neto J, Nahas EAP, Barral ABCR, de Araujo Buttros D, Uemura G. Evaluation of postural balance in postmenopausal women and its relationship with bone mineral density-a cross sectional study. BMC musculoskeletal disorders. 2012;13(1):1-7.
251. Mehlsen M, Heegaard L, Frostholm L. A prospective evaluation of the Chronic Pain Self-Management Programme in a Danish population of chronic pain patients. Patient education and counseling. 2015;98(5):677-80.
252. Bohman T, Alfredsson L, Jensen I, Hallqvist J, Vingård E, Skillgate E. Does a healthy lifestyle behaviour influence the prognosis of low back pain among men and women in a general population? A population-based cohort study. BMJ open. 2014;4(12):e005713.
253. Williamson E, Williams MA, Gates S, Lamb SE. Risk factors for chronic disability in a cohort of patients with acute whiplash associated disorders seeking physiotherapy treatment for persisting symptoms. Physiotherapy. 2015;101(1):34-43.

APPENDIX A – DATABASE SEARCH FOR SYSTEMATIC REVIEW OF PROGNOSTIC FACTORS

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('painful heel syndrome':ab,ti OR 'plantar fasciitis':ab,ti OR 'plantar fasciopathy':ab,ti OR 'subcalcaneal bursitis':ab,ti OR 'medial arch pain':ab,ti OR 'subcalcaneal pain':ab,ti OR 'stone bruise':ab,ti OR 'calcaneal periostitis':ab,ti OR 'subcalcaneal spur':ab,ti OR calcaneodynia:ab,ti OR 'heel spur syndrome':ab,ti OR 'chronic plantar fasciitis':ab,ti OR 'fasciitis chronic plantar':ab,ti OR 'plantar fasciitis chronic':ab,ti OR 'fasciitis plantar chronic':ab,ti OR 'plantar heel pain':ab,ti) AND (predict*:ab,ti OR prognosis*:ab,ti OR prognostic:ab,ti OR indicat*:ab,ti OR 'disease course':ab,ti OR 'disease progression':ab,ti OR 'follow up':ab,ti OR 'natural history':ab,ti OR factor*:ab,ti OR 'risk factor*':ab,ti OR 'associated factor*':ab,ti) AND (observational:ab,ti OR cohort:ab,ti OR prospective:ab,ti OR 'case control':ab,ti OR longitudinal:ab,ti OR 'randomised controlled':ab,ti OR 'randomized controlled':ab,ti OR 'randomised clinical':ab,ti OR 'randomized clinical':ab,ti) NOT ((((((retrospective:ti OR cross:ti) AND sectional:ti OR systematic:ti) AND review:ti OR literature:ti) AND review:ti OR scoping:ti) AND review:ti OR meta:ti) AND analysis:ti)

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(((Painful-heel-syndrome OR plantar-fasciitis OR plantar-fasciopathy OR subcalcaneal-bursitis OR medial-arch-pain OR subcalcaneal-pain OR stone-bruise OR calcaneal-periostitis OR subcalcaneal-spur OR calcaneodynia OR Heel-Spur-Syndrome OR Chronic-Plantar-Fasciitis OR Fasciitis-Chronic-Plantar OR Plantar-Fasciitis-Chronic OR Fasciitis-Plantar-Chronic OR plantar-heel-pain) AND (Predict* OR prognosis* OR prognostic OR indicat* OR disease course OR disease progression OR follow-up OR natural history OR factor* OR risk factor* OR associated factor*) AND (Observational OR cohort OR prospective OR case-control OR Longitudinal OR randomised controlled OR randomized controlled OR randomised clinical OR randomized clinical)).ab,ti.) NOT ((retrospective OR cross AND sectional OR systematic AND review OR literature AND review OR scoping AND review OR Meta AND analyses).ti.)

