

Associations Between Body Mass Index and Foot Joint Pain in Middle-Aged and Older Women: A Longitudinal Population-Based Cohort Study

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Objective. To investigate the relationship between body mass index (BMI) and foot joint pain (FJP) over a 5-year period in a community-based cohort.

Methods. We examined a subset of women from the Chingford Women's Study, a community cohort followed up for 20 years. From a baseline of 1,003 female participants, we reviewed data from 639 women (64%) for whom complete data sets for FJP and BMI were obtained over a 5-year period between year 10 (Y10) and year 15 (Y15). Descriptive statistics, binary regression modeling, and odds ratios (ORs) were used to examine the longitudinal relationship between BMI and FJP.

Results. For Y10 and Y15, the median age was 61 years (interquartile range [IQR] 57–67) and 66 years (IQR 62–72), respectively, and the mean \pm SD BMI was 26.7 ± 4.6 kg/m² and 27.2 ± 4.8 kg/m², respectively. FJP prevalence was 21.6% at Y10 and 26.6% at Y15. Longitudinal analyses showed that both BMI and FJP increased significantly from Y10 to Y15 ($P < 0.001$). The odds of having FJP after a 5-year period increased by 4.9% for each BMI unit increase 5 years earlier (OR 1.049 [95% confidence interval (95% CI) 1.011–1.089], $P = 0.012$). This remained significant when adjusted for age, diabetes mellitus, and rheumatoid arthritis (OR 1.051 [95% CI 1.011–1.091], $P = 0.012$).

Conclusion. This is the first large longitudinal cohort study demonstrating that, in middle-aged women, a high BMI precedes and is predictive of FJP independent of age. Evidence from our findings can be used to identify those individuals at risk of developing FJP.

INTRODUCTION

Foot and ankle problems may form 8% of a general practitioner's caseload in the UK, with the most frequent of those consultations involving middle-aged women with nontraumatic foot pain (1). The occurrence of disabling foot pain appears to be greatest in women of late middle age (55–64 years) (2). Although not life threatening, foot

pain is associated with loss of mobility, increase in falls, and reduction in health-related quality of life (3–5).

Being overweight or obese appears to be a key associated factor with foot pain (6) and both foot pain and obesity peak around middle age, predominantly in women (7). Two hypotheses are that either foot pain develops first and causes a decrease in activity levels resulting in weight gain

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Significance & Innovations

- Foot joint pain (FJP) is highly prevalent in middle-aged women.
- Over time, a higher body mass index yields a significantly increased likelihood of developing FJP and sustaining FJP.
- Such information is useful to health care providers in determining demand for foot health services as well as directing foot health interventions toward public health messages for weight control.

(8) or that a high body mass index (BMI) or obesity precedes foot pain. For the latter, pain could be caused by the increased load that is placed on the joints and structures of the feet with increasing body weight (9,10). A third, more recent hypothesis suggests that there may be a metabolic element with regard to body composition, generally increased adipose tissue, and foot pain (11,12).

When describing the theorized impact of obesity on the feet, a series of interlinked events becomes apparent in which foot pain could develop at any point. Whether obesity precedes or follows foot pain, foot pain in obese people is not conducive to exercise and weight loss/management, thus creating a paradoxical situation. However, because of the cross-sectional nature of the studies identified, it is difficult to determine the order and combination of events. This is a disadvantage of cross-sectional research; associations but not cause or effect can be inferred (13). Therefore, it is possible that any order and combination could lead to foot pain, which may explain some of the variation observed in cross-sectional foot pain studies. It is notable that very few studies have reported on the longitudinal relationship between BMI and foot pain. A detailed systematic review conducted in 2011 considered the prevalence of foot and ankle pain in middle-aged and older populations (14). Through comprehensive review, the authors included 34 articles (31 studies) and a total of 75,505 participants with pooled prevalence estimates that showed the frequency of foot pain to be 24%. All of the studies used for the analysis were cross-sectional; therefore, the review authors emphasized the need for more longitudinal studies relative to foot pain (14).

A further problem highlighted was the widespread heterogeneity within study protocols of the case definition of foot pain (14). While an association between higher BMI and foot pain is well documented, these investigations have tended to use different methods to assess foot pain. According to Thomas et al, the case definitions for foot pain in these studies usually relate to generalized foot pain, global foot pain, or disabling foot pain and are not specific to anatomical structure or pathology (14,15). This is particularly relevant for the context of investigation of symptomatic osteoarthritis (OA), where studies have shown that a higher BMI is a risk factor for knee OA and knee pain (16,17). To our knowledge, no studies have

focused on pain specific to foot joints, namely, foot joint pain (FJP).

