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Prevalence of foot/ankle osteoarthritis and pain in retired male professional footballers compared to general population male controls: a cross-sectional study

Ahmed Ali Thanoon[1,2,3], Shima Espahbodi[1,2,3], Monirah Ali Shuaib[1,2,3], Bonnie Millar[1,3,10], Ashely Duncan[5], Catherine J Bowen[6], Terence W O'Neill[7], Richard J Wakefield[8], Fiona E Watt[9], David A Walsh[1,3,10,13], Gordon Fuller[11], Mark E Batt[2], Sanjay M Parekh[12], Gwen Sascha Fernandes[1,4], Michael Doherty[1,2,3], Weiya Zhang[1,2,3,10*]

[1] Academic Rheumatology, Injury Inflammation and Recovery Sciences, School of Medicine, University of Nottingham, Nottingham, UK.

[2] Arthritis UK Centre for Sport, Exercise and Osteoarthritis, University of Nottingham, Nottingham, UK.

[3] Arthritis UK Pain Centre, University of Nottingham, Nottingham, UK.

[4] South West Critical Thinking Unit, Population Health Directorate, NHS England, UK.

[5] National Institute for Health Research ARC EM, University of Nottingham, Nottingham, UK.

[6] Faculty of Environmental and Life Sciences, University of Southampton, Southampton, UK.

[7] NIHR Manchester Biomedical Research Centre, Manchester Academic Health Sciences Centre, Manchester University Foundation NHS Trust, Manchester, UK.

[8] NIHR Leeds Biomedical Research Centre, University of Leeds, Leeds, UK.

[9] Department of Immunology and Inflammation, Imperial College London, London, UK.

[10] NIHR Nottingham Biomedical Research Centre, Nottingham University Hospitals, NHS Trust, UK.

[11] Centre for Urgent and Emergency Research, University of Sheffield, Sheffield, UK.

[12] Perspectum, Oxford, UK.

[13] Advanced Pain Discovery Platform.

*Corresponding author weiya.zhang@nottingham.ac.uk

Academic Rheumatology, School of Medicine, University of Nottingham, Clinical Sciences Building, City Hospital, Nottingham NG5 1PB, UK

ORCID: https://orcid.org/0000-0003-1142-1460

Abstract

Objectives. To examine whether retired male professional footballers have a higher risk of foot/ankle osteoarthritis (OA) and pain than general population male controls.

Methods. In this cross-sectional study, questionnaires for self-reported foot/ankle OA outcomes were posted to 878 footballers and 1060 controls, and subsequently a sample of responders per group underwent assessment for radiographic OA (ROA) irrespective of symptoms. ROA was defined using the La Trobe atlas when definite osteophyte (score≥2) or definite joint space narrowing (score≥2) was observed at any assessed foot/ankle joint. Symptomatic ROA (sROA) was defined as presence of ROA and pain in the same region of the foot for most days of the past month. Adjusted relative risks (aRRs) with 95% confidence intervals (CI) were calculated using robust Poisson regression.

Results. 468 footballers (53%) and 619 controls (58%) completed questionnaires, of whom 113 footballers and 319 controls underwent radiographic assessment. Compared to controls, footballers were more likely to: (1) report General Practitioner diagnosed foot/ankle OA (aRR 1.77, 95% CI 1.22-2.57), forefoot/ankle surgery (aRR 2.80, 95% CI 2.04-3.84), and current foot/ankle pain (aRR 1.33, 95% CI 1.09-1.62); and (2) have foot/ankle ROA (aRR 1.04, 95% CI 1.01-1.07) and sROA (aRR 1.63, 95% CI 1.21-2.19).

Conclusion. Retired male professional footballers were more likely to have self-reported and radiographic foot/ankle OA than general population male controls. The ankle appeared the joint most affected by OA in footballers compared to controls. Further study is needed in female footballers and to determine specific risk factors related to this increased risk.

Keywords: foot/ankle OA, professional footballers, general populations

Key messages:

- Outcomes of foot/ankle OA are more common in retired male professional footballers than community-based controls.
- Further research into the football-specific risk factors for foot/ankle OA is required.
- These findings have significant implications for professional practice and policy to safeguard professional footballers.

Introduction

Football is the most popular sport worldwide. Over 128,000 male professional footballers are estimated to play across 4000 clubs in 135 countries around the world [1]. The average career span of a professional footballer is approximately 13.5 years [1]. Although professional footballers are typically very fit, engaging in high-intensity match-play and regular training can result in sport-related health risks [2,3]. Professional football associates with a high injury rate, a significant proportion of which affect the knee and foot/ankle joints [4]. Apart from overt acute injury, the cumulative effect of repetitive microtrauma and high loading to the foot/ankle joints also may be harmful [5].

Osteoarthritis (OA) is a common complex disorder with multiple genetic, constitutional and environmental risk factors [6]. Foot/ankle OA can cause foot pain and deformities, which may result in poor balance and increased risk of falling [7,8]. Despite long-held concerns about the risk of foot/ankle OA in professional footballers, only five studies have examined the long-term effects of injuries and intense physical demands of a football career on foot and ankle joints [2,4,9-11]. However, only one of these compared the prevalence of ankle OA between 170 male footballers (mean age 49.8 years) and 132 general population male controls (mean age 50.7 years). That study found a higher prevalence of ankle radiographic OA (ROA) in the footballers compared to controls (8.8% versus 3.7%, respectively, $p < 0.05$) [10]. However, whether the prevalence of OA at other foot joints is higher in professional footballers than the general population remains unknown.

