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Obesity, foot pain and foot disorders in older men and women

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Abstract

Objective—We investigated obesity, foot pain and selected foot disorders, and determined if associations differed by foot posture or dynamic foot function.

Methods—We included 2445 men and women (4888 feet) from the Framingham Foot Study (2002–2008). A foot examination assessed presence of disorders and pain on each foot. Body mass index (BMI, kg/m²) was categorized as normal (<25), overweight (25–29.99), moderate-obesity (30–34.99) severe-obesity (35+). Foot posture (normal, cavus, planus) and dynamic foot function (normal, supinated, pronated) were defined using plantar pressure measurement system. We used sex-specific logistic regression with generalized estimating equations to account for correlation between two feet of the same person, adjusted for age and stratified by foot posture and dynamic foot function.

Results—Average age was 68±11 years, 56% female, average BMI 28±5 kg/m². 18% of feet had pain, 25% hallux valgus, 2% claw toes, 18% hammer toes, 7% overlapping toes. In men, severe-obesity was associated with foot pain (OR=2.4, p=0.002) and claw toes (OR=3.4, p=0.04). In women, overweight, moderate-obesity and severe-obesity were associated with foot pain. Women with severe-obesity were less likely to have hallux valgus. Similar patterns were evident after stratification by foot posture and dynamic foot function.

Conclusion—Both men and women were at increased odds of foot pain as BMI increased. Data suggested foot posture and dynamic foot function had no effect, thus are unlikely mechanisms.

Keywords

foot pain; foot disorders; obesity; body mass index; epidemiology

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1. Introduction

Data from the National Health and Nutrition Examination Survey 2009–2010 reported that 69% of all adults age 20 and older are overweight (BMI ≥ 25)¹. Older adults (≥ 60 years) have an increased prevalence of being overweight, while 37% of men and 42% of women over age 60 have obesity (BMI ≥ 30)¹. Many negative health-related outcomes have been associated with obesity, including increased risk for early death, cardiovascular disease, Type II diabetes, some cancers, osteoarthritis and disability². Recent studies have also reported that adults who are overweight and those who have obesity are more likely than their normal weight counterparts to have foot pain^{3–10}, flat feet and high peak planter pressures when walking¹¹.

Foot pain is also a common problem among older adults. A systematic review¹² found that nearly one quarter of adults over age 45 experienced frequent foot pain. Foot pain has been associated with poor balance and gait problems^{13,14}, activities of daily living^{15,16} and health-related quality of life^{17,18}. In addition to foot pain, structural foot disorders affect up to 60% of community-dwelling older adults^{19,20} and are associated with mobility limitations^{14,21} and decreased health-related quality of life⁷. Given that the foot is the body's main base of support and is a key basis for mobility, balance and activities of daily living, excess weight is likely to have a negative impact on foot function.

Several recent studies have reported associations between obesity and foot pain^{3–10}. However, the underlying mechanisms responsible for this association have not been explored in detail. We propose that this relationship may be mediated by the variation in foot posture and dynamic foot function, as this may alter the load bearing function of the foot. Therefore, the purpose of our current study was to describe the associations between obesity categories, foot pain and foot disorders (hallux valgus, claw, hammer, overlapping toes) in a community-based cross-sectional study of older men and women. Further, to add insight into the potential underlying mechanisms, we examined whether these associations differed by foot posture or by dynamic foot function.

2. Methods

2.1. Study Sample

Participants in this study were from the Framingham Foot Study cohort, which is comprised of members from the Framingham Heart Study Original Cohort and the Framingham Offspring Cohort who were examined between 2002 and 2008 (mean age 68 years), as described previously^{22,23}. In brief, the Framingham Study Original Cohort was formed in 1948 from a two-thirds sample of the town of Framingham, MA in order to study risk factors for heart disease and have been followed biennially since that time. The Framingham Offspring cohort, formed in 1972, consists of adult offspring who had a parent in the Original Cohort, and the offspring spouses. This group has been followed every four years since cohort inception to study familial risk factors for heart disease. Members of the Framingham cohorts were examined for the Framingham Foot Study, an ancillary exam to the Framingham Heart Study, either at their scheduled Framingham clinic examination or at a call-back examination. The Framingham Foot Study conducted a physical examination of

the foot and collected participant history, performance measures and other data using a validated questionnaire.