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TS=((Painful-heel-syndrome OR plantar-fasciitis OR plantar-fasciopathy OR subcalcaneal-bursitis OR medial-arch-pain OR subcalcaneal-pain OR stone-bruise OR calcaneal-periostitis OR subcalcaneal-spur OR calcaneodynia OR Heel-Spur-Syndrome OR Chronic-Plantar-Fasciitis OR Fasciitis-Chronic-Plantar OR Plantar-Fasciitis-Chronic OR Fasciitis-Plantar-Chronic OR plantar-heel-pain) AND (Predict* OR prognosis* OR prognostic OR indicat* OR disease course OR disease progression OR follow-up OR natural history OR factor* OR risk factor* OR associated factor*) AND (Observational OR cohort OR prospective OR case-control OR Longitudinal OR randomised controlled OR randomized controlled OR randomised clinical OR randomized clinical)) NOT TI=(retrospective OR cross AND sectional OR systematic AND review OR literature AND review OR scoping AND review OR meta AND analyses)

Pubmed 393

(((Painful-heel-syndrome[Title/Abstract] OR plantar-fasciitis[Title/Abstract] OR plantar-fasciopathy[Title/Abstract] OR subcalcaneal-bursitis[Title/Abstract] OR medial-arch-pain[Title/Abstract] OR subcalcaneal-pain[Title/Abstract] OR stone-bruise[Title/Abstract] OR calcaneal-periostitis[Title/Abstract] OR subcalcaneal-spur[Title/Abstract] OR calcaneodynia[Title/Abstract] OR Heel-Spur-Syndrome[Title/Abstract] OR Chronic-Plantar-Fasciitis[Title/Abstract] OR Fasciitis-Chronic-Plantar[Title/Abstract] OR Plantar-Fasciitis-

Chronic[Title/Abstract] OR Fasciitis-Plantar-Chronic[Title/Abstract] OR plantar-heel-pain[Title/Abstract])) AND (Observational[Title/Abstract] OR cohort[Title/Abstract] OR prospective[Title/Abstract] OR case-control[Title/Abstract] OR Longitudinal[Title/Abstract] OR randomised controlled[Title/Abstract] OR randomized controlled[Title/Abstract] OR randomised Clinical[Title/Abstract] OR randomized clinical[Title/Abstract])) NOT (NOT retrospective NOT cross-sectional NOT systematic review [Title])

Scopus 15

(TITLE-ABS-KEY (painful-heel-syndrome OR plantar-fasciitis OR plantar-fasciopathy OR subcalcaneal-bursitis OR medial-arch-pain OR subcalcaneal-pain OR stone-bruise OR calcaneal-periostitis OR subcalcaneal-spur OR calcaneodynia OR heel-spur-syndrome OR chronic-plantar-fasc) AND TITLE-ABS-KEY (predict* OR prognosis* OR prognostic OR indicat* OR disease AND course OR disease AND progression OR follow-up OR natural AND history OR factor* OR risk AND factor* OR associated AND factor*) AND TITLE-ABS-KEY (observational OR cohort OR prospective OR case-control OR longitudinal OR randomised AND controlled OR randomized AND controlled OR randomised AND clinical OR randomized AND clinical) AND NOT TITLE (retrospective OR cross AND sectional OR systematic AND review OR literature AND review OR scoping AND review OR meta AND analysis))

APPENDIX B – ONLINE QUESTIONNAIRE FORMS FROM SMART TRIAL DATABASE

Due to high number of pages, we presented forms via Drobbox link. Please click on the link to see the forms.
https://www.dropbox.com/sh/vgk30rz4gli8tnx/AAALFf2Y4hwMeQhyMJQMVZuTa?dl=0

APPENDIX C – ETHICS APPROVALS FOR FEASIBILITY STUDY

Queen Mary
University of London

Queen Mary, University of London
Room E16
Queen's Building
Queen Mary University of London
Mile End Road
London E1 4NS

Queen Mary Research Ethics Committee
Hazel Covill
Research Ethics Administrator
Tel: +44 (0) 20 7882 2207
Email: h.covill@qmul.ac.uk

Dr Dylan Morrissey
Department of Sports Medicine
Mile End Hospital
Bancroft Road
London E1 4NS

16th December 2019

To Whom It May Concern:

Re: QMREC2014/24 – Human performance measurement and surveys – a generic ethics application.

