Original article

Coexistence of plantar calcaneal spurs and plantar fascial thickening in individuals with plantar heel pain

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Abstract

Objectives. To examine associations between plantar calcaneal spurs, plantar fascia thickening and plantar heel pain (PHP), and to determine whether tenderness on palpation of the heel differentiates between these presentations.

Methods. Adults aged ≥ 50 years registered with four general practices were mailed a Health Survey. Responders reporting foot pain within the last 12 months underwent a detailed clinical assessment. PHP in the past month was documented using a foot manikin. Plantar calcaneal spurs were identified from weight-bearing lateral radiographs and plantar fascia thickening (defined as >4 mm) from ultrasound. Tenderness on palpation of the plantar fascia insertion was documented. Associations between these factors and PHP were explored using generalized estimating equations.

Results. Clinical and radiographic data were available from 530 participants (296 women, mean [s.d.] age 64.9 [8.4] years), 117 (22.1%) of whom reported PHP. Plantar calcaneal spurs and plantar fascia thickening were identified in 281 (26.5%) and 501 (47.3%) feet, respectively, but frequently coexisted ($n=217$, 20.4%). Isolated plantar calcaneal spurs were rare ($n=64$, 6.0%). Participants with PHP were more likely to have a combination of these features compared with those without PHP (odds ratio 2.16, 95% CI 1.24, 3.77, $P=0.007$). Tenderness on palpation of the heel was not associated with plantar calcaneal spurs or plantar fascia thickening, either in isolation or in combination, in those with PHP.

Conclusion. Plantar calcaneal spurs and plantar fascial thickening are associated with PHP, but frequently coexist. Tenderness on palpation of the heel does not appear to differentiate between clinical presentations of PHP.

Key words: plantar fasciitis, heel spur syndrome, calcaneal spur

Rheumatology key messages

- Plantar calcaneal spurs and plantar fascial thickening frequently coexist in individuals with plantar heel pain.
- Tenderness on palpation of the heel has limited value for clinical assessment.
- Plantar heel pain is multifactorial and cannot be exclusively attributed to individual imaging findings.

Introduction

Plantar heel pain (PHP) is a common condition that affects $\sim 10\%$ of the general population [1–3] and is associated with activity limitation, depression and reduced health-related quality of life [4, 5]. In the USA, it has been estimated that management of PHP accounts for one million

physician visits per year [6], at a total annual cost of US\$284 million [7]. In the UK, the 12-month period prevalence of general practitioner consultation by individuals with PHP is 43% [8], and it has been estimated that 12% of all musculoskeletal foot and ankle consultations in primary care are related to heel pain [9].

Despite the high prevalence and burden of PHP, the underlying aetiology of the condition is not well understood. Several foot-level risk factors have been identified, including pronated foot type, limited ankle and first metatarsophalangeal joint dorsiflexion and reduced muscle strength [10–12], although the most consistently associated factor is an increased body mass index [13]. Imaging studies have revealed associations between PHP and the presence of plantar calcaneal spurs, thickening and hypoechogenicity of the plantar fascia, perifascial oedema and calcaneal bone marrow oedema [13–15],

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Submitted 26 March 2018; accepted 19 July 2018

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while histological investigations have noted plantar fascia degeneration, fragmentation and calcaneal spur fracture [16, 17]. These findings suggest that PHP is a complex condition involving a range of osseous and soft tissue abnormalities, and is not simply an inflammatory condition affecting the plantar fascia in isolation [18].

In clinical practice, PHP is typically diagnosed based on clinical signs and symptoms, with point tenderness over the insertion of the plantar fascia into the medial tubercle of the calcaneus being a characteristic feature [19]. Diagnostic imaging is not always necessary, although the most common approaches used are the identification of plantar calcaneal spurs using plain radiography, and detection of plantar fascial thickening using ultrasound; observations that have strong associations with PHP [13, 15]. However, the degree to which plantar calcaneal spurs and plantar fascial thickening may coexist has not been well established, nor has the value of palpation of the plantar fascial insertion in identifying these abnormalities. Understanding how these factors inter-relate would provide useful insights into the underlying cause of the condition and may influence treatment planning.