The purpose of this study was to determine if a high BMI predicts FJP in middle-to-older-aged women. To explore the longitudinal associations of BMI and FJP, we drew upon data collected as part of a well-established prospective cohort of middle-aged and older women in the UK.

PATIENTS AND METHODS

Study sample. The participants were selected from the Chingford Women's Study, a prospective population-based longitudinal study of osteoporosis (OP) and OA. All women derived from the register of a large general practice based in Chingford, North London who were between ages 45 and 64 years were contacted in 1988–1989 and asked to participate. Of the 1,353 women contacted, 1,003 women (74% response rate) participated at baseline.

The collection of data and information from the Chingford Women's Study has focused on the natural history of OA and OP using anthropometric, psychosocial, radiologic and dual-energy x-ray absorptiometry, and metabolic variables and has followed strict, well-established protocols. The participants were seen at least once per year up to year 11, and thereafter at years 15 and 20. All participants gave written informed consent; full ethical approval was granted by the Waltham Forest and Redbridge local research ethics committee (reference number: LREC R&WF 96). The study was sponsored by Whipps Cross Hospital Research and Development Unit.

All participants for whom completed data sets for FJP and BMI were obtained over a 5-year period between year 10 (Y10) and year 15 (Y15) were included in this study. Y10 and Y15 were selected because FJP data were specifically collected at these time points only.

Assessment of demographic and clinical characteristics. Age was recorded in whole years depending on the participant's age on the day of their first visit (year 1) and recorded again at each clinical visit thereafter. Height and weight were recorded at each clinical visit. Height was measured in cm (to the nearest 0.1 cm) in a standing position and barefoot using a wall-mounted stadiometer (Leicester Height Measure [Secal]). Weight was measured in kg (to the nearest 0.1 kg) by electronic scales with shoes removed. To investigate change in weight per individual between Y10 and Y15 (Y15 weight – Y10 weight), weight data were categorized as either weight gain (>0), weight loss (<0), or stable weight (= 0).

BMI. The height and weight measures were used to calculate the participants' BMI (weight in kg divided by the square of height in meters). Stratification of BMI was made using the World Health Organization (WHO) international classification for BMI: underweight (<18.50 kg/m²), normal (18.50–24.99 kg/m²), overweight (25.00–29.99 kg/m²), and obese (≥30.00 kg/m²) (18). BMI classification groupings were used for descriptive statistics; however, any inferential statistical analysis used BMI as a continuous variable.

FJP. A standardized self-reported joint symptom questionnaire was used to capture information regarding the hands, knees, hips, and back at years 3, 4, 5, 6, 8, 9, 10, and 15 (URL: <http://www.chingfordstudy.org.uk/>). The questionnaire asked the participants to identify if in the last year they had had any problems with their joints (yes/no) and to specify for which joints they had experienced pain. Questions specific to FJP data were added at Y10 and Y15. Until then, other years had free text space only for “any other joint pains,” in which FJP may have been captured.

Data for responses to the questions related to feet, namely, “any painful episodes in the last year for left and/or right feet,” were extracted from Y10 and Y15 to answer the specific research question. Responses were recorded as yes/no for left and right feet individually and, for the purposes of analysis, were collapsed into the following 2 groups: FJP/ no FJP.

Statistical analysis. Analysis was conducted using a subset of the Chingford Women’s Study cohort that included only participants for whom complete data sets for age, height, weight, and FJP were available at Y10 and Y15 as well as data for all pertinent baseline characteristics. Data from the Chingford Women’s Study are maintained in a Microsoft Access 2000 database and were converted to IBM SPSS, version 19.0 for Mac OS format to perform the analyses.

Descriptive statistics were generated to describe the study population. For normally distributed data, this was achieved using the mean and SD. For data that were not normally distributed, the median and the interquartile range were used. For the cross-sectional analyses, at Y10 and Y15, differences in age, weight, height, and BMI between those with and without FJP were assessed. For normally distributed continuous data, the 2-tailed independent samples *t*-test was used. For data that were not normally distributed, the Mann-Whitney U test was used. *P* values were considered significant if they were less than 0.05 (2-tailed).