To address this gap, we undertook the current study which aimed to compare the prevalence of foot/ankle OA overall and by anatomical region (forefoot, midfoot and ankle), between retired male professional footballers and general population male controls.

Methods

Study design

This was a cross-sectional study comparing self-reported outcomes obtained by questionnaire and radiographic outcomes of foot/ankle OA between retired male professional footballers and general population male controls. The study was conducted in the United Kingdom (UK) between August 2020 and March 2023. The East Midlands-Leicester Central Research Ethics Committee approved the study (REC Ref: 19/EM/0354). Completion of the questionnaire was taken as implied consent, and for those invited to a subsequent hospital visit, written informed consent was obtained prior to their radiographic assessment.

The study was part of the Foot/ankle Osteoarthritis and Cognitive impairment in retired UK Soccer players (FOCUS) study, the protocol of which is published [12]. The FOCUS study measured both foot/ankle and neurodegenerative outcomes, and the neurodegenerative findings have been published elsewhere [13,14].

Participants

Participants were recruited from our previous study examining the prevalence of knee osteoarthritis (KOA) in retired male professional footballers living throughout the UK and general population male controls from the East Midlands region of England [15]. Of those who participated in the KOA study, 878 of 1207 retired professional footballers and 1060 of 1443 general population controls had indicated willingness to participate in future research and were the source populations for this foot/ankle OA study (Figure 1).

Inclusion criteria for footballers were males aged 40 years and over living in the UK who had played professionally in the top four tiers of the English Football League. Controls were males aged 40 years and over living in the East Midlands with no history of playing football professionally. All participants could read and write in English, and none had known terminal illness, or inability to give informed consent or complete a questionnaire. Inclusion criteria for radiographic assessment were similar for footballers and controls who could attend one of five collaborating National Health Service (NHS) hospitals. Exclusion criteria for radiographs were having previously undergone bilateral ankle joint replacement or having any contraindication to having radiographs of their feet and ankles.

Questionnaire survey

The questionnaire contained questions on basic demographics (e.g., age, height and weight), pain (e.g., current foot/ankle pain for most days of the past month and significant foot/ankle pain ever experienced for most days over a 3-month period, each using a line-drawing foot manikin [8], and age of onset of foot/ankle pain), details of any injury, injection and surgery to foot/ankle joints, General Practitioner (GP)-diagnosed foot/ankle OA, risk factors (e.g., current and constitutional toe alignment [16], index-to-ring finger length ratio [17], and nodal OA status [18]), Charlson Comorbidity Index [19], gout, (reported as a self-reported physician diagnosis

[20]), flat-footedness (defined as present if a subject had been informed of this by a health professional [21]), Index of Multiple Deprivations according to postcode [22], and quality of life (QoL) using The Short Form-36 (SF-36) Health Survey [23]. Further details of the questionnaire are available in the published protocol [12].

Radiographic assessment of foot/ankle OA

Footballers who returned completed questionnaires, indicated willingness to undergo foot/ankle radiographic assessment, and lived reasonably close to one of five collaborating NHS hospitals (Nottingham, Manchester, Leeds, Southampton, and London) were invited to attend a single hospital Radiology appointment for bilateral foot and ankle radiographs, irrespective of self-reported foot/ankle OA outcomes. Similarly, the general population controls who indicated willingness to undergo radiographic assessment, irrespective of foot/ankle OA outcomes, were invited to attend a single appointment at the City Hospital, Nottingham University Hospital NHS Trust.

All five hospitals used the same radiographic protocol [24]. For the dorsoplantar foot view, participants stood on the detector with their feet flat and the X-ray tube angled 15° upward, with a vertical central ray centred on the third metatarsal base. For the lateral view, participants stood on a low platform with the detector positioned on the side of their foot with the X-ray tube angled at 90° with a central horizontal ray centred on the first metatarsal [24]. For the anteroposterior ankle view, the ankle was dorsiflexed 90° with the leg rotated 20° medially until medial and lateral malleoli were equidistant from the image receptor. Each ankle was assessed separately [24].

Using the La Trobe radiographic atlas, foot radiographic OA (ROA) was defined primarily as definite osteophyte (OST ≥2) or joint space narrowing (JSN ≥2) in any of the five-foot joints included in the atlas, specifically, in the forefoot the 1st metatarsophalangeal joint (1^{st} MTPJ), and in the midfoot the 1^{st} cuneo-metatarsal joint (CMJ), 2nd CMJ, navicular-1^{st} cuneiform joint (N1stCJ), and talo-navicular joint (TNJ), in either dorsoplantar or lateral views [24]. Ankle ROA was defined by presence of either OST ≥2 or JSN ≥2 in at least one ankle (talocrural) joint in either the anterior-posterior or lateral view [24]. In addition, we used a more stringent ROA definition requiring the presence of both OST ≥2 plus JSN ≥2 (i.e., definite OST plus definite JSN). Symptomatic radiographic OA (sROA) was defined as presence of ROA in a joint and pain in the same region as the joint for most days in the past month, using the questionnaire line-drawing foot manikin [25-27].