Therefore, the objectives of this study were to (i) examine associations between plantar calcaneal spurs, plantar fascia thickening and self-reported PHP in the past month, and (ii) determine whether tenderness on palpation of the heel differentiates between the presence of calcaneal spurs, plantar fascia thickening or both these features combined. To do this, we conducted a cross-sectional analysis of people aged 50 years and over who participated in a population-based observational cohort study [20].

Methods

Study design

This paper utilises baseline data from the Clinical Assessment Study of the Foot [20]. Adults aged 50 years and over registered with four general practices were invited to take part in the study, irrespective of consultation for foot pain or problems. Ethical approval was obtained from Coventry Research Ethics Committee (reference number: 10/H1210/5). Written informed consent was obtained from all participants.

Health survey questionnaire

All eligible participants were mailed a Health Survey questionnaire that gathered information on demographic and socio-economic characteristics (age, gender, education and occupation) and aspects of general health including the Short Form-12 (SF-12) [21] and the Hospital Anxiety and Depression Scale (HADS) [22]. Specific questions included the presence of pain in and around the foot in the past 12 months and the Manchester Foot Pain and Disability Index (MFPDI) [23]. Participants were asked to indicate the location of foot pain experienced in the right and left feet in the past month using a foot manikin (© The University of Manchester 2000. All rights reserved) [24],

and those who shaded the region of the plantar heel were documented as having PHP in the selected foot [25]. Participants who reported pain in and around the foot in the past 12 months and provided written consent to further contact were invited to attend a research clinic where radiographs, ultrasound measurements and clinical assessments were undertaken.

Radiographic assessment

Weight bearing lateral radiographs were obtained from both feet according to a defined standardized protocol [26]. Participants were excluded from the current analyses if medical records (primary care and local hospital) or a clinical radiology report by a consultant musculoskeletal radiologist identified them as having inflammatory arthritis (non-specific inflammatory arthritis, rheumatoid arthritis or psoriatic arthritis). Plantar calcaneal spurs were scored by a single reader (M.M.), blind to all other participant information, and documented as absent (score=0), small (score=1), moderate (score=2) or severe (score=3) using standard atlas images (Fig. 1). Plantar calcaneal spurs were then dichotomized as being absent (score 0 or 1) or present (score 2 or 3). To establish inter-rater reliability, M.M. and H.B.M. independently scored 120 lateral radiographs (60 right foot, 60 left foot). Inter-rater reliability was excellent (quadratic weighted kappa 0.82, 95% CI 0.762, 0.886, $P < 0.001$, percentage agreement 94.4%).

Ultrasound assessment

The ultrasound examination was performed using a variable frequency 8–13 MHz linear transducer with a Logiq-e ultrasound system (GE Healthcare, Pollards Wood, UK) by one of three clinicians trained as research assessors. The three ultrasound assessors—a physiotherapist, radiographer and nurse—had successfully completed a Consortium for the Accreditation of Sonographic Education accredited, competency-assessed ultrasound training course to accurately measure the thickness of the plantar fascia using standard protocols (<http://www.case-uk.org> (17 August 2018, date last accessed)). Their clinical training and competency assessments were completed by a consultant musculoskeletal sonographer (A.H.). Assessors were blind to the findings of the clinical assessment, radiography, postal questionnaires and medical records. The participant was positioned in a sitting position on a couch with their feet hanging over the end of the couch and ankles dorsiflexed to 90 degrees. Real-time sagittal (longitudinal) imaging of the plantar fascia was performed with the focus adjusted to the depth of the fascia for each participant. Plantar fascia thickness was measured where the plantar fascia crossed the anterior aspect of the inferior border of the calcaneus on the longitudinal view, but at its thickest point in the transverse plane [27]. See Fig. 2. Three repeated measurements were obtained, and plantar fascia thickening was defined as >4 mm for the highest of the measurements [14].