2.2. Assessment of Foot Disorders and Foot Pain

A podiatric-trained examiner performed a validated physical examination of participants' feet to determine the presence or absence of specific foot disorders. Participants were weight-bearing as their feet were assessed to determine the presence of hallux valgus, hammer toes, claw toes and overlapping toes. Hallux valgus was defined as a 15° or greater abduction of the hallux from the first metatarsal determined by comparison to a laminated depiction of the angle. Hammer toes were considered present if there was a contraction of the proximal interphalangeal joint. Claw toes were defined as a contraction of both the proximal and distal interphalangeal joint. Overlapping toes were considered present in any instance where a toe overrode an adjacent one. Foot-specific pain was defined by asking participants the following NHANES-type query: "On most days, do you have pain, aching or stiffness in either foot?"

2.3 Body Mass Index/Obesity

Weight and height were measured at the time of the foot exam to determine BMI in kg/m². Weight in pounds was measured using a standardized balance beam scale and recorded to the nearest half pound. Height (without shoes) was measured in inches using a calibrated stadiometer and recorded to the nearest one-quarter inch. Categories of BMI were created, using cut points as suggested by the World Health Organization²⁴ in order to maintain generalizability to other population-based studies, as <25 (normal weight), 25–29.99 (overweight), 30–34.99 (obesity), and 35+ (severe-obesity) kg/m².

2.4 Foot Posture and Dynamic Foot Function

The Tekscan® Matscan system, a 5-mm thick floor mat was used to collect plantar pressure data, sampled at 40 Hz. These data were used to define foot posture and dynamic foot function. The Matscan system has been shown to be reliable in measuring plantar pressures, as described in detail previously²⁵.

From plantar pressure scans during standing, foot posture was defined using the Modified Arch Index (MAI)²⁶. The MAI is correlated with other measures of foot posture, notably navicular height²⁷ and arch height²⁶. From the plantar pressure scan, the foot, not including the toes, was divided into thirds along the longitudinal axis²⁸. To calculate the MAI, the plantar pressure in the arch was divided by pressure in the entire foot, not including the toes²⁶. For each foot separately, foot posture was classified based on sex-specific quintile distribution of the MAI scores. Using the entire distribution of Framingham Foot Study participants, cavus foot posture was defined as the lowest 20%, normal foot posture (referent) was defined as the middle 60%, and planus foot posture was defined as the highest 20% of the MAI values. The cut off scores to define each category were cavus (<0.030), normal (0.031–0.163), and planus (>0.163).

From plantar pressure scans obtained while walking, dynamic foot function was defined using the center of pressure excursion index (CPEI)²⁹. To determine the CPEI value, a line

was drawn from the first and last points of each foot's center of pressure trajectory, and the distance of the center of pressure curve at the distal third of the foot from the constructed line was recorded, as previously described³⁰. This value was normalized by foot width and multiplied by 100 to obtain a percentage excursion of the center of pressure. CPEI has been shown to be sensitive to changes in clinical measures of static foot alignment²⁹. Similar to the method used for MAI, CPEI was categorized into three groups: CPEI > 20.9 (highest quintile) was classified as supinated foot function, CPEI from 7.4 to 20.9 (middle three quintiles) was classified as normal foot function (referent) and CPEI < 7.4 was classified as pronated foot function.

2.5. Statistical Analysis

As the distribution of BMI and foot problems are different between men and women, all analyses were done separately by sex. Sex-specific logistic regression was used to examine the age-adjusted association between foot problems (foot pain, hallux valgus, claw toes, hammer toes, overlapping toes and lesser toe deformities) and categories of BMI (<25 kg/m² as referent). As both feet of each participant were included in the analyses, generalized estimating equations were used to adjust for the correlation between the left and right foot of each person. To determine if the associations differed by foot posture or dynamic foot function categories and provide insights into possible mechanisms, analyses were further stratified by foot posture and foot function categories.