All radiographic images were read by a single observer (AT), using RadiAnt DICOM Viewer software 2021 [28]. When interpretation of OST or JSN was difficult, a conservative approach was adopted. For example, if there was ambiguity between grades 2 and 3, the lower grade (2) was assigned [29]. To establish intra-rater and inter-rater reliability for scoring OA, radiographs from 60 randomly selected participants were re-scored two weeks later by AT and were scored also by a second assessor (MS) blinded to the original scores. The procedure was repeated three times with 20 different participants at each time point (start, midpoint, and end of the study), resulting in evaluation of 120 feet and ankles in 60 participants [30]. Both scorers (AT and MS) had undergone training by the same experienced senior assessor (CJB) prior to formal scoring, until the inter-rater reliability between the two scorers reached moderate to excellent, with weighted kappa values at least 0.80 [29].

Statistical analysis

The sample size was calculated according to the 14.3% prevalence of foot/ankle OA in general population male controls and an odds ratio of 2 as a minimum clinically important difference (MCID) between footballers and general population controls [8]. This required 250 participants per group accounting for a 12% dropout and attrition rate to provide 90% statistical power with 5% type I error. The calculation involved using a z-test and a multiple logistic regression model with an R^2 of 0.3 between multiple covariates, as implemented in G*Power V.3.1.9.2 [31].

Comparisons were made between footballers and controls using the Chi-square test for categorical data, independent t-test for normally distributed data or Mann-Whitney U-test for non-normally distributed data. The prevalence of foot/ankle OA was calculated based on the number of participants with OA at any foot/ankle joint on any side divided by the total number of people per group. The prevalence of OA by anatomic region was also calculated to see which specific anatomic region of foot/ankle joints was more likely to be affected in footballers compared to controls.

Robust Poisson regression model was used to calculate adjusted relative risks (aRRs) with 95% confidence interval (CI) between footballers and controls [32]. The aRR was adjusted for potential confounding factors based on existing knowledge from the literature and significant differences between footballers and controls in the univariate analysis. Agreement for intra-rater and inter-rater radiographic assessments were estimated using the kappa statistic [30]. All analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 29, with a p-value of 0.05 indicating statistical significance.

Participant and Public Involvement (PPI)

Several retired male professional footballers and people with OA from our Centre PPI groups were involved in the design and test of the questionnaire, and the development of FOCUS newsletters to assist the recruitment and dissemination of the project.

Results

468 footballers (53%) and 619 controls (58%) returned completed questionnaires. Of these, 362 footballers and 497 controls indicated willingness to undergo radiographic assessment but only 113 footballers and 319 controls eventually underwent radiographic assessment, because of the COVID-19 pandemic and post-pandemic railway and NHS strikes (Fig. 1). There were no significant differences in age, BMI, or socioeconomic status between the source population, questionnaire sample, and radiographic assessment sample in either the footballer or control groups (Table 1).

Table 2 shows the characteristics of both self-reported and radiographic samples of this study. Footballers were younger (mean age 63.27 versus 68.42 years; $p<0.001$) and had a higher socioeconomic status (median 8.00 versus 6.50; $p<0.001$) but similar BMI (mean 27.16 versus 26.81; $p=0.124$). Footballers scored higher on the SF-36 physical component score (mean 72.02 versus 69.25; $p=0.046$) but not the mental component score (mean 77.98 versus 77.27; p 0.559), had lower Charlson comorbidity scores (mean 1.07 versus 1.33; $p=0.048$) and less body pain (22% versus 29%; $p<0.014$), but a higher prevalence of prior foot/ankle injuries (44.71% versus 18.73%; $p<0.001$) and foot/ankle injections (53.13% versus 6.25%; $p<0.001$). Similar characteristics were observed for the radiographic assessment between the two groups (Table 2).

Both intra-rater (AT) agreement (weighted kappa ranged from 0.61 to 0.96) and inter-rater (AT with MS) agreement (weighted kappa ranged from 0.83 to 0.95) were good to excellent for OST and JSN across all assessed joints (Supplementary Table S1 and S2, respectively). Imputation was not considered because under 10% of data was missing for any outcome [33].

Prevalence of GP-diagnosed foot/ankle OA at any joint was 13% in footballers versus 8% in controls ($p=0.011$), and footballers were three times more likely than controls to report forefoot/ankle surgery (24.18% versus 7.90%, respectively; $p<0.001$). Current foot/ankle pain was reported by 35% of footballers versus 26% of controls ($p=0.003$). Foot/ankle ROA was present in 99.11% of footballers and 97.17 of controls ($p=0.072$), and sROA occurred in 39.82% of footballers versus 28.21% of controls ($p=0.022$) when ROA was defined as either OST or JSN≥2 at any foot/ankle joint. The prevalence of ROA and sROA reduced when ROA was defined more stringently as both OST and JSN ≥2 at any foot/ankle joint (Supplementary Table S4).