Fig. 1 Standardized images used to identify presence of plantar calcaneal spurs

Spurs were considered to be present if a score of 2 or above was documented.

Fig. 2 Ultrasound measurement of plantar fascial thickness

Clinical assessment

Participants underwent a standardized clinical interview and physical examination conducted by therapists blinded to the findings from ultrasound, radiography, postal questionnaires and medical records. In addition to anthropometric measurements (height and weight used to calculate body mass index), a detailed clinical assessment of the foot and ankle was undertaken to document tenderness to palpation of the heel, foot posture and range of motion. Tenderness on palpation of the heel (documented as present or absent) was performed with the participant in a supine position with the knee extended and ankle dorsiflexed. The assessor moved the first metatarsophalangeal joint into full dorsiflexion and then applied firm pressure with their thumb to the plantar-medial heel, approximating the insertion of the plantar fascia into the calcaneus. Foot posture was assessed with the participant standing in a relaxed bipedal position using Foot Posture Index, Arch Index (AI) and navicular height measurements. The Foot Posture Index is a multidimensional visual observation tool consisting of six criteria scored on a 5-point scale (range, -2 to +2 [28]) and scores of the six criteria were converted to a single Rasch-transformed logit scale, with higher scores representing a more pronated (flatter) foot [29]. The AI was calculated from static carbon paper footprints as the ratio of area of the middle third of the footprint to the entire footprint area ignoring the toes. The flatter the foot, the higher the AI [30]. To determine navicular height, the most

medial prominence of the navicular tuberosity was palpated and marked with a marking pen. A ruler was then used to measure the height of the navicular tuberosity from the ground, and this value divided by the total length of the foot. The lower the navicular height, the flatter the foot [31]. Each of these measures of foot posture have been shown to have good reliability and to reflect the underlying skeletal alignment of the medial longitudinal arch [31].

Range of motion was assessed at the first MTP joint, subtalar joint and ankle joint. First MTP joint dorsiflexion range of motion was measured using a goniometer as the maximum angle at which the hallux could not be passively moved into further extension in a non-weight bearing position [32]. Passive ankle/subtalar joint inversion and eversion were measured with the participant supine, using a flexible goniometer as described by Menadue *et al.* [33]. Ankle joint dorsiflexion was measured using the weight bearing lunge test, with the knee flexed [34] and extended [35]. The reliability of each of these tests has been reported previously [32–36].

Statistical analysis

All analyses were conducted using SPSS Version 22 (IBM Corporation, Armonk, NY, USA). Comparisons of person-level variables between participants with and without PHP in one or both feet were analysed using independent samples *t*-tests or χ^2 tests as appropriate. Comparisons of foot-level variables according to the presence of PHP

were undertaken using linear mixed models to account for the correlation between measurements obtained from the right and left feet. Associations between plantar calcaneal spurs, plantar fascia thickening, tenderness on palpation of the heel and PHP in the past month were explored using generalized estimating equations to account for the correlation between measurements obtained from the right and left feet. Body mass index was considered to be a confounding variable for the associations of PHP with plantar calcaneal spurs and plantar fascia thickening, and was adjusted for in the analysis. Odds ratios with 95% CIs are presented and statistical significance was determined as $P < 0.05$.

Results

Study population

As previously reported, a total of 5109 completed Health Survey questionnaires were received (adjusted response 56%) [37]. Of these, 1635 individuals who reported pain in and around the foot in the past 12 months and provided written consent to further contact were invited to the research assessment clinic and 560 attended. The median time between receiving the completed health survey and questionnaire and clinic attendance was 37 days (inter-quartile range 27–47 days). Individuals with inflammatory arthritis ($n = 24$) were excluded, as were those with missing radiographs ($n = 3$), ultrasound ($n = 2$) or foot pain ($n = 1$) data, leaving a total of 530 eligible participants for

this analysis (296 women and 234 men, mean [s.d.] age 64.9 [8.4] years, mean [s.d.] body mass index 30.4 [5.7] kg/m²). Data for tenderness on palpation of the heel were missing for four feet (three right and one left).