This is to confirm that the following study was agreed under the above ethical approval:

Re: QMERC2014/24/153 - Tendinopathy TEAM 3*a* – predictors of outcome for tendinopathy: *a feasibility study.*

***(*Running title: T-TEAM 3(*a*): predictors of outcome for tendinopathy)**

Date of approval
This was noted and fully approved on the 1st March 2018

Yours faithfully

Dr Helen Jenner – QMREC Chair.

APPENDIX D - ETHICS APPROVAL FROM 'QUEEN MARY ETHICS OF RESEARCH COMMITTEE' ON 15TH OF MAY 2019:

Queen Mary
University of London

Queen Mary, University of London
Room W104
Queen's Building
Queen Mary University of London
Mile End Road
London E1 4NS

Queen Mary Ethics of Research Committee
Hazel Covill
Research Ethics Facilitator
Tel: +44 (0) 20 7882 7915
Email: h.covill@qmul.ac.uk

c/o Professor Dylan Morrissey
Department of Sports Medicine
Mile End Hospital
Bancroft Road
London

15th May 2019

To Whom It May Concern:

Re: QMERC2018/92 – Tendinopathy Team 3a – predictors of outcomes for tendinopathy.

The above study was conditionally approved by The Queen Mary Ethics of Research Committee (Review Panel G) on the 19th December 2018; full approval was ratified by Chair's Action on the 21st February 2019.

This approval is valid for three years, (if the study is not started before this date then the applicant will have to reapply to the Committee).

Amendment

1. A minor amendment (small changes to materials) was agreed via Chair's Action on the 14th May 2019.

Yours faithfully

Dr Helen Jenner – QMERC Chair.

APPENDIX E- ETHICS APPROVAL FROM 'NHS, HEALTH RESEARCH AUTHORITY, LONDON – CITY & EAST RESEARCH ETHICS EAST COMMITTEE' ON 10TH OF SEPTEMBER 2019:

NHS
Health Research Authority
London - City & East Research Ethics Committee
Bristol Research Ethics Committee Centre
Whitefriars
Level 3, Block B
Lewins Mead
Bristol
BS1 2NT

Telephone: 02071048033/53

Please note: This is an acknowledgement letter from the REC only and does not allow you to start your study at NHS sites in England until you receive HRA Approval

10 September 2019

Professor Dylan Morrissey
Bart's Health NHS Trust and the WHRI, QMUL
Sports and Exercise Medicine
Mile End Hospital, Bancroft Road
London E1 4DG

Dear Professor Morrissey

Study title:	**3T - the 10000 Tendons study, outcome prediction for tendinopathy: an international cohort study**
REC reference:	**19/LO/1340**
Protocol number:	**v1.0 23-52019**
IRAS project ID:	**264615**

Thank you for your letter of 09 September 2019. I can confirm the REC has received the documents listed below and that these comply with the approval conditions detailed in our letter dated 26 August 2019

Documents received

The documents received were as follows:

Document	*Version*	*Date*
Confirmation of any other Regulatory Approvals (e.g. CAG) and all correspondence [Email HRA questions]	1	03 September 2019
Covering letter on headed paper [Covering letter]		27 August 2019
IRAS Application Form [IRAS_Form_09092019]		09 September 2019
Response to Additional Conditions Met		09 September 2019
Schedule of Events or SoECAT	1.1	02 September 2019
Schedule of Events or SoECAT [Soecat]	1	02 September 2019

APPENDIX F – PATIENTS INFORMATION FORMS

Participant Information Sheet

Tendinopathy TEAM 3*a* – predictors of outcome for tendinopathy:

Invitation paragraph

We would like to invite you to be part of this research project. If you choose not to take part there won't be any disadvantages for you. Before you decide we would like you to understand why the study is being done and what it would involve. Please take time to read the following information carefully before you decide to take part as it will tell you why the research is being done and what you will be asked to do. Please ask the researchers if there is anything that is not clear or if you would like more information.