After adjusting for age, socioeconomic status and Charlson Comorbidity Index, footballers were more likely to have GP-diagnosed foot/ankle OA (aRR 1.77, 95% CI 1.22-2.57), forefoot/ankle surgery (aRR 2.80, 95% CI 2.04-3.84), current foot/ankle pain (aRR 1.33, 95% CI 1.09-1.62), foot/ankle ROA (aRR 1.04, 95% CI 1.01-1.07) and sROA (aRR 1.63, 95%CI 1.21-2.19) but not ever foot/ankle pain for ≥ 3 months (Table 3).

Table 4 summarises the prevalence of foot/ankle OA outcomes by anatomical region (forefoot, midfoot and ankle/hindfoot) between the two groups. The ankle/hindfoot was the region more likely to be affected by OA in footballers than controls across all outcomes.

Additionally, footballers reported foot/ankle pain a decade earlier than controls (mean age of onset 45.24 versus 56.98 years; $p<0.001$) (Fig. 1). After adjusting for age, socioeconomic status and Charlson Comorbidity Index, there were no significant differences between footballers and controls for pain catastrophising (aRR 1.47, 95% CI 0.43-4.98) or neuropathic-like pain (aRR1.97, 95% CI 0.92-4.25) (Supplementary Table S3).

Discussion

To date, this is the largest UK study for the prevalence of foot/ankle OA in retired male professional footballers compared with general population male controls. Key findings were that compared to controls, footballers were at higher risk of GP-diagnosed foot/ankle OA, forefoot/ankle surgery, current foot/ankle pain and foot/ankle ROA and sROA. The ankle/hindfoot was the region more likely to be affected by OA in footballers than controls across all outcomes. In addition, footballers experienced foot/ankle pain a decade earlier than general population controls.

The prevalence of self-reported GP-diagnosed ankle OA in retired footballers (9.83%) closely aligns with a previous study that reported a 9.2% (37/401) prevalence of self-reported physician-diagnosed ankle OA in retired male professional footballers from multiple countries [2]. However, unlike that study, we included a similarly aged male control group, which confirmed that the risk of self-reported GP-diagnosis of foot/ankle OA was indeed higher in footballers than in the general population.

The 11.6% prevalence of midfoot sROA in the general population male controls was slightly higher than the 10.3% reported in the previous UK Clinical Assessment Study of the Foot (CASF) [34]. Additionally, the prevalence of forefoot (1st MTPJ) sROA in our study was slightly higher than that in general population males in the CASF (8.15% versus 6.7%, respectively) [8], perhaps because their mean age was 68 years, which is 8 years older than that for men in the CASF cohort [8]. However, caution is required when comparing prevalence data of foot/ankle OA across different studies due to differences in recruitment, population characteristics, and definitions of the condition. Nevertheless, our findings in the male general population of the East Midlands in general accords with those reported previously.

The prevalence of self-reported OA and ROA was significantly higher in the ankle/hindfoot region of footballers than in general population controls. This may be because the ankle is more likely to be injured through playing professional football and such acute direct trauma may be sufficient to cause ankle OA in later life [3,35-37]. Ankle ligament strains, especially of the lateral collateral ligament complex, are very common because of swerving and being tackled, and may cause instability and subsequent OA [2,3]. Moreover, although footwear helps protect the midfoot and forefoot, professional football boots are very open at the back and offer no secure protection for the ankle. Improved football boot design might have some potential to better protect the hindfoot and influence development of subsequent OA [3].

Apart from having a higher risk of foot/ankle OA following retirement, male footballers also developed foot/ankle pain on average 10 years earlier than males in the general population and may even develop this before they fully retired. Despite the higher prevalence of foot/ankle OA and pain in retired footballers than controls, we found no differences in the type of pain experienced in each group, as reflected by the prevalence of neuropathic-like pain or catastrophising state or trait. It is often assumed that foot/ankle OA in footballers is predominantly "secondary" to severe acute or repetitive low-grade trauma (including fracture and ligamentous instability – "post-traumatic OA") [38]. In contrast, foot/ankle OA in the general population is considered more "primary" and to result from multiple genetic, constitutional, and environmental risk factors rather than one type of joint insult [6]. Our findings suggest that the clinical pain experience from foot/ankle OA is similar in footballers and the general population males irrespective of the cause. However, previous studies suggest that the type of pain may differ between primary and post-traumatic OA due to different pathogenesis and underlying mechanisms [39,40]. The absence of a significant difference in type of pain in our study may be due to the small sample size and recall bias.

It is noteworthy that using the La Trobe radiographic atlas and the Menz et al definition of OA according to a single OA feature (either OST≥2 or JSN≥2), the prevalence of foot/ankle ROA was extremely high (almost saturated) and did not significantly differ between footballers (99.11%) and controls (97.17%) ($p=0.072$) [24]. However, a significant difference was apparent (81.25% in footballers versus 57.69% in controls; $p<0.001$), when we used a more stringent definition of OA (OST≥2 plus JSN≥2) that required both definite OST and JSN (Supplementary Table S4), as is suggested when using a line drawing radiographic atlas for knee OA [41]. The stricter radiographic definition requiring both JSN and OST ≥2 is likely to be more clinically meaningful, as it reflects established structural osteoarthritis rather than isolated or age-related radiographic features [41]. This approach improves discriminatory power and aligns more closely with definitions associated with symptomatic disease and functional impact [41]. Future foot OA studies should consider adopting stricter, standardised definitions to enhance clinical relevance and comparability across studies These results suggest that the Menz et al definition may be too sensitive, and further study concerning the optimal radiographic threshold for foot/ankle ROA is warranted [24]. The omission of the subtalar joint from the La Trobe atlas represents an additional important limitation of the imaging protocol, as it is a common site of post-traumatic ankle OA that may be particularly relevant in professional footballers [4,42,43].