Binary logistic regression models were used to estimate associations of BMI with FJP. We modeled the effect of BMI on FJP cross-sectionally at Y10 and longitudinally modeled Y15 FJP on Y10 BMI. Additionally, chi-square tests were used to explore BMI category change and new FJP and persistent FJP between Y10 and Y15. Estimates were in the form of odds ratios (ORs) with 95% confidence intervals (95% CIs). All parameter estimates used 2-sided 5% significance levels.

The sample size of the Chingford Women’s Study cohort was predetermined at the inception of the Chingford

Women’s Study. Using the observed percentage of FJP at Y15 (27%) and allowing for 10 events per variable with 3 covariates (BMI, age, and previous FJP), the number of participants with FJP required for logistic regression was 111. We estimated that this would be sufficient to detect an OR of ~ 1.2 by using a Shieh-O’Brien approximation (19).

RESULTS

Data from 639 women (64%) were included in this study (Table 1). Of the original 1,003 participants at baseline, 808 women (81%) attended the Y10 followup and 657 women (66%) attended the Y15 followup. Of the 657 women who attended the Y15 followup, 639 had complete followup data for FJP. The reasons for loss to followup included died (101), dropped out (120), moved (79), disappeared (23), did not attend Y10 or Y15 visit (38), and had missing data (3). The participants lost to followup were slightly older (mean age 65 years [range 55–74 years]) but were similar in height (mean \pm SD 159.7 \pm 5.8 cm) and weight (mean \pm SD 69.0 \pm 13.6 kg) at Y10.

BMI. The height, weight, BMI, and WHO BMI categories are shown in Tables 1 and 2. Longitudinally, there was a significant reduction in mean \pm SD height of -1.4 ± 1.2 cm between Y10 and Y15; however, while there was an observed mean \pm SD weight change for the cohort of 0.1 ± 5.7 kg, this was not significant. On an individual level, weight change ranged from a minimum loss of 29 kg to a maximum gain of 44 kg. Of 639 women, 49.6% gained weight ($n = 317$; mean \pm SD weight gain 4.1 ± 4.1 kg), 47.6% lost weight ($n = 304$; mean \pm SD weight loss 4.2 ± 4.0 kg), and 2.8% remained static ($n = 18$).

There was a significant increase in mean BMI from Y10 to Y15 ($P < 0.001$). The largest change in BMI over the 5-year period occurred in the obese category. This group had a 5.3% increase from 21.1% (135 of 639 women) in Y10 to 26.4% (169 of 639 women) in Y15. A chi-square test estimated this change to be significant ($P < 0.001$).

FJP. Of 639 women, 21.6% ($n = 138$) reported FJP at Y10, with 8.8% (56 of 639 women) reporting unilateral FJP (i.e., FJP in either their left or their right foot) and 12.8% (82 of 639 women) reporting bilateral FJP (i.e., FJP in both feet). For those reporting unilateral FJP at Y10, 42.9% (24 of 56 women) reported FJP in their left foot and 57.1% (32 of 56 women) reported FJP in their right foot. At Y15, FJP was reported by 26.6% ($n = 170$ women), with 16.0% (102 of 639 women) reporting unilateral FJP and 10.6% (68 of

Table 1. Demographic and clinical characteristics of the study participants (n = 639)*

	Year 10	Year 15	Change	<i>P</i>
Age, median (IQR) years	61 (57–67)	66 (62–72)	+5	–
Height, cm	161.0 \pm 6.0	159.6 \pm 6.1	-1.4 ± 1.2	$P < 0.001$
Weight, kg	69.2 \pm 12.3	69.3 \pm 12.7	$+0.1 \pm 5.7$	$P = 0.788$
BMI, kg/m ²	26.7 \pm 4.6	27.2 \pm 4.8	$+0.5 \pm 2.2$	$P < 0.001$

* Values are the mean \pm SD unless indicated otherwise. IQR = interquartile range.

Table 2. Participants by World Health Organization BMI categories at years 10 and 15*

	Year 10	Year 15	Change, %
Underweight	5 (0.8)	10 (1.6)	+0.8
Normal	252 (39.4)	224 (35.1)	-4.3
Overweight	247 (38.7)	236 (36.9)	-1.8
Obese	135 (21.1)	169 (26.4)	+5.3

* Values are the number (percentage) unless indicated otherwise. BMI = body mass index.

639 women) reporting bilateral FJP. For those reporting unilateral FJP at Y15, 40.2% (41 of 102 women) reported FJP in their left foot and 59.8% (61 of 102 women) reported FJP in their right foot (Figure 1).