If you decide to take part you will be asked to electronically sign a consent form on the next page. You are still free to withdraw at any time and without giving a reason.

What is the purpose of the study and why have I been invited to take part?

You have been invited to take part because you have been diagnosed with a tendinopathy affecting the hip, knee, ankle, shoulder or foot (plantar heel pain, or plantar fasciitis). Alternatively, you have another musculoskeletal condition affecting these areas. We are also very keen to recruit people without such problems so we can be sure that the findings of the research are true.

Tendinopathy is common and problematic if it does not resolve. It also affects quality of life. Surprisingly, although tendinopathy is a common problem, the causes of non-recovery or recurrence of tendinopathy remain unclear. The main study aim is to develop ways of predicting the course of tendinopathy and then inform clinicians. This may provide better health care services for patients.

What will happen if I take part?

We will firstly ask you to fill out some questionnaires about your general health and physical conditions which will take about half an hour. If you find any of this difficult we can help you.

We will send you a short (5 minutes maximum to fill out) follow-up questionnaire every four weeks for a year to help record your progress and find out when you recover.

Secondly, we are keen to collect information from your clinical or ultrasound examination that clinicians usually collect from a thorough examination. We are happy to help your clinician fill this out.

Thirdly, if you have shoulder pain, we are interested in shoulder blade movement which is important for shoulder. We want you to record your scapular movement video. When you send the video we will examine your scapular and shoulder movement.

Finally, we will invite people who live in London or cities surrounding London for an assessment of how they move in Human Performance Laboratory at Queen Mary University of London. We are happy to discuss this further.
No expenses or payments will be offered, but we are happy to pay reasonable travel expenses to come to the laboratory.

We do not foresee any risks from taking part in this study. We will keep your data safe, in accordance with QMUL data protection policies which are GDPR compliant. For people with shoulder pain although the back is being filmed you can be identified the due to physical differences. However, the videos will not be used to identify you and the video will be kept in locked cabinet by anonymising. Moreover, please record the video with your primary relatives or friend who you can trust.
We cannot promise the study will help you personally, however the study findings should help us manage tendinopathy better in the future. You will play an active role in shaping this development by taking part in the study, and would gain a deeper understanding of your condition. We are happy to send you the results of the study if you would like.

What happens if there is a problem?

If you have any questions or concerns about any aspect of the study please, in the first instance, contact the researcher responsible for the study Professor Dylan Morrissey and his team via teamcohort@qmul.ac.uk or 07305249149. They will try their best to answer your questions. If this is unsuccessful, or not appropriate, or you wish to make a formal complaint, please contact Hazel Covill, the Secretary at the Queen Mary Ethics of Research Committee, Room W117, Queen's Building, Mile End Campus, Mile End Road, London or research-ethics@qmul.ac.uk tel: 02078827915

Will my taking part in this study be kept confidential?

Yes. We will use secure online data collection tools called 'SmartTrial' and 'Navigate Pain' . These are approved platforms and follow Queen Mary's privacy notice for research participants.

You can find important information about your personal data and your rights at:
http://www.arcs.qmul.ac.uk/media/arcs/policyzone/Privacy-Notice-for-ResearchParticipants.pdf.

What happens if I don't want to carry on with the study?

You are free to withdraw at any time, without giving a reason. If you withdraw from the study, we will stop any future data collection, but will use the de-identified data collected up until your withdrawal.

What will happen to the results of the study?

The results of the study will be analysed and presented as written work, presentation material and possible publication in peer reviewed journals as a part of postgraduate study. Your data will be anonymized, and the results may be presented at meetings. You can request to have a copy of the completed results.

