Fat Mass Is Associated with Foot Pain in Men: The Geelong Osteoporosis Study

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ABSTRACT. ***Objective.*** Foot pain is a common complaint in adults. Evidence suggests that body composition is involved in the development of foot pain. However, whether this is the case in men remains unclear because previous studies mainly examined women. The aim of this cross-sectional study was to determine the relationship between body composition and foot pain in men while accounting for important risk factors.

Methods. Among 978 men (median age 60 yrs, range 24–98) from the Geelong Osteoporosis Study who participated in a followup study in 2006 to 2011, 796 provided responses to questions on health status and foot pain. Foot pain was determined using the Manchester Foot Pain and Disability Index, and body composition was measured using dual-energy x-ray absorptiometry.

Results. Of the 796 respondents, 177 (22%) had foot pain. Risk factors for foot pain were age (OR 1.03, 95% CI 1.02–1.04), self-reported depression (OR 2.05, 95% CI 1.30–3.20), decreased mobility (OR 1.54, 95% CI 1.05–2.24), and lower education (OR 1.47, 95% CI 1.03–2.09). Foot pain was associated with body mass index (OR 1.05, 95% CI 1.00–1.10), fat mass (OR 1.02, 95% CI 1.03–1.05), and fat mass index (OR 1.08, 95% CI 1.01–1.15), but not fat-free mass (OR 1.01, 95% CI 0.98–1.04) or fat-free mass index (OR 1.05, 95% CI 0.95–1.15) after appropriate adjustments were made.

Conclusion. Fat mass is associated with foot pain in men. These findings complement those in studies that have mainly examined women, and provide further evidence for the relationship between obesity and foot pain. (First Release December 1 2015; J Rheumatol 2016;43:138–43; doi:10.3899/jrheum.141331)

Key Indexing Terms:
FAT MASS FOOT PAIN OBESITY BODY MASS INDEX BMI

Foot pain is a significant health problem and is associated with locomotor disability, balance impairment, and an increased risk of falling[1,2]. Foot pain also impairs functional activities of daily living among older adults[3,4], decreasing health-related quality of life (HRQOL)[5]. Foot pain is common; a systematic review of 31 population-based studies, involving 75,505 participants, identified 24% of adults over the age of 45 as having foot pain on most days[6].

Risk factors for foot pain include older age[7] and poor mental health[5,8,9]. Several studies have also indicated that women are more likely to have foot problems than men[6,10]. Footwear is considered to be partially responsible for the higher rate of foot pain in women because narrow-fitting footwear is strongly associated with hallux valgus and lesser toe deformities[11]. However, women more commonly report musculoskeletal pain compared with men[12], and sex is a significant effect modifier for pain perception[13].

Obesity has been recognized as a risk factor for foot pain; a systematic review of 25 studies reported that overweight and obese adults are more likely to have foot pain than those of normal weight[14]. Another study[15] has also demonstrated an association between foot pain prevalence and increased fat mass, rather than increased body mass alone. In addition, increased fat mass has been shown to be a predictor of incident foot pain in a longitudinal study[16]. Most of these studies involved mainly women, so it is not clear whether this

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Supported by the National Health and Medical Research Council (NHMRC; Project Grant 299831 and 628582). HBM is a NHMRC Senior Research Fellow (1020925). DMU was supported by a NHMRC Career Development Fellowship (Clinical level 1, 1011975). SLB was supported by a NHMRC Early Career Fellowship (1012472). AEW was supported by a NHMRC Career Development Fellowship (Clinical level 2, 1063574).

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Accepted for publication September 30, 2015.

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relationship is also true in men because sex-specific analyses were not performed.

Therefore, the aim of our cross-sectional study was to examine the relationship between body composition and foot pain in a population-based cohort of men while accounting for important confounding factors.

MATERIALS AND METHODS

Study population. The Geelong Osteoporosis Study (GOS) began as a population-based study in southeastern Australia, designed to investigate the epidemiology of osteoporosis in both men and women, characterizing the risks for osteoporosis and fracture. The baseline recruitment of male participants (n = 1540) occurred between 2001 and 2006. These participants were followed during a reassessment phase commencing in 2006 and ending in 2011, referred to as the 5-year followup assessment. Recruitment of an age-stratified sample was through the Australian electoral roll that encompassed the Barwon Statistical Division. Individuals selected at random from the electoral roll were mailed a letter of invitation to attend a clinical assessment. Followup letters were dispatched to nonresponders. Participants were excluded if they were unable to provide written informed consent or resided in the Barwon region for less than 6 months[17].