Clinical Implications

The findings of this study support consideration of strategies to prevent ankle injuries in footballers and also tailored post-career medical support [37]. Recommended strategies include education, strengthening exercises, neuromuscular training, and effective injury management to prevent long-term complications [37]. The findings also call for further investigation of the specific risk factors for the increased risk of foot/ankle OA in professional footballers to inform the development of preventative strategies that may reduce this risk [1].

Limitations

This study has several limitations. Firstly, self-reported questionnaire data have an inherent potential for recall bias and possible misclassification, including the assessment of flat-footedness. Secondly, the study is not free from selection bias, as footballers were recruited from a previously established KOA footballer study rather than randomly sampled from all professional clubs. Thirdly, due to logistical issues caused by the COVID-19 pandemic/lockdown and subsequent strikes, not all willing participants were able to undergo radiographic assessment. Although we found no significant differences between the source population, questionnaire responders, and those who had radiographs, the lower response rates in footballers to the questionnaire survey and the attendance for radiographic assessment may affect the representativeness and power of the study. Fourthly, as the study was focused specifically on foot/ankle pain and OA, people with foot/ankle symptoms and a diagnosis of OA might be more likely to respond to the questionnaire and attend radiographic assessment. Fifthly, foot/ankle specific patient-reported outcome measures were not included, which may have limited the ability to capture detailed foot-related pain and functional impairment. Sixthly, the scorers' limited prior experience in radiographic OA assessment may have influenced scoring sensitivity/specificity. Although training was undertaken, misclassification in borderline cases cannot be excluded, which may have contributed to an overestimation of foot/ankle ROA prevalence. Seventhly, this study was restricted to male professional footballers in England, and further studies that include female footballers are required to determine any differences between male and female footballers. Further studies in other countries are also required to confirm the generalisability of the findings. Also, future qualitative research could complement these findings by exploring ex-professional footballers' experiences and perceptions of foot/ankle OA.

Conclusion

This study found that retired UK male professional footballers in their later life were more likely to have GP-diagnosed foot/ankle OA, current foot/ankle pain, forefoot/ankle surgery, foot/ankle ROA and sROA than general population male controls. The ankle appeared to be the joint most affected by OA in footballers compared to controls. Further studies are needed in female professional footballers and to determine the specific risk factors related to this increased risk in professional footballers.

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Data sharing: De-identified participant data of this study is available only for research purposes upon request, subject to the Data Transfer Agreement (DTA) between the University of Nottingham and the data requester according to the university data protection policy and the European General Data Protection Regulation (GDPR).

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Table 1. Comparison among source population, questionnaire responders, and samples undergoing radiographic assessment in retired male professional footballers and general population male controls.

Footballers	Source population (n=878)	Questionnaires completed (n=468)	Radiographic assessment (n=113)	p-value -
Age (years), mean (SD)	64.17 (11.17)	64.37 (10.51)	63.10 (8.58)	0.529[a]
Boday mass index (kg/m2), mean (SD)	27.34 (3.00)	27.22 (2.89)	27.01 (2.66)	0.480[a]
Socioeconomic, (decile), median (IQR)	8.00 (6-9)	8.00 (6-10)	9.00 (7-10)	0.173[b]
General population	**Source population (n=1060)**	**Questionnaires completed (n=619)**	**Radiographic assessment (n=319)**	**p-value -**
Age (years), mean (SD)	69.51 (9.55)	69.10 (9.30)	68.17 (8.53)	0.076[a]
Boday mass index (kg/m2), mean (SD)	27.19 (4.27)	26.80 (4.27)	26.68 (3.71)	0.070[a]
Socioeconomic, (decile), median (IQR)	6.00 (4-10)	6.50 (4-10)	6.00 (4-10)	0.092[b]

a = ANOVA test.

b= Kruskal–Wallis test.

IQR = Interquartile range.

SD: Standard deviation.

Table 2. Characteristics of retired male professional footballers and general population male controls.