APPENDIX G – PATIENTS CONSENT FORMS

Queen Mary University of London

Consent form

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: **Tendinopathy TEAM 3a – predictors of outcome for tendinopathy**

Queen Mary Ethics of Research Committee Ref: QMERC2018/92.

Please initial box

I confirm I have read and understood the participant information sheet dated ……for the above study and have had the opportunity to consider the information, to ask questions and to have these answered.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, this will not affect how I am treated in any way.	☐
I understand that all information about me will be kept in a confidential way and destroyed once the study is completed.	☐
I would like to learn study results.	☐
I consent to have a copy my questionnaire results.	☐
I consent to attend the clinical and ultrasound examination part of the study.	☐
I consent to attend the movement analyses part of the study.	☐
I am happy to come and discuss further steps of the study such as clinical examination and movement analyses.	☐
People with shoulder pain only I consent to analysis of my shoulder movement video and I understand risks of video recording.	☐
I agree to take part in this study	☐

Name of participant…… ……..
Signature …….. Date …….

Name of Witness (Researcher) ……
Signature ……. ….. Date …….

When completed, 1 copy for patient, 1 for researcher site file

APPENDIX H – CLINICAL AND ULTRASOUND TESTING PROTOCOL:

Queen Mary University of London

Barts and The London School of Medicine and Dentistry

SOP Title	**Clinical Assessment**
SOP Reference	Team_COHORT
Version Number	V.2.8 15.02.2019
Approval Date	
Effective Date	

Author	Dylan Morrissey	
Reviewed by	Halime Gulle	

Approved by	Dylan Morrissey Chief investigator	

Key 3 things about patient story

1.

2.

3.

What is your primary Diagnosis?

What is the patient injury mechanism?

What do you think about prognosis of this patient?

What improvement do you predict for your patient? (%)

How confident are you with this recovery prediction?(%)

Please predict how long this recovery will take?

Please rate your confidence in your recovery time prediction?(%)

What deterioration do you predict for this patient (%)?

How confident are you with this prediction of worsening? (%)

Why do you think this patient will get worse?

Why do you think this patient will not improve?

Primary diagnosis:
Secondary Diagnosis:

Please note anything else you think is important.

Clinical Examination

Height (cm):_____ **Weight** (kg):_____

FOOT POSTURE INDEX **(please circle related grade)**

	Factor	Plane	Left	Right
Rearfoot	Talar head palpation	Transverse	-2 -1 0 1 2	-2 -1 0 1 2
	Curves above and below the lateral malleolus	Frontal/transverse	-2 -1 0 1 2	-2 -1 0 1 2
	Inversion/ eversion of calcaneal	Frontal	-2 -1 0 1 2	-2 -1 0 1 2
Forefoot	Prominence in the region of the TNJ	Transverse	-2 -1 0 1 2	-2 -1 0 1 2
	Congruence of the medial longitudinal arch	Sagittal	-2 -1 0 1 2	-2 -1 0 1 2
	Abd/adduction forefoot on rearfoot	Transverse	-2 -1 0 1 2	-2 -1 0 1 2
	TOTAL			

FOOT MOBILITY

Sitting	**R**	**L**
Foot length	cm	cm
Midfoot width	mm	mm
Dorsal arch height	mm	mm
Weight bearing (Standing)		
Midfoot width	mm	mm
Dorsal arch height	mm	mm

Lunge Test	**R**	**L**
*Navicular drop distance	mm	mm
*DROM when navicular start to drop	°	°
*DROM for front limb at the end	°	°
DROM for back limb at the end	°	°

*Measurements for the front limb only

Lower limb ROMs

R		(Goniometer, supine)	L
Active	Passive		Active
<50 / ≥50	S / M	1st MTPJ DF	<50 / ≥50
<70 / ≥70	-	SLR	<70 / ≥70