Of the 1540 men enrolled in the baseline GOS between 2001 and 2006, 1203 were eligible for the 5-year followup because 141 had died before the 5-year followup, 41 had left the region, 16 were unable to provide informed consent, and 139 were not able to be contacted. Further, an additional 225 potential subjects declined to participate[17]. Thus, 978 participants, representing 81% of the potential study population, participated in the 5-year followup. These participants were invited in writing to attend a clinical assessment that included the completion of a questionnaire designed to assess demographics, health status, and pain. The subjects' written consent was obtained according to the Declaration of Helsinki, and the GOS men's followup study (2006–2011) was approved by the Barwon Health Human Research Ethics Committee and the Monash University Human Research Ethics Committee.

Main outcome: foot pain. The assessment of foot pain status was achieved using the Manchester Foot Pain and Disability Index (MFPDI) questionnaire at the followup clinical assessment. The MFPDI is a validated questionnaire[8,18,19] used to document disabling foot pain in population-based studies[20,21]. The MFPDI consists of 19 items that are preceded with the phrase, "because of pain in my feet," formalized under 4 categories: (1) functional limitation (10 items), (2) pain intensity (5 items), (3) personal appearance (2 items), and (4) difficulties with work or leisure activities (2 items). Each item is documented as being present "none of the time" (0 points), "on some days" (1 point), or "on most/every day" (2 points). Using the definition of foot pain described by Roddy, *et al*, participants who reported 1 or more of the 10 functional limitation items "on most/every day(s)" were defined as having disabling foot pain[19]. An *a priori* decision was made to use the definition proposed by Roddy, *et al*[19] because this has been validated for use in populations incorporating a broad range of age groups, such as the current sample (age range 22–98 yrs), and it is more sensitive to age differences in people with disabling foot pain[7].

Demographics, general health, and mobility. Participants self-reported measures of general health for the current analysis. Depression (from baseline) was measured using the question, "Have you ever been diagnosed as suffering depression?" because self-reported depression has been shown to be an appropriate proxy for clinically diagnosed depression[22]. Education was determined using the question, "What is your highest completed level of education?" with 6 possible answers available (no school, primary school, some secondary school, completed secondary school, postsecondary qualification, tertiary qualification). The nominal data were then combined to create a binary variable that differentiated between those who did and did not complete secondary school. Similarly, mobility was determined using the question, "How would you best describe your activity now?" with 7 possible answers available (very active, active, sedentary, limited, inactive, chair or bedridden, bedfast). The nominal data were then combined to create a binary variable that differentiated between those who were considered physically active or inactive. Participant age (yrs) was determined at the time of our current study.

Measures of body composition. Measures of body composition taken at followup, at the time that foot pain was determined, were used in our current analysis. Body composition was measured using dual-energy x-ray absorptiometry (DEXA; GE Lunar Prodigy, GE Lunar Corp.). Weight was measured to the nearest 0.1 kg and height was measured to the nearest 0.1 cm using a stadiometer (with shoes and bulky clothing removed). From these data, body mass index (BMI) was calculated[23]. Waist (smallest circumference between the lower rib and iliac crest) and hip (maximal gluteal) circumferences were measured in a transverse plane with a narrow, non-elastic tape measure, and the waist-hip ratio was calculated accordingly[24]. Based on the DEXA data, fat mass index (FMI) and fat-free mass index (FFMI) were calculated as follows: FMI = fat-mass ÷ height^2 and FFMI = fat-free mass ÷ height^2, where fat-free mass = lean tissue mass + bone mineral content.