Characteristics of participants with PHP

Of the 530 participants, 117 (22.1%) reported PHP in one or both feet in the past month. Of these, approximately half were unilateral ($n = 51$, 43.6%) and half bilateral ($n = 66$, 56.4%). Participants with PHP had a higher body mass index, reported worse scores on the SF-12 Physical, SF-12 Mental, HADS anxiety and HADS depression questionnaires, were more likely to report that their foot pain was disabling, reported worse scores on the MFPDI pain and function subscales, and feet with PHP had a higher AI (indicative of a flatter foot). There were no sex differences in the prevalence of PHP (Table 1).

Prevalence of plantar calcaneal spurs and plantar fascia thickening

At the person level, a plantar calcaneal spur in at least one foot was identified in 185 (35%) participants (48% unilateral, 52% bilateral), and plantar fascial thickening in at least one foot was identified in 317 (60%) participants (42% unilateral, 58% bilateral). At the foot level, plantar calcaneal spurs and plantar fascia thickening were identified in 281 (26.5%) and 501 (47.3%) feet, respectively. Sex was not associated with plantar calcaneal spurs (OR 1.04, 95% CI 0.74, 1.47, $P = 0.816$), however women were less

TABLE 1 Characteristics of participants with and without plantar heel pain

	Participants with no plantar heel pain in either foot ($n = 413$)	Participants with plantar heel pain in one or both feet ($n = 117$)	<i>P</i>
Person level variables			
Age, years	65.1 (8.4)	64.3 (8.5)	0.393
Female, n (%)	236 (57.1)	60 (51.3)	0.292
BMI, kg/m ²	29.7 (5.3)	32.5 (6.4)	<0.001
SF-12 physical (0–100) ^a	39.7 (12.0)	33.9 (12.4)	<0.001
SF-12 mental (0–100) ^a	50.0 (10.7)	45.8 (11.2)	0.001
HADS anxiety (0–21) ^b	6.8 (4.4)	8.2 (4.2)	0.002
HADS depression (0–21) ^b	5.2 (3.8)	6.8 (4.1)	<0.001
Disabling foot pain, n (%)	208 (52.1)	87 (76.3)	<0.001
MFPDI—pain ^b	−0.5 (1.5)	0.7 (1.4)	<0.001
MFPDI—function ^b	−1.0 (2.1)	0.5 (2.0)	<0.001
	Feet with no plantar heel pain ($n = 877$ feet)	Feet with plantar heel pain ($n = 183$ feet)	
Foot level variables			
1st MTP joint dorsiflexion, degrees	62.1 (19.2)	62.8 (15.2)	0.644
Ankle dorsiflexion—knee flexed, degrees	52.5 (8.7)	52.1 (8.5)	0.641
Ankle dorsiflexion—knee extended, degrees	62.4 (8.8)	62.7 (8.9)	0.702
Foot Posture Index ^c	2.6 (1.8)	2.4 (1.8)	0.287
Navicular height, mm ^d	0.17 (0.03)	0.17 (0.03)	0.821
Arch index ^c	0.24 (0.05)	0.26 (0.05)	<0.001

Values are mean (s.d.) unless otherwise stated. ^aHigher score indicates better function. ^bHigher score indicates worse function. ^cHigher score indicates flatter (more pronated) foot. ^dAdjusted for foot length; lower score indicates flatter (more pronated) foot. MFPDI: Manchester Foot Pain and Disability Index; SF-12: Short Form-12; HADS: Hospital Anxiety and Depression Scale.

likely to have plantar fascia thickening compared with men (OR 0.42, 95% CI 0.31, 0.57, $P < 0.001$). Plantar calcaneal spurs and plantar fascial thickening frequently coexisted, with isolated plantar calcaneal spurs being an uncommon presentation (Fig. 3). Plantar calcaneal spurs were associated with plantar fascial thickening in feet with and without PHP (OR 3.86, 95% CI 2.22, 6.69, $P < 0.001$ and OR 4.35, 95% CI 3.10, 6.10, $P < 0.001$, respectively), and this association persisted after adjusting for body mass index (OR 3.78, 95% CI 2.11, 6.81, $P < 0.001$ and OR 3.75, 95% CI 2.63, 5.35, $P < 0.001$, respectively).