Longitudinal analysis of change in FJP between Y10 and Y15 (Figure 2) showed that 62.4% ($n = 399$ women) remained pain free (at least for the 12 months preceding the surveys), 16% ($n = 102$ women) reported new FJP (i.e., pain free at Y10 but reporting FJP at Y15), 11% ($n = 70$ women) reported resolution of their FJP (i.e., FJP present at Y10 but no FJP reported at Y15), and 10.6% ($n = 68$ women) reported persistent FJP (i.e., FJP present at both Y10 and Y15). Therefore, in this cohort, there was a proportional increase in FJP over time of 20.4%. A chi-square test estimated this change to be significant ($P < 0.001$).

Relationship between BMI and FJP. Those with FJP had a significantly higher weight at both study time points ($P = 0.006$ for Y10 and $P = 0.017$ for Y15) than those without FJP but had no difference in height. Consequently, those with FJP had a significantly higher BMI at both study time points ($P = 0.015$ for Y10 and $P = 0.017$ for Y15) than those without FJP. No significant differences were found for age of the participants with and without FJP at either time point ($P = 0.491$ for Y10 and $P = 0.935$ for Y15) (Table 3).

When FJP was analyzed by BMI group (Table 4), an incremental increase in the percentage of participants reporting FJP for each increasing BMI group was observed. In Y10, none of the participants in the underweight group reported FJP; however, 28.9% reported FJP in the obese

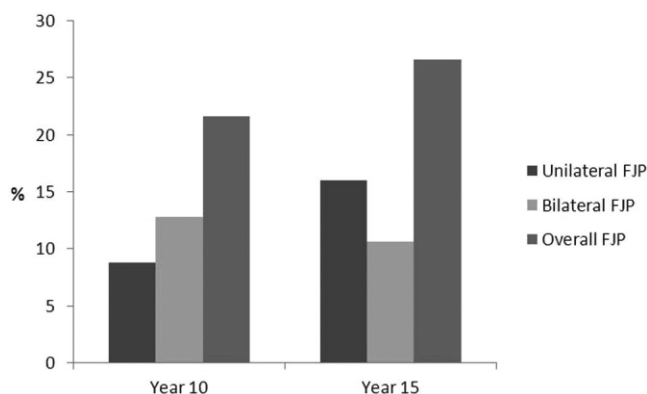


Figure 1. Prevalence (%) of unilateral and bilateral foot joint pain (FJP) at years 10 and 15.

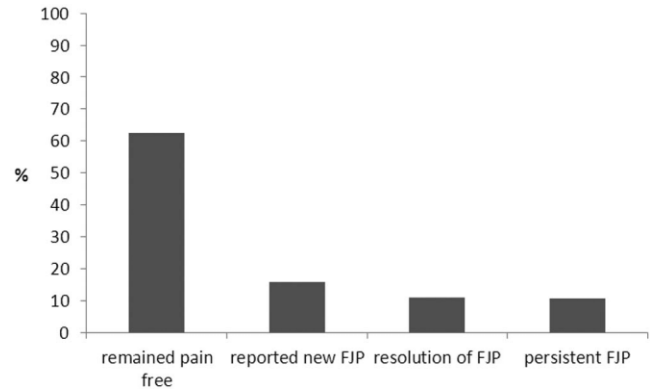


Figure 2. Proportion of change in foot joint pain (FJP) longitudinally from year 10 to 15.

category. In Y15, 10% of the underweight category reported FJP and 32% reported FJP in the obese category.

At Y10, the odds of having FJP increased by 5% per unit of BMI (OR 1.050 [95% CI 1.009–1.092]). This was a linear trend and remained significant when adjusted for age (OR 1.049 [95% CI 1.008–1.092]). At Y15, the odds of having FJP increased by 4.5% per unit of BMI (OR 1.045 [95% CI 1.008–1.083]). This also remained significant when adjusted for age (OR 1.045 [95% CI 1.008–1.083]).

There was a significant longitudinal relationship between BMI at Y10 and having FJP 5 years later (Y15). The unadjusted odds of having FJP at Y15 increased by 4.9% for each BMI unit increase at Y10 (OR 1.049 [95% CI 1.011–1.089], $P = 0.012$). This remained significant when adjusted for age, diabetes mellitus, and rheumatoid arthritis, all at Y10 (OR 1.051 [95% CI 1.011–1.091], $P = 0.012$). When further adjusted for FJP at Y10, the longitudinal relationship between BMI at Y10 and FJP at Y15 remained significant (OR 1.042 [95% CI 1.002–1.083], $P = 0.042$). However, it was noted that FJP at Y10 was also a strong univariable predictor of having FJP at Y15 (OR 3.800 [95% CI 2.551–5.659], $P < 0.001$).