	Self-reported questionnaire			Radiographic assessment		
	Footballers (n=468)	**General population (n=619)**	**p-value**	**Footballers (n=113)**	**General population (n=319)**	**p-value**
Age (years), mean (SD)	63.27 (10.46)	68.42 (9.25)	**<0.001**[a*]	63.63 (8.46)	68.56 (8.55)	**<0.001**[a*]
Body mass index (kg/m2), mean (SD)	27.16 (3.22)	26.81 (4.13)	0.124[a]	26.80 (3.01)	26.58 (3.68)	0.563[a]
Socioeconomic (decile), median (IQR)	8.00 (6-10)	6.50 (4-10)	<0.001[c*]	9.00 (7-10)	6.00 (4-10)	0.006[c*]
Charlson Comorbidity Index, mean (SD)	1.07 (2.09)	1.33 (2.28)	**0.048**[a*]	0.81 (1.83)	1.14 (2.05)	0.122[a]
SF-36[1] components summary, mean (SD)						
Physical components	72.02 (21.63)	69.25 (23.90)	**0.046**[a*]	75.03 (19.45)	71.53 (22.56)	0.143[a]
Mental components	77.98 (19.25)	77.27 (20.36)	0.559[a]	81.33 (15.83)	79.30 (18.90)	0.307[a]
Foot/ankle injury n/total (%)	190/425 (44.71)	112/598 (18.73)	**<0.001**[b*]	50/108 (46.30)	69/308 (22.40)	**<0.001**[b*]
Foot/ankle injections n/total (%)	221/416 (53.13)	36/576 (6.25)	**<0.001**[b*]	52/102 (50.98)	25/295 (8.47)	**<0.001**[b*]
Nodal OA, n/total (%)	29/463 (6.26)	43/598 (7.20)	0.556[b]	4/112 (3.57)	26/308 (8.44)	0.087[b]
Gout, n/total (%)	56/468 (12.00)	70/619 (11.31)	0.737[b]	18/113 (15.93)	36/318 (11.32)	0.204[b]
Pattern 3 2D:4D finger ratio, n/total (%)	300/452 (66.37)	373/598 (62.37)	0.181[b]	72/109 (66.06)	203/310 (65.48)	0.914[b]
Current hallux valgus n/total (%)	118/454 (25.99)	159/607 (26.19)	0.941[b]	32/111 (28.83)	69/316 (21.84)	0.136[b]
Constitutional (aged 20years) n/total (%)	27/428 (6.31)	39/568 (6.90)	0.710[b]	10/105 (9.52)	15/297 (5.05)	0.103[b]
Flat feet, n/total (%)	39/443 (8.80)	55/600 (9.17)	0.840[b]	10/109 (9.17)	32/314 (10.19)	0.760[b]
Body pain, n/total (%)	103/468 (22.00)	177/619 (29.00)	**0.014**[b*]	20/113 (17.70)	84/318 (26.42)	0.063[b]

*p ≤ 0.05 is defined as significant and marked in bold.
[1] The SF-36 scores range from 0 to 100, with lower scores indicating poorer health status and higher scores indicating better health status.
Socioeconomic decile was measured according to the postcode.
Nodal OA was defined as reporting nodes on at least two rays of both hands.
2D<4D (pattern 3): The index finger is shorter than the ring finger.
Constitutional: refers to conditions or characteristics established during early adult life, specifically in individuals aged 20 years.
OA = osteoarthritis. a = Independent sample T-test. b = Chi-Square test. c = Mann-Whitney U test. IQR = Interquartile range.
SD = Standard deviation.
n = number.

Table 3. Prevalence of foot/ankle OA in retired male professional footballers and general population male controls.

	Prevalence, n (%)		
Self-reported outcomes	**Footballers (n=468)**	**General population (n=619)**	**aRR[1] (95% CI)**
GP-diagnosed foot/ankle OA	55/424 (13.00)	47/581 (8.00)	**1.77 (1.22 - 2.57)***
Surgery forefoot/ ankle	103/426 (24.18)	47/595 (7.90)	**2.80 (2.04 - 3.84)****
Current foot/ankle pain	150/429 (35.00)	150/574 (26.00)	**1.33 (1.09 - 1.62)***
Ever foot/ankle pain ≥3 months	133/438 (30.00)	160/590 (27.00)	1.15 (0.93 - 1.41)
Radiographic outcomes	**(n=113)**	**(n=319)**	**aRR[2] (95% CI)**
ROA foot/ankle			
JSN or OST≥2	112/113 (99.11)	309/318 (97.17)	**1.04 (1.01 - 1.07)***
sRAO foot/ankle			
JSN or OST≥2	45/113 (39.82)	90/318 (28.21)	**1.63 (1.21 - 2.19)***

* p<0.05. ** p<0.001. CI is defined as significant and is marked in bold.
[1] Adjusted for age, socioeconomic status, and Charlson Comorbidity Index.
[2] Adjusted for age and socioeconomic status.
Foot included only five joints (1st Metatarsophalangeal joint, 1st Cuneo-metatarsal joint, 2nd Cuneo-metatarsal joint, Navicular-1st cuneiform joint and Talonavicular joint).
Ankle = (Talocrural joint).
JSN = Joint space narrowing, OST = Osteophyte on La Trobe atlas scale 0-3.
GP = General practitioner.
ROA = Radiographic osteoarthritis.
sROA = Symptomatic radiographic osteoarthritis.
n = number

Table 4. Prevalence of foot/ankle OA by anatomical region in retired male professional footballers and general population male controls.