Associations between plantar calcaneal spurs, plantar fascia thickening and PHP

PHP in the past month was not significantly associated with plantar calcaneal spurs (OR 1.32, 95% CI 0.87, 1.98, $P = 0.188$), but was significantly associated with plantar fascia thickening (OR 1.55, 95% CI 1.09, 2.18, $P = 0.013$). The association between PHP and plantar fascial thickening was stronger in women (OR 1.70, 95% CI 1.01, 2.85, $P = 0.046$) than men (OR 1.33, 95% CI 0.84, 2.08, $P = 0.224$). After adjustment for body mass index, these associations were attenuated (OR 1.11, 95% CI 0.73, 1.68, $P = 0.622$ and OR 1.41, 95% CI 0.98, 2.04, $P = 0.065$, respectively). When combinations of these imaging findings were considered, PHP in the past month was associated with plantar fascial thickening in isolation and a combination of plantar fascial thickening and plantar calcaneal spurs, but not plantar calcaneal spurs in isolation (Table 2). Further examination of these associations using plantar calcaneal spur severity (i.e. the four categories of spurs shown in Fig. 1) demonstrated: (i) an independent association between plantar fascial thickening and PHP in the absence of plantar calcaneal spurs (i.e. grade 0), and (ii) a strong association between grade 3 spurs in the presence of plantar fascial thickening and PHP (Supplementary file, available at *Rheumatology* online).

Associations with tenderness on palpation of the heel

Tenderness on palpation of the heel was evident in 177 (16.8%) feet and was associated with PHP in the past month ($n = 53$ [29.0%] vs $n = 124$ [14.2%]; OR 2.20, 95% CI 1.53, 3.17, $P < 0.001$). In feet with PHP, plantar fascial tenderness was not associated with the presence of

plantar calcaneal spurs (OR 0.82, 95% CI 0.39, 1.70, $P = 0.588$) or plantar fascia thickening (OR 1.20, 95% CI 0.73, 1.98, $P = 0.468$). Similarly, there were no associations between tenderness on palpation of the heel when combinations of plantar calcaneal spurs and plantar fascial thickening were considered (Table 3).

Discussion

The objectives of this study were to examine associations between plantar calcaneal spurs, plantar fascia thickening and PHP in a population-based sample, and to determine whether tenderness on palpation of the heel differentiates between these presentations. We found that plantar calcaneal spurs and fascial thickening frequently coexisted, with isolated spurs being particularly uncommon. The presence of both of these imaging findings in combination were more strongly associated with PHP than either observation in isolation, in part due to the greater severity of spurs and thickening in those with both features combined. We also found that participants with PHP in the past month were more likely to report tenderness on palpation of the heel than those without PHP, although tenderness on palpation of the heel did not differentiate between the presence of plantar calcaneal spurs, fascial thickening or both features combined. Taken together, these findings suggest that PHP is a complex, multifactorial condition that cannot be exclusively attributed to individual imaging findings, and that tenderness on palpation of the plantar heel has limited clinical assessment value.

The role of plantar calcaneal spurs in the pathogenesis of PHP has been debated for some time. First described in 1900, calcaneal spurs were initially considered to be causally related to heel symptoms (hence the term 'heel spur syndrome'). It is now recognized that between 10 and 63% of asymptomatic individuals have calcaneal spurs [38]. In contrast to recent systematic reviews [13, 14], we did not find a significant association between PHP and the presence of plantar calcaneal spurs. There are three possible explanations for this discrepancy. Firstly, our sample were older (mean age 64.9 years) and had a relatively high body mass index (mean 30.4 kg/m²) compared with previous studies; factors that are strongly associated with plantar calcaneal spurs [38]. Secondly,

TABLE 2 Imaging findings in feet with and without plantar heel pain in the past month