3. Results

We included 2445 men and women, contributing 4888 feet, who had valid information from the foot examination and body mass index. Of the participants, average age was 68 (SD 11) years, 56% were female, and mean BMI was 28 (SD 5) kg/m². As seen in Table I, 28% were in the normal BMI category, 38% were overweight, 24% had obesity and 10% were in the severely obese BMI category. Of the 4888 feet, 18% had pain, 25% hallux valgus, 2% claw toes, 18% hammer toes, and 7% had overlapping toes. In both men and women, increasing obesity categories were typically associated with increasing odds of foot pain, claw toes and hammer toes, adjusting for age (Table II). Statistically significant results were observed in men with severe obesity, where they were at an increased odds of having foot pain (OR=2.4; 95% CI: 1.4–4.3) and claw toes (OR=3.4; 95% CI: 1.1–10.7) compared to men with normal BMI. Similar age-adjusted patterns were seen in women, with statistically significant increased odds of foot pain with all categories of obesity (Table II). Most notably, women with severe obesity had 3.2 times the odds of foot pain compared to women with normal BMI ($p<.0001$). Additionally, women with severe obesity had 40% reduced odds of hallux valgus (OR=0.61; 95% CI: 0.4–0.9) compared to women with normal BMI. No associations were seen between obesity categories and overlapping toes in either men or women.

3.1. Foot posture

Patterns of association were similar when stratified by foot posture categories in both men and women, although some associations were stronger after stratification. Notably, men with severe obesity and a cavus foot posture had 5.62 times the odds of hammer toes (95% CI: 1.06, 29.69) compared to men with normal weight and cavus foot posture. Men with obesity

and severe obesity and a planus foot posture had 63% (95% CI: 0.14, 1.01) and 73% (95% CI: 0.08, 0.96) reduced odds of hallux valgus, respectively, compared to men with normal weight and planus foot posture. Women who are overweight with a normal foot posture had 40% reduced odds of hammer toes (95% CI: 0.4, 0.9) compared to women with normal weight and normal foot posture. Obese women with a planus foot posture had 54% reduced odds of hammer toes (95% CI: 0.22, 0.97), compared to normal weight women with planus foot posture. Women with obesity and severe obesity and a normal foot posture had 36% (95% CI: 0.44, 0.93) and 49% (95% CI: 0.28, 0.93) reduced odds of hallux valgus, respectively, when compared to women of normal weight with a normal foot posture. These stratified results for the association between obesity categories and hallux valgus are shown in Figure I and Figure II.

3.2. Foot function

Patterns of association were also similar when stratified by foot function categories in both men and women, although some associations were stronger after stratification. Notably, men with obesity and a supinated foot function had 2.59 times the odds of hammer toes (95% CI: 1.1, 6.11) compared to men of normal weight with supinated foot function. Men with obesity and severe obesity and a pronated foot function had 64% (95% CI: 0.14, 0.94) and 88% (95% CI: 0.01, 0.97) reduced odds of hallux valgus, respectively, compared to men of normal weight with pronated foot function. Women who were overweight, had obesity and severe obesity and a normal foot function had 19% (95% CI: 0.59, 1.1), 41% (95% CI: 0.4, 0.88) and 50% (95% CI: 0.29, 0.88) reduced odds of hallux valgus, respectively, when compared to women of normal weight with a normal foot function. These stratified results for the association between obesity categories and hallux valgus are shown in Figure III and Figure IV.

4. Discussion

This study examined the association between obesity and foot problems in older adults and found that both men and women are at increased odds of foot pain with increasing BMI categories. Additionally, men with severe obesity were more likely to have claw toes, and severely obese women were less likely to have hallux valgus. We also examined foot posture and dynamic foot function with the thought that the patterns of results would inform our basic understanding of possible underlying mechanisms for these associations. Somewhat surprisingly, these variables had little effect on our main findings, and they were not able to explain the apparent protective relationship between obesity and hallux valgus.