The odds of developing new FJP between Y10 and Y15 (i.e., not having FJP at Y10 but subsequently having FJP at Y15) increased by 2.7% (OR 1.027 [95% CI 0.981–1.074]) per unit of BMI. Similarly, the odds of having persistent FJP (i.e., those with FJP at Y10 still having it at Y15) increased by 7.9% (OR 1.079 [95% CI 0.998–1.167]) per unit of BMI. However, neither of these associations was statistically significant.

DISCUSSION

To our knowledge, this is the first study to identify a significant longitudinal relationship between higher BMI and FJP in a large established cohort of middle-to-older-aged women selected from a general population within the UK. From this investigation, we have observed that FJP is highly prevalent among this population and that, over time, a higher BMI yields a significantly increased likelihood of developing and sustaining FJP. Our findings are thus important because many studies have examined the cross-sectional relationship between BMI and general or disabling foot pain or foot problems (3,4,20–25), but very

Table 3. Characteristics of participants with and without FJP at Year 10 and Year 15*

Characteristic	Year 10			Year 15		
	FJP (n = 138)	No FJP (n = 501)	P	FJP (n = 170)	No FJP (n = 469)	P
Age, median (IQR) years†	61 (57–67.3)	61 (56.5–66.5)	0.491	67 (62–72)	66 (62–72)	0.935
Weight	71.8 ± 11.7	68.5 ± 12.4	0.006	71.3 ± 12.5	68.6 ± 12.7	0.017
Height	161.5 ± 6.4	160.8 ± 5.9	0.286	159.7 ± 6.2	159.6 ± 6.1	0.746
BMI‡	27.6 ± 4.4	26.5 ± 4.6	0.015	28.0 ± 4.8	26.9 ± 4.8	0.017

* Values are the mean ± SD unless indicated otherwise. FJP = foot joint pain; IQR = interquartile range; BMI = body mass index.
 † P calculated for difference between participants with and without foot pain using the Mann-Whitney U test.
 ‡ P calculated for difference between participants with and without foot pain using independent samples t-test.

few have investigated the longitudinal relationship specifically with FJP.

The longitudinal analysis of FJP showed that ~40% of our cohort experienced FJP at some point within the 5-year study period, and that during this time the prevalence of FJP increased significantly (22% at Y10 to 27% at Y15). Of note, unilateral FJP increased (8.8% at Y10 to 16.0% at Y15) and bilateral FJP decreased (12.8% at Y10 to 10.6% at Y15). From these findings, it cannot be determined if the FJP only occurred twice in total (once within the 12 months preceding both assessments at Y10 and Y15), the FJP was intermittent over the course of the 5-year period, the FJP was persistent over the 5-year period, or if different FJP was being reported at each time point, considering a foot examination was not conducted and there was a lack of detail on the specific location of FJP. Interestingly, the strongest association and therefore a predictor of FJP over time was that of already having had an episode of FJP (i.e., persistent FJP). Therefore, our data further support the generally accepted clinical observation that some foot conditions never completely resolve (7). It is also possible that with more participants reporting new incidences of FJP (20.4%) than those reporting resolution of FJP (11%), there is a likely increasing demand for foot health services for middle-to-older-aged women.

As would be expected from overall trends observed in the UK for the study period (26), when stratified according to WHO BMI categories, there was a drift in the category proportions for study participants from the normal to overweight categories toward the overweight and obese categories. A chi-square test estimated this change to be significant ($P < 0.001$). When participants with and without FJP were analyzed according to BMI status, those with FJP had a statistically significant higher mean BMI than those without FJP at both time points ($P = 0.015$ for Y10 and $P =$

0.017 for Y15). These findings are consistent with previously reported cross-sectional studies (4,20,22–25).