	No plantar heel pain ($n = 877$ feet)	Plantar heel pain ($n = 183$ feet)	OR (95% CI)	P	Adjusted OR (95% CI) ^a	P
No plantar calcaneal spur or plantar fascia thickening	426 (48.6)	69 (37.7)	1 (referent)		1 (referent)	
Plantar calcaneal spur alone	56 (6.4)	8 (4.4)	0.74 (0.36, 1.54)	0.422	0.75 (0.36, 1.57)	0.449
Plantar fascia thickening alone	233 (26.6)	51 (27.9)	1.47 (1.03, 2.12)	0.036	1.50 (1.04, 2.16)	0.029
Plantar calcaneal spur and plantar fascia thickening	162 (18.5)	55 (30.1)	2.12 (1.21, 3.70)	0.009	2.16 (1.24, 3.77)	0.007

Values are n (%). ^aAdjusted for BMI.

Fig. 3 Stacked bar chart of imaging findings according to presence of plantar heel pain **TABLE 3** Imaging findings in relation to tenderness to palpation in participants with plantar heel pain

	Not tender to palpation (n = 130 feet)	Tender to palpation (n = 53 feet)	OR (95% CI)	P
No plantar calcaneal spur or plantar fascia thickening	414 (47.1)	81 (45.8)	1 (referent)	
Plantar calcaneal spur alone	52 (5.9)	12 (6.8)	1.11 (0.58, 2.10)	0.762
Plantar fascia thickening alone	237 (27.0)	45 (25.4)	0.94 (0.65, 1.37)	0.760
Plantar calcaneal spur and plantar fascia thickening	176 (20.0)	39 (22.0)	1.11 (0.70, 1.74)	0.662

Values are n (%).

participants without PHP were not true asymptomatic controls, as inclusion in the clinical assessment stage of the study required all participants to report pain in and around the foot in the past 12 months. Thirdly, plantar calcaneal spurs may remain long after the initial incident that caused them to develop, so the relatively recent time period for reporting PHP that we used (1 month) may have missed participants who were previously symptomatic.

Thickening of the plantar fascia appears to be a characteristic feature of PHP, with a systematic review of 15 ultrasound studies concluding that symptomatic individuals were >100 times more likely to have plantar fascia thickness > 4 mm compared with controls [14]. We also found associations between plantar fascial thickening and PHP, both in isolation and in the presence of plantar calcaneal spurs, which were attenuated after adjusting for body mass index but remained significant. The underlying mechanism linking fascial thickening to heel symptoms is not well understood, but may involve myxoid degeneration [16] or neurovascular ingrowth associated with

hyperaemia [39]. Plantar fascial thickening may be more strongly associated with PHP than plantar calcaneal spurs, as it may represent an active inflammatory process more directly linked to symptoms. Indeed, a reduction in thickness of the plantar fascia following treatment has been shown to be associated with the degree of symptomatic improvement [40, 41].

In contrast to previous studies, which have examined either plantar calcaneal spurs or plantar fascia thickening in isolation, a novel aspect of our study was the ability to document these key imaging features of PHP concurrently. In those with PHP in the past month, plantar calcaneal spurs and fascial thickening frequently coexisted (30%), while plantar calcaneal spurs in the absence of fascial thickening were uncommon (4%). When the combinations of these features were examined for associations with PHP, the presence of isolated plantar calcaneal spurs was not significant, while isolated thickening and thickening in conjunction with plantar calcaneal spurs was significantly associated. These

observations suggest that the association between plantar calcaneal spurs and PHP may be largely driven by their association with fascial thickening. Indeed, histological studies suggest that fascial thickening may precede the development of plantar calcaneal spurs, and that spur formation may be a protective mechanism to buttress the enthesis against further damage from compressive loads [42].