Key: S= same; M=more; SLR Straight Leg Raise

R	Strength	L
<5/5	Toe flexors *(by oxford scale X/5)*	<5/5
Passive	Inversion *(by oxford scale X/5)*	<5/5
S / M		
-	*Hip Ext *(by oxford scale X/5)*	<5/5
	Ankle PF *(by single leg heel rising) (repetition until dropping below 50% of first ROM)*	

**Please measure 3 times and write max. value.*

R	Palpation (please circle)	L
	The main:	The main:
+ve /-ve	Midpoint of heel	+ve /-ve
+ve /-ve	Medial Plantar fascia Origin	+ve /-ve
+ve /-ve	Medial Longitudinal Arc	+ve /-ve
+ve /-ve	Posterior calcaneus	+ve /-ve
+ve /-ve	Mid Achilles	+ve /-ve
+ve /-ve	Calf Muscle	+ve /-ve

R	Other tests (please circle)	L
+ve / -ve	Tarsal tunnel tests	+ve / -ve
+ve / -ve	Calcaneal squeeze	+ve / -ve
Normal / Delayed / Absent	Windlass	Normal / Delayed / Absent

Observation of Lower limb

Knee (sagittal) Standing	Knee (Frontal) Standing	Right Hip Rotation Prone	Left Hip Rotation Prone	Leg length (based on MM) Prone
☐ Normal	☐ Normal	☐ IR=ER	☐ IR=ER	☐ L=R
☐ Flexed	☐ Valgus	☐ IR<ER	☐ IR<ER	☐ L<R
		Total arch	Total arch	
☐ Recurvatum	☐ Varum	☐ IR>ER	☐ IR>ER	☐ L>R
		……	……	

Any deformities on foot?
Normal / Big toe bunion / Pes cavus / claw toes / hammer toes / hallux valgus / hallux limitus / hallux rigidus / calcaneal exostosis / cuneiform exostosis / dorsal ganglion / other(spesify)…….

Which one of deformities that your patient have are painful? (more than 3 out of 10 (NRS)):

Analysis

Ankle essentially normal? Y / N

Control □

Plan

PHP □ Other foot problems □

Graded Loaded Challenge (GLC)

The patient is asked to perform the following set of tests. During testing;

1. in order
2. Long step: increase in stride length by 50%. Weight: external loading with 25% of body weight
3. Stopping at the point at which pain is reproduced at >5/10
4. Record the challenge level and number of reps to get to that point

Task	Repetition	Pain (NRS/10)	Comment
Walking (11 m)	/10		
Walking with long step length	/10		
Walking with weight	/10		
Walking with long step length and weight	/10		