Statistical analysis. The distributions of all continuous data were explored and found to approximate the normal distribution. Independent-samples Student t tests and chi-square tests were used to assess differences in depression, mobility, education, and body composition in those with and without foot pain. Mann-Whitney U tests were used to assess differences between those with and without foot pain in relation to age. Binary logistic regression models were used to assess: (1) the relationship between foot pain and age, BMI, depression, mobility, and education; (2) the relationship between foot pain and measures of body composition, adjusted for age, depression, mobility, and education; and (3) the relationship between foot pain and measures of body composition with age, assessing for interaction with age, adjusted for depression, mobility, and education. To examine the association of body composition measures (fat mass and fat-free mass, FMI and FFMI, respectively) with foot pain, we examined collinearity between body weight and BMI, as appropriate, while taking into account the involvement of body weight or body size. Because there was significant collinearity between body size and measures of body composition ($r > 0.78$, $p < 0.001$ for all), all multivariable analyses included the residuals of weight (for fat mass, and fat-free mass) or BMI (for FMI and FFMI) using the approach of Karvonen-Gutierrez, *et al*[25]. P values < 0.05 (2-tailed) were regarded as statistically significant. All analyses were performed using the SPSS statistical package (standard version 18.0; SPSS Inc.).

RESULTS

Of 978 potential participants, 796 (81%) provided data for our study. Of the 796 participants (median age 60 yrs, range 24–98), 177 (22%) had foot pain. Within the sample, BMI ranged from underweight to morbidly obese (mean ± SD 27.1 ± 3.8 kg/m^2, range 17.3 kg/m^2 to 46.0 kg/m^2). The 182 participants with incomplete data were of similar age (59.5 ± 18.4 yrs vs 59.5 ± 16.7 yrs, p = 0.99), but had a higher mean BMI (28.8 ± 5.7 kg/m^2 vs 27.3 ± 3.9 kg/m^2, p < 0.01) and similar fat mass (24.7 ± 8.9 kg vs 23.4 ± 8.5 kg, p = 0.12) compared with those who completed the followup study. There were no other differences between these participants.

Characteristics of participants with and without foot pain are shown in Table 1. Participants with foot pain were older, more likely to self-report depression, were less likely to be active, and less likely to have attained higher education than those without foot pain (p < 0.01). Those with foot pain had greater BMI (p = 0.01), waist-hip ratio (p < 0.01), fat mass

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Table 1. Participant characteristics. Values are mean ± SD unless otherwise specified.

Characteristics	Foot Pain, n = 177	No Foot Pain, n = 619	p
Age, yrs, median (IQR)	68 (24–90)	57 (25–98)	< 0.01*
Depression, n (%)	42 (24)	78 (13)	< 0.01**
Mobility, n (%)	103 (58)	469 (76)	< 0.01**
Education, n (%)	73 (41)	345 (56)	< 0.01**
No schooling	0 (0)	4 (1)	
Primary school	7 (4)	14 (2)	
Some secondary	97 (55)	256 (41)	< 0.01**
Completed secondary	25 (14)	103 (17)	
Postsecondary education	21 (12)	78 (13)	
Tertiary qualification	27 (15)	164 (26)	
Body composition			
Weight, kg	84.6 ± 14.7	83.2 ± 13.1	0.24†
BMI, kg/m^2	28.0 ± 4.3	27.1 ± 3.8	0.01†
Waist/hip ratio	0.97 ± 0.5	0.95 ± 0.6	< 0.01†
Fat mass, kg	25.2 ± 9.0	22.8 ± 8.3	< 0.01†
FMI, kg/m^2	8.4 ± 3.0	7.4 ± 2.7	< 0.01†
Fat-free mass, kg	56.8 ± 7.9	57.8 ± 7.2	0.11†
FFMI, kg/m^2	18.8 ± 1.9	18.8 ± 1.8	0.90†

* P value calculated for differences between participants with and without foot pain using Mann-Whitney U test. ** P value calculated for differences between participants with and without foot pain using chi-square test. † P value calculated for differences between participants with and without foot pain using independent-samples Student t test. IQR: interquartile range; BMI: body mass index; FMI: fat mass index; FFMI: fat-free mass index.

($p < 0.01$), and FMI ($p < 0.01$) than those without foot pain.

Risk factors for foot pain were examined and results are shown in Table 2. Foot pain was associated with older age ($p < 0.01$), self-reported depression ($p < 0.01$), decreased mobility ($p = 0.03$), and lower levels of education ($p = 0.03$) in multivariate analyses.

The relationships between foot pain and measures of obesity, including body composition, were examined (Table 3). Both weight ($p = 0.04$) and BMI ($p = 0.03$) were associated with foot pain in multivariate analyses, although waist-hip ratio was not related to foot pain. However, fat mass ($p = 0.03$) and FMI ($p = 0.04$) were associated with foot pain, adjusted for age, depression, mobility, education, and the relevant residuals. We did not detect an association between foot pain and fat-free mass or FFMI in any of the analyses.