The secondary objective of our study was to examine the clinical assessment value of tenderness on palpation of the heel, a widely used test in clinical practice when assessing heel pain [19]. Because the test involves compressing the plantar fascia at its insertion in the medial tubercle of the calcaneus, it could theoretically assist in the identification of plantar calcaneal spurs and/or fascial thickening. However, although individuals with PHP were more likely to report tenderness on palpation, this test could not differentiate between the presence of plantar calcaneal spurs, fascial thickening, or combinations of these two features. As such, a positive test result can only be considered to be a non-specific confirmation of localized PHP, and is therefore of limited value regarding the presence or severity of the underlying plantar fascia and/or calcaneal spur pathology.

The key clinical implication of our study is that ultrasonography would appear to be a more informative imaging modality than radiographs in patients with PHP, as plantar fascial thickening identified with ultrasound is more strongly associated with symptoms, and reduction in thickness may be a marker of symptomatic improvement following treatment [40, 41]. In contrast, radiographs are only capable of identifying plantar calcaneal spurs, which are not associated with PHP in isolation, and their presence does not appear to influence treatment outcomes [43].

Strengths of our study include the population-based sample, the use of standardized imaging of both plantar calcaneal spurs and fascial thickening, blinding of the assessors, standardized training of ultrasound assessors, and review of ultrasound images by a consultant musculoskeletal sonographer (A.H.) to ensure measurement accuracy. However, several limitations of our study are worthy of acknowledgement. Firstly, the overall response to the postal health survey questionnaire from which the clinical sample was derived was lower than expected, although responders to the health survey questionnaire did not differ greatly from the mailed population [37]. Secondly, because pain in and around the foot in the past 12 months was an inclusion criterion for the clinical sample, participants without PHP were not asymptomatic controls, as they had pain elsewhere in the foot. Stronger associations between imaging findings, palpation and symptoms may have been observed if the controls were completely free of foot pain. Thirdly, the time-lag between reporting of PHP in the past month on the survey and the date of clinical examination may have resulted in misclassification due to either the onset or resolution of symptoms in some participants. Finally, diagnostic imaging was limited to plain film X-ray to detect spurs and

ultrasound to measure plantar fascial thickness. Although these are the most commonly used imaging modalities for these observations, further insight may have been obtained by documenting plantar fascia echogenicity and neovascularity, or by utilizing other techniques such as magnetic resonance imaging [44] and sonoelastography [45]. However, such techniques are likely to be too time-consuming or expensive for routine clinical use.

In summary, this study has demonstrated that plantar calcaneal spurs and plantar fascial thickening frequently coexist in individuals with PHP, that isolated plantar calcaneal spurs are rare and that tenderness on palpation of the heel does not appear to differentiate between these features. These findings support the view that PHP is a complex, multifactorial condition involving multiple tissues. Future research using a wider array of imaging techniques may assist in identifying different subgroups of PHP and help identify the underlying cause of symptoms.

Acknowledgements

H.B.M. is currently a National Health and Medical Research Council of Australia Senior Research Fellow (ID: 1135995). M.J.T. is currently supported by an Integrated Clinical Academic Programme Clinical Lectureship from the National Institute for Health Research (NIHR) and Health Education England (HEE) (ICA-CL-2016-02-014). The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the NIHR, HEE or the Department of Health. The authors would like to thank the administrative, health informatics and research nurse teams of Keele University's Arthritis Research UK Primary Care Centre, the staff of the participating general practices and the Haywood Hospital, particularly Dr Jackie Saklatvala, Carole Jackson and the radiographers at the Department of Radiography. We would also like to acknowledge the contributions of Linda Hargreaves, Gillian Levey, Liz Mason, Dr Jennifer Pearson, Julie Taylor, Deborah D'Cruz and Dr Laurence Wood to data collection. We would like to thank Adam Garrow and the University of Manchester for permission to use the foot manikin (© The University of Manchester 2000. All rights reserved).

Funding: This work was supported by an Arthritis Research UK Programme Grant (18174) and service support through the West Midlands North CLRN. The study funders had no role in the study design; data collection, analysis or interpretation; in the writing of the paper; or in the decision to submit the paper for publication.

Disclosure statement: The authors have declared no conflicts of interest.

Supplementary data

Supplementary data are available at *Rheumatology* online.

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