Self-reported outcomes	Region	Prevalence, n (%) Footballers (n=468)	Prevalence, n (%) General population (n=619)	aRR[1] (95% CI)
GP- diagnosed OA	Forefoot	33/468 (7.05)	29/619 (4.68)	1.58 (0.72 - 3.45)
	Midfoot	17/468 (3.63)	17 619 (2.75)	1.45 (0.74 - 2.84)
	Ankle	46/468 (9.83)	28/619 (4.52)	**2.39 (1.50 - 3.79)****
Surgery	Forefoot	26/468 (5.56)	26/619 (4.20)	1.28 (0.80 - 2.05)
	Midfoot	n/a	n/a	n/a
	Ankle	82/468 (17.52)	22/619 (3.55)	**4.36 (2.71 - 7.44)****
Current pain	Forefoot	97/468 (20.73)	93/619 (15.02)	**1.35 (1.03 - 1.76)***
	Midfoot	55/468 (11.75)	71/619 (11.47)	1.15 (0.83 - 1.60)
	Hindfoot^	113/468 (24.15)	97/619 (15.67)	**1.57 (1.22 - 2.02)***
Ever pain ≥3 months	Forefoot	69/468 (14.74)	85/619 (13.73)	1.10 (0.81 - 1.50)
	Midfoot	47/468 (10.04)	65/619 (10.50)	1.12 (0.78 - 1.59)
	Hindfoot^	99/468 (21.15)	92/619 (14.86)	**1.42 (1.09 - 1.86)***
Radiographic outcomes	**Region**	**(n=113)**	**(n=319)**	**aRR[2] (95% CI)**
ROA	Forefoot	61/112 (54.56)	147/314 (46.82)	**1.30 (1.06 - 1.60)***
	Midfoot	94/112 (83.93)	286/317 (90.22)	0.97 (0.89 - 1.06)
	Ankle	107/112 (95.54)	206/315 (65.40)	**1.52 (1.37 - 1.96)****
sROA	Forefoot	14/113 (12.38)	26/319 (8.15)	1.74 (0.91 - 3.31)
	Midfoot	12/113 (10.62)	37/319 (11.60)	1.10 (0.60 - 2.04)
	Ankle	25/113 (22.12)	29/319 (9.09)	**3.40 (2.04 - 5.65)****

* $p<0.05$.** $p<0.001$. CI is defined as significant and is marked in bold.
[1]Adjusted for age, socioeconomic status and Charlson Comorbidity Index
[2]Adjusted for age and socioeconomic status.
Forefoot (1st Metatarsophalangeal joint)
Midfoot included only four joints (1st Cuneo-metatarsal joint, 2nd Cuneo-metatarsal joint, Navicular-1st cuneiform joint and Talonavicular joint).
Ankle (Talocrural joint)
ROA = Radiographic osteoarthritis, sROA = Symptomatic radiographic osteoarthritis
^Hindfoot pain refers to pain in the foot's posterior region, including the heel and ankle area.
n/a = Not available.
n = number

Legend for figures

Figure 1. Recruitment of retired male professional footballers and general population male controls. The flowchart summarises the recruitment process of participants from retired male professional footballers (left) and general population male controls (right) for both questionnaire survey and radiographic assessment.

Alt text for Figure 1: Recruitment of retired male professional footballers and general population male controls.

Figure 2. Age of onset current foot/ankle pain in in retired male professional footballers and general population male controls. The histogram shows the onset of current pain at the foot/ankle overall, and at specific sites in male footballers (blue bar) compared to general population male controls (grey bar).

Alt text for Figure 2: Age of onset current foot/ankle pain in in retired male professional footballers and general population male controls.