Table 2. Relationship between participant characteristics and foot pain.

Characteristics	Foot Pain vs No Foot Pain: Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
Age, yrs	1.04 (1.02–1.05)	< 0.01	1.03 (1.02–1.04)	< 0.01*
Depression	2.16 (1.41–3.28)	< 0.01	2.05 (1.30–3.20)	< 0.01**
Mobility	2.25 (1.58–3.19)	< 0.01	1.54 (1.05–2.24)	0.03†
Education	1.79 (1.28–2.51)	< 0.01	1.47 (1.03–2.09)	0.03‡

* Adjusted for depression, education, mobility, and BMI. ** Adjusted for age, education, mobility, and BMI. † Adjusted for age, depression, education, and BMI. ‡ Adjusted for age, depression, mobility, and BMI. BMI: body mass index.

Table 3. Relationship between obesity, measures of body composition, and foot pain.

Variables	Foot Pain vs No Foot Pain: Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
Weight, kg	1.07 (0.99–1.02)	0.24	1.01 (1.00–1.03)	0.04*
BMI, kg/m^2	1.06 (1.02–1.11)	< 0.01	1.05 (1.00–1.10)	0.03*
Waist/hip ratio, cm	1.05 (1.02–1.08)	< 0.01	1.02 (0.99–1.06)	0.12*
Fat mass, kg	1.03 (1.01–1.05)	< 0.01	1.02 (1.003–1.05)	0.03**
FMI, kg/m^2	1.13 (1.06–1.20)	< 0.01	1.08 (1.01–1.15)	0.04***
Fat-free mass, kg	0.98 (0.96–1.00)	0.11	1.01 (0.98–1.04)	0.46†
FFMI, kg/m^2	0.91 (0.92–1.10)	0.91	1.05 (0.95–1.15)	0.36‡

* Adjusted for age, depression, mobility, and education. ** Adjusted for age, depression, mobility, education, and residual of weight on fat mass. *** Adjusted for age, depression, mobility, education, and residual of BMI on FMI. † Adjusted for age, depression, mobility, education, and residual of weight on fat-free mass. ‡ Adjusted for age, depression, mobility, education, and residual of BMI on FFMI. BMI: body mass index; FMI: fat mass index; FFMI: fat-free mass index.

We examined whether the relationships between foot pain and measures of body composition differed according to age (Table 4). We found that with increasing age, the relationship tended to strengthen statistically between all measures of body composition (except waist-hip ratio) and foot pain (interaction $p \leq 0.04$). In the middle-aged group, both fat mass ($p = 0.19$) and FMI ($p = 0.09$) tended to be associated with foot pain, whereas fat-free mass ($p < 0.01$) and FFMI ($p = 0.06$) tended to show a protective effect for foot pain. The association between foot pain and body composition was not statistically significant in the younger age group. We found no evidence for interaction between the degree of obesity and the relationship between measures of obesity and disabling foot pain.

DISCUSSION

In this population-based cohort of men, we found that age, depression, mobility, and low educational attainment were associated with foot pain. Foot pain was also shown to be related to obesity, as measured by weight and BMI. When body composition was examined, foot pain was associated with fat mass and FMI, but not fat-free mass or FFMI, suggesting a metabolic mechanism contributes to the relationship between obesity and foot symptoms.

These data are consistent with the known established relationship between obesity and foot pain demonstrated in a systematic review[14]. Previous cross-sectional[15] and longitudinal[16] studies have shown a relationship between fat mass and both prevalent and incident foot pain. However, these studies[15,16] predominantly examined female participants (85% and 73%, respectively), with the authors acknowl-

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Table 4. Relationship between obesity, foot pain, and age.