The novel findings of our study are that there was an incremental linear increase in the percentage of reported FJP across the BMI categories cross-sectionally at both time points and longitudinally from Y10 to Y15 (i.e., the lowest percentage of FJP was reported in the underweight category while the highest percentage of FJP was reported in the obese category). A higher BMI is therefore likely to predict FJP over time, signifying a longitudinal causal relationship that has long been suspected in clinical practice and is concurrent with longitudinal relationships that have been identified for BMI and knee pain (17) and BMI and foot problems (7). Critically, the longitudinal relationship between the increase in BMI and odds of developing FJP was independent of age. The latter findings that age did not predict FJP over time are comparative to findings of other longitudinal data from Australia (3,11) but are in contrast to previous UK cross-sectional findings (2). Other studies have found that conditions such as rheumatoid arthritis, symptomatic hand and knee OA (20), and diabetes mellitus (7) have an association with foot pain and foot problems and other body site or overall body pain (2,24,27). While we did not have information on all of the potential medical condition confounders, we were able to rerun our analysis to adjust for the presence of rheumatoid arthritis and diabetes mellitus, and the results (ORs and P values) were virtually unchanged with the new adjustment factors additionally included.

A final interesting observation of clinical relevance was that those developing new episodes of FJP and those with persistent FJP appeared to also have an increase in their BMI. While further analysis showed that this was not a significant finding, it is possible that the numbers within those groups were not of sufficient power such that further

Table 4. Crosstabulation of years 10 and 15 by FJP and BMI category*

BMI category	Year 10			Year 15		
	Total no.	FJP	No FJP	Total no.	FJP	No FJP
Underweight	5	0 (0)	5 (100)	10	1 (10)	9 (90)
Normal	252	42 (16.7)	210 (83.3)	224	53 (23.7)	171 (76.3)
Overweight	247	57 (23.1)	190 (76.9)	236	62 (26.3)	174 (73.7)
Obese	135	39 (28.9)	96 (71.1)	169	54 (32)	115 (68)
Total	639	138 (21.6)	501 (78.4)	639	170 (26.6)	469 (73.4)

* Values are the number (percentage) per group unless indicated otherwise. FJP = foot joint pain; BMI = body mass index.

specific investigation with larger numbers may be of interest.

A key strength of this study is that it is a large population-based prospective cohort study representative of middle-aged women (ages 45–64 years) recruited from a general practice in North East London, UK. The potential limitations of this study include confounding variables that required acknowledgement and consideration. Other potential confounding variables include activity levels, foot and ankle injuries, occupation, management of FJP, type of footwear, and major and chronic medical conditions other than rheumatoid arthritis or diabetes mellitus. This is not an exhaustive list, but it helps to provide perspective of the potential task at hand and why we adopted a more simple approach, especially given the sample size and the risk of multiple testing. A very large study sample would be required to complete multivariate logistic regression for all potential confounding variables.

The case definition for FJP in this study assumed pain to be related to foot joints, considering the questionnaire specifically asked about FJP. It is possible that participants were experiencing pain in their feet due to other causes, such as a callus or thickened nails, and reported this as FJP. Because a foot examination was not conducted, it cannot be confirmed that the FJP was a result of joint pain alone and no other causes. Interestingly, our results are similar to the estimated pooled prevalence (24%) of foot pain reported in middle and old age (≥ 58 years) (14).

A specific limitation common to all long-term cohort studies is the attrition of participants with potential for study bias due to deaths and participants withdrawing because of disability and illness and generally having a healthier cohort at followup visits. The return rate, data collection, and data entry are considered particular strengths of the Chingford Women's Study, with a high response rate ($>50\%$) of the original 1,003 women attending all clinic visits over the 15 years. The participants excluded from this study were older than those included, although they were similar in height and weight and the possibility remains that the older participants lost to followup for whatever reason may have affected the analysis.

While the women were representative of women in the UK general population with respect to weight, height, and smoking characteristics (28,29), the area from which the participants were recruited was predominantly middle-class, ranging in all social groups, although 98% of the women were white (30). The study findings may therefore be subject to selection bias with regard to geographic location. Subsequently, the results may not be generalizable to women outside of this region and cannot be applied to male counterparts.

This is the first large longitudinal cohort study demonstrating that a high BMI is likely to predict FJP in middle-aged and older women in the UK, thus confirming a longitudinal relationship that has been alluded to in clinical practice for many years. Evidence from our findings that a high BMI precedes FJP and is independent of age as well as chronic conditions such as diabetes mellitus and rheumatoid arthritis is useful to health care providers in determining demand for foot health services as well as directing

foot health interventions toward public health messages for weight control.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Bowen had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design. Gay, Arden, Bowen.

Acquisition of data. Gay, Culliford, Leyland, Bowen.

Analysis and interpretation of data. Gay, Culliford, Leyland, Bowen.

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