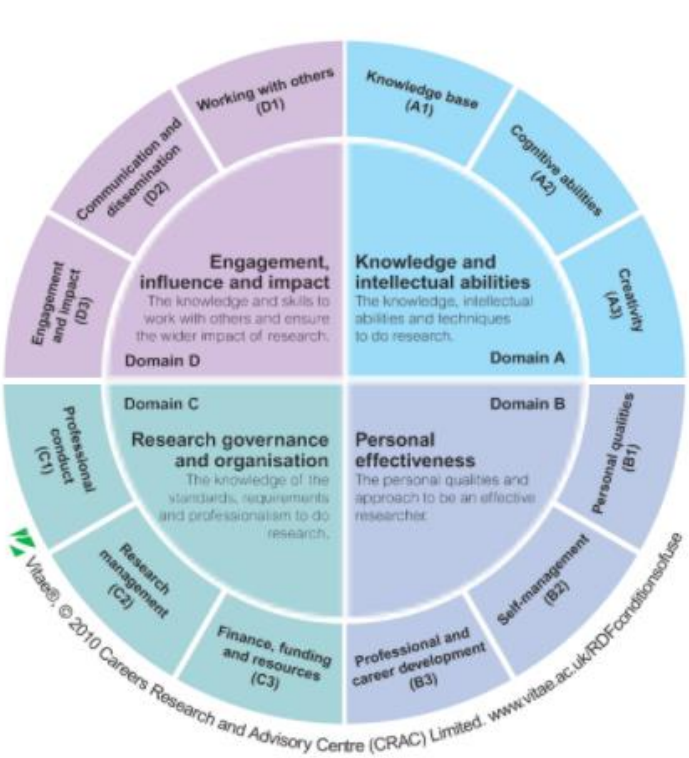
Ultrasound report form

	Left	Right
Longitudinal Plantar Fascia thickness **from insertion** of Calcaneus	mm	mm
Longitudinal Plantar Fascia thickness **from 0.5 cm** to insertion of Calcaneus	mm	mm
Heel pad thickness from proximal plantar fascia	mm	mm
Heel Spur	Y/N	Y/N
Fascial tear seen?	Y/N	Y/N
Cyst seen?	Y/N	Y/N
Calcification within the PF	Y/N	Y/N
US Provocation test	+ve / -ve	+ve / -ve
Comments		

APPENDIX I – SKILL POINT DATABASE

Progress

Click on each quadrant to find out how to develop your skills in that area



Points Summary

Show Yearly Totals

Year	Type	Pts:	A	B	C	D	Total	Cap:	A	B	C	D	Total
Total	*Conference Attendance (One day)*		6,0	4,0	0,0	0,0	10,0						
	Conference Attendance (Three days)		9,0	6,0	0,0	0,0	15,0						
	Conference Attendance (Two days)		6,0	4,0	0,0	0,0	10,0						
	Conference attendance sub-total		**18,0**	**12,0**	**0,0**	**0,0**	**30,0**		**18.0**	**12.0**			**30.0**
	Core research knowledge or methods course (e.g. LTCC, IALS courses, masters lectures)		74,0	0,0	0,0	0,0	74,0		120.0				120.0
	Doctoral College event/course		0,0	5,0	3,0	5,0	13,0						
	Education & Learning Course (Queen Mary Academy)		0,0	2,0	0,0	2,0	4,0						
	Other CPD course		0,0	0,0	6,5	2,0	8,5						
	Other Teaching/demonstrating training		0,0	2,0	0,0	2,0	4,0			10.0		10.0	20.0
	Other course/event attendance		20,0	9,0	0,0	4,0	33,0						
	Researcher Development Course		38,0	52,0	23,0	19,5	132,5						
	Course/event/seminar attendance sub-total		**132,0**	**70,0**	**32,5**	**34,5**	**269,0**						
	Ethical Approval (standard, not fast-track)		3,0	0,0	9,0	3,0	15,0		3.0		9.0	3.0	15.0
	Ethical approval sub-total		**3,0**	**0,0**	**9,0**	**3,0**	**15,0**						
	Cafe Scientifique Presentation		0,0	2,0	0,0	2,0	4,0						
	Conference Presentation (Oral)		3,0	3,0	0,0	4,0	10,0		9.0	9.0		12.0	30.0
	Conference Presentation (Poster)		6,0	6,0	0,0	8,0	20,0		9.0	9.0		12.0	30.0
	Internal Presentation (< or =30 mins)		2,0	2,0	0,0	4,0	8,0		3.0	3.0		6.0	12.0
	Giving presentations sub-total		**11,0**	**13,0**	**0,0**	**18,0**	**42,0**						
	Journal Club/Reading Group/lab meeting/mentoring group - attendance		15,0	0,0	0,0	0,0	15,0		30.0				30.0
	Representing School or Research Group at meeting or committee		0,0	0,0	1,0	1,0	2,0				12.0	12.0	24.0
	Meeting/club/reading group attendance sub-total		**15,0**	**0,0**	**1,0**	**1,0**	**17,0**						
	Mentoring/supervising of Project Student		2,0	1,0	0,0	2,0	5,0		8.0	4.0		8.0	20.0
	Teaching sub-total		**2,0**	**1,0**	**0,0**	**2,0**	**5,0**						
	Total (with caps applied)		**181,0**	**96,0**	**42,5**	**58,5**	**378,0**						