Variables	Aged ≤ 50 Yrs Foot Pain, n = 27 No Foot Pain, n = 232 Multivariate OR (95% CI)	p	Aged > 50 to ≤ 65 Yrs Foot Pain, n = 56 No Foot Pain, n = 171 Multivariate OR (95% CI)	p	Aged > 65 Yrs Foot Pain, n = 94 No Foot Pain, n = 216 Multivariate OR (95% CI)	p	Whole Group, Interaction w/Age Interaction p
Weight, kg	0.98 (0.95–1.01)	0.36*	0.99 (0.97–1.01)	0.55*	1.03 (1.01–1.05)	< 0.01*	< 0.01
BMI, kg/m^2	0.93 (0.83–1.04)	0.23*	1.01 (0.94–1.09)	0.69*	1.10 (1.03–1.17)	< 0.01*	0.02
Waist/hip ratio	0.99 (0.92–1.07)	0.97*	1.04 (0.98–1.09)	0.12*	1.02 (0.98–1.07)	0.37*	0.97
Fat mass, kg	0.96 (0.92–1.01)	0.16**	1.03 (0.99–1.07)	0.19**	1.05 (1.01–1.08)	< 0.01**	0.01
FMI, kg/m^2	0.88 (0.75–1.04)	0.13***	1.11 (0.99–1.24)	0.09***	1.14 (1.03–1.25)	< 0.01***	0.04
Fat-free mass, kg	0.96 (0.91–1.01)	0.09†	0.92 (0.87–0.97)	< 0.01†	1.05 (1.01–1.09)	0.01†	0.02
FFMI, kg/m^2	0.99 (0.79–1.25)	0.93‡	0.83 (0.69–1.005)	0.06‡	1.17 (1.01–1.36)	0.03‡	0.11

* Adjusted for depression, mobility, and education. ** Adjusted for depression, mobility, education, and residual of total fat mass on weight. *** Adjusted for depression, mobility, education, and residual of FMI on BMI. † Adjusted for depression, mobility, education, and residual of fat-free mass on weight. ‡ Adjusted for depression, mobility, education, and residual of FFMI on BMI. BMI: body mass index; FMI: fat mass index; FFMI: fat-free mass index.

edging the small numbers of men to be a limitation. Our current study provides complementary data in a population-based cohort of men. These findings in men suggest that, as in women, it is fat mass rather than fat-free mass that contributes to the association between obesity and foot pain. While these findings appear less pronounced than in previous studies that have mainly assessed women[16], this may be because women tend to express higher pain levels than men in other musculoskeletal conditions[26]. Alternatively, it may be more pronounced in the previous study[16] because that study population was enriched for obesity. In contrast, our current study is composed of a more generalizable population. Nevertheless, this relationship remains constant after accounting for potential confounding factors such as age, depression, and level of mobility, and suggests that fat mass may be associated with foot pain, regardless of sex.

There are a number of possibilities by which fat may influence foot pain. Fat consists of adipose tissue, which is a highly metabolically active endocrine organ[27,28] that produces hormones such as leptin, estrogen, resistin, and cytokines such as tumor necrosis factor-α and interleukin 6. Previous studies have shown the involvement of proinflammatory cytokines in the development and progression of pain[29,30]. Moreover, studies have shown that foot and ankle tendinopathy is associated with abdominal obesity, dyslipidemia, hypertension, and insulin resistance[31,32]. There are, however, a number of biomechanical mechanisms that may contribute to the link between obesity and foot pain, including changes in structure and function of the foot and increased plantar pressures[33]. Therefore, we cannot exclude the potential contribution of biomechanical mechanisms because we did not assess foot structure and function in our study. Consequently, it is possible that foot pain in this population may be attributed to a combination of increased mechanical loading of the foot, and systemic inflammatory effects of increased adiposity.

Previous studies have reported psychosocial issues to be a significant predictor of the outcome of joint pain[34]. Pain and depression co-occur 30% to 50% of the time and have adverse effects on HRQOL, disability, and healthcare costs[35,36]. Foot pain has been associated with depression and poor mental health in cross-sectional analyses[5,8,9]. Although mental health is related to the persistence of musculoskeletal pain, our understanding of the relationship between mental health and foot pain is limited. To our knowledge, the only longitudinal study to examine this relationship found that better mental health at baseline was associated with a slower progression of foot pain over a 3-year period[37]. However, our study is the first to examine this relationship in men only; the results suggest that foot pain may be associated with mental health problems in men, such as depression. One possible explanation for this relationship is that depression may reduce an individual's pain threshold[38] or alter pain perception[36]. Further, depression is considered an inflammatory state[39,40], and inflammation is associated with increased pain[41]. For example, systemic inflammation is an independent predictor of worsening knee pain[42]. It is possible, therefore, that depression may increase the likelihood of foot pain. We were unable to examine this, however, because inflammatory variables were not measured at the same time as foot pain. Our current study results suggest that clinicians should consider the possible coexistence of depression and mental health in their management of foot pain, consistent with the management of other musculoskeletal conditions.