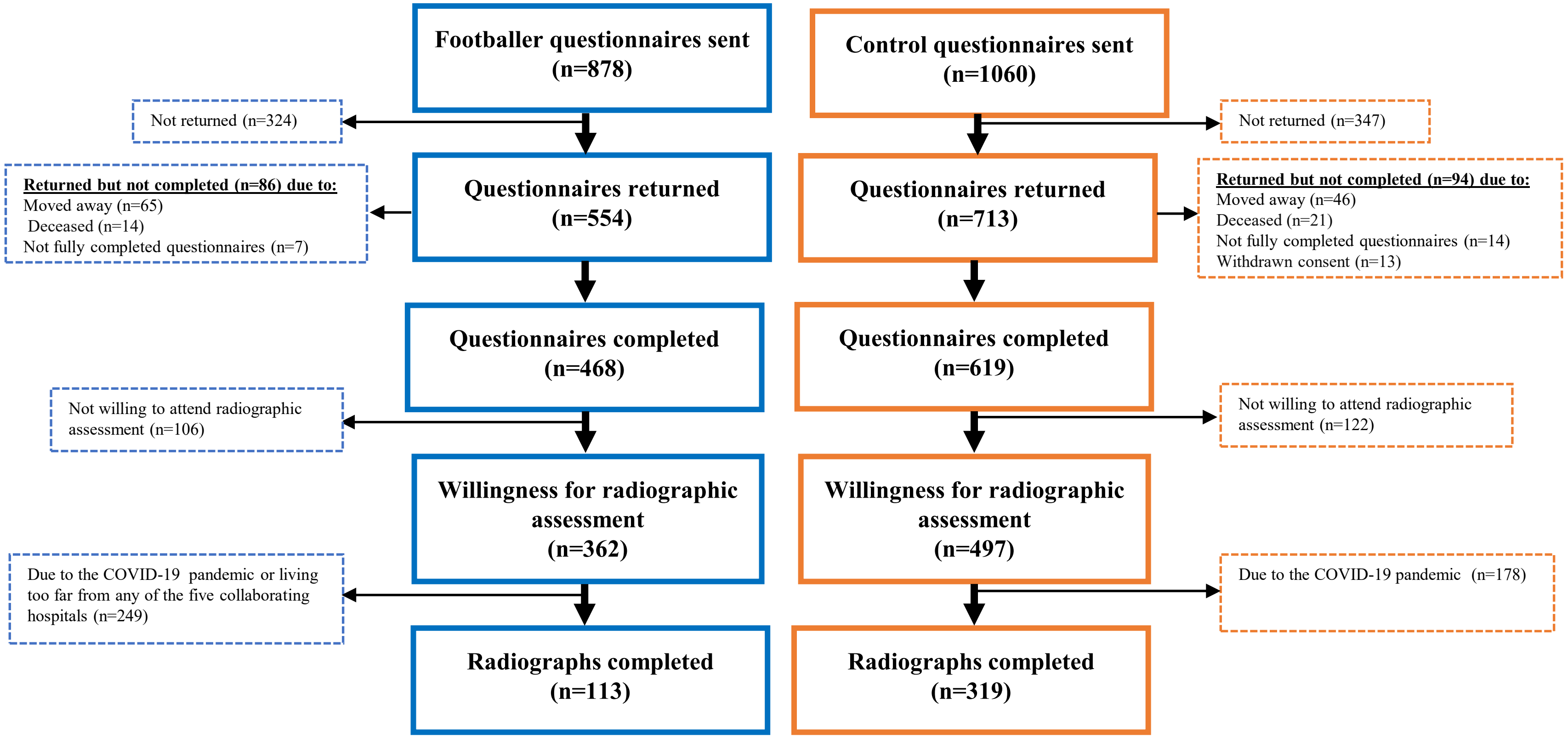

Fig 1. Recruitment of retired male professional footballers and general population male controls.

Alt text: Flow diagram summarising the recruitment process of participants from retired male professional footballers (left) and general population male controls (right) for both questionnaire survey and radiographic assessment.

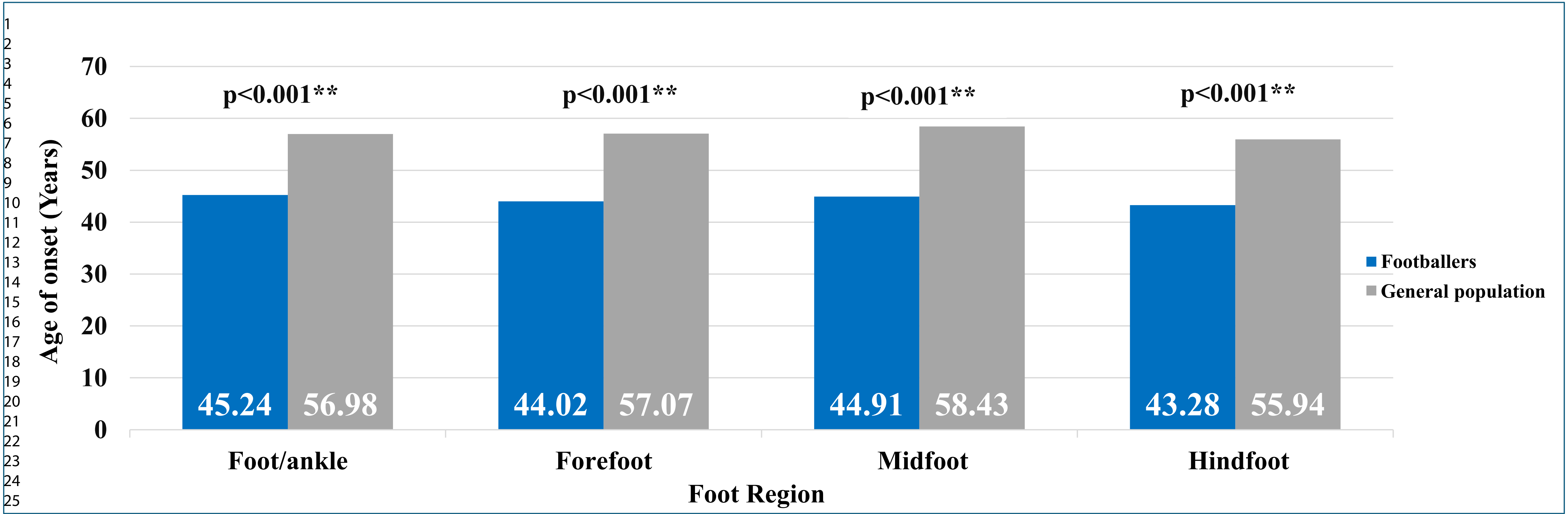

Fig 2. Age of onset current foot/ankle pain in in retired male professional footballers and general population male controls.

Alt text: The histogram showing the mean age of onset current pain at the foot/ankle overall, and at specific sites in male footballers (blue bar) compared to general population male controls (grey bar).