People with foot problems have been shown to have a lower income level than those without foot problems[43]. Accordingly, studies evaluating foot pain have also begun to consider education as a confounding factor, finding that lower education levels are associated with foot pain[44,45]. A similar relationship has also been found between lower education and other musculoskeletal diseases, such as osteoporosis[46] and low back pain[47]. The relationship between low education attainment and foot pain may occur through a number of potential mechanisms. For example, a study[48] found the prevalence of foot symptoms was higher for fishery workers, trade workers, and plant and machine operators and assem-

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blers than for more highly educated professionals involved in lighter duties. Therefore, gaining postsecondary qualifications may reduce the rate of employment in manual labor industries that could, in turn, reduce the risk of musculoskeletal injury. Our study found a relationship between low education attainment and foot pain in men, and this relationship persisted after adjustment for potential confounders.

Our results suggest that older age is associated with an increased risk of foot pain compared with younger people. These findings reflect previous research in women that has found an increased prevalence of foot pain in a similar age group[9]. The results from our current study show that with increasing age, the relationship between measures of foot pain and obesity, including weight, increased BMI, fat mass, and FMI, becomes stronger, and that in the middle-aged men, fat-free mass and FFMI tend to be protective of foot pain. It is possible that as age increases, so too the prevalence of foot disease increases, such as osteoarthritis. This in turn may predispose the individual to inflammation within the foot, and in the presence of increased fat, inflammatory change is facilitated by obesity-associated inflammation[49]. This may account for our observation that with increasing age, the relationship between foot pain and adiposity increases in statistical significance. Those with foot pain were also more likely to be less active, indicating a potential link between foot pain, older age, and a sedentary lifestyle.

The results of our study should be considered in light of a number of limitations. First, the cross-sectional character of the study design does not enable us to examine the effect of change in variables on foot pain over time. While we have shown a positive association between foot pain and fat mass, it is possible that foot pain inhibits physical activity, leading to increased fat mass. Nevertheless, studies have shown that despite improved health from physical activity, clinically significant weight loss is unlikely to occur unless the overall volume of aerobic exercise is very high[50]. Second, we were unable to provide missing data for 18% of the eligible participants at baseline, thereby raising the possibility of response bias. While there were no differences detected in age or fat mass, those who did not complete the foot pain questionnaire had higher BMI. Despite a reduction in the power of our study to detect a relationship between BMI and foot pain, we still found a relationship between these 2 variables. Third, it is possible that because FFMI did not vary as much as other variables, our study had limited ability to identify a significant relationship with foot pain. However, there was no suggestion of any relationship with fat-free mass and foot pain, and the results for fat-free mass were similar to those of FFMI. Fourth, we cannot exclude the possibility that self-reported depression documented at baseline had changed over the following 5 years, providing the potential for misclassification bias, which may affect our results. Nevertheless, we showed a relationship between depression and foot pain, and the identified relationships strengthened when depression was excluded from the analyses (data not presented). Finally, it is possible for the relationship between foot pain and obesity to be affected by potential confounding variables, such as the increased risk of osteoarthritis related to obesity and increased fat mass. Similarly, biomechanical factors, including increased plantar pressures related to obesity, may also account for some of the relationships we observed. Therefore, future studies will need to account for these variables to clarify these relationships.

There were, however, several strengths to our study. First, the participants were recruited from the electoral roll, which strengthens the generalizability of our findings to the broader population. Second, we recruited participants from a broad age and BMI range, further strengthening the generalizability of our findings. Third, we were able to adjust for the potential confounding variables of age, education, mobility, and depression. Fourth, our use of a comprehensive range of obesity and body composition measures allows our results to be compared with other studies that have used these variables. Finally, a substantial strength was the use of an established and validated instrument to measure foot pain.

Our study has found that foot pain is related to obesity in men, and that this relationship is related to fat mass rather than fat-free mass, suggesting that metabolic factors may contribute to foot pain. These findings complement those in studies that have mainly examined women, a cause for concern considering the rising prevalence of obesity in the population. Further work is required to investigate the mechanism underlying this relationship and the effect of change in weight on foot pain.

ACKNOWLEDGMENT

The authors acknowledge and thank all of the participants who made this study possible.

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