Our observation of an association between obesity and foot pain is consistent with previous studies³. The underlying mechanism for this association may be both mechanical and metabolic. Individuals with obesity have flatter feet, less range of motion, and generate larger forces under the foot when walking, all of which may result in excessive loads being placed on osseous and soft tissue structures¹¹. However, body composition studies have found that foot pain is more strongly associated with fat mass than BMI or skeletal muscle mass^{4,5,10}. These observations suggest that the metabolic effects of excess adipose tissue,

such as the downregulation of potentially beneficial adipokines and an overproduction of pro-inflammatory cytokines¹⁰, may also play a role in the development of foot symptoms.

Two previous studies have found higher BMI to be associated with decreased odds of hallux valgus. A previous study of 600 MOBILIZE Boston cohort participants found that obesity (BMI ≥ 30 kg/m²) was associated with a decreased odds of hallux valgus in older women, while finding a non-significant, but increased risk of hallux valgus with increasing body mass index in older men³¹. Additionally, in a previous study from the Framingham Foot Study, it has been shown that obesity (BMI ≥ 30 kg/m²) was associated with a decreased odds of hallux valgus both when considering the presence of hallux valgus alone and with hallux valgus without pain at the forefoot in both women and men³². Both of these studies relied on a visual inspection of the foot to characterize hallux valgus. On the other hand, there have been two studies that used radiographs to assess hallux valgus and found no association between hallux valgus and body mass index^{33,34}. This suggests that visual inspection of the foot to characterize hallux valgus may not accurately identify cases of the disorders as compared to using radiographs and therefore the association seen in our study may be due to an ascertainment bias. Alternatively, if the results seen in our study represent a true association between increased BMI and reduced odds of hallux valgus, this may be due to selection of footwear, wherein women of normal BMI may be more likely to wear fashionable shoes with a tighter and narrower shoe box, as suggested by Nguyen³¹. Further study is needed to determine whether footwear plays a role in the associations seen here.

This study has other important strengths and limitations that should be acknowledged. A major limitation is that our cross-sectional study design cannot determine the temporal sequence between obesity and the foot problems. We are also limited by our present/absent definition of the foot disorders as we did not collect information on the severity of each disorder. Also, the Framingham study is primarily Caucasian, so our results are not generalizable beyond this racial group. This study also has important strengths. We have a large population-based sample which includes both men and women and we conducted a validated foot examination to assess foot disorders as well as self-report questionnaire of pain. Importantly, we have information on foot posture and foot function which allows us to examine these aspects of the foot with larger numbers than seen in typical laboratory studies.

4.1 Conclusion

In our study, women and men with obesity are more prone to foot pain compared to their normal weight counterparts. It was surprising that consideration of foot structure and foot function did not change the associations between foot problems and obesity as we had expected. We believe that our results indicate that either persons may adapt to the extremes of foot function and structure as seen at a population-level or these foot aspects are part of a different mechanism of a pain-weight load consideration. Further studies are needed to investigate the possible mechanisms behind these pain and obesity associations. The examination of the role of longitudinal trajectories of body mass index on foot problems may provide helpful insights to our current gaps in knowledge.

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Figure I.

Odds ratios and 95% confidence intervals for the association between hallux valgus and BMI categories in men, with separate models for each foot posture (MAI)* category. P-value indicates significance level for test of linear trend across BMI categories within each foot posture category. Horizontal line representing an odds ratio of 1 indicates the reference category of normal BMI within each model.

Figure II.

Odds ratios and 95% confidence intervals for the association between hallux valgus and BMI categories in women, with separate models for each foot posture (MAI) category. P-value indicates significance level for test of linear trend across BMI categories within each foot posture category. Horizontal line representing an odds ratio of 1 indicates the reference category of normal BMI within each model.

Figure III.

Odds ratios and 95% confidence intervals for the association between hallux valgus and BMI categories in men, with separate models for each dynamic foot function (CPEI) category. P-value indicates significance level for test of linear trend across BMI categories within each foot posture category. Horizontal line representing an odds ratio of 1 indicates the reference category of normal BMI within each model.

Figure IV.

Odds ratios and 95% confidence intervals for the association between hallux valgus and BMI categories in women, with separate models for each dynamic foot function (CPEI) category. P-value indicates significance level for test of linear trend across BMI categories within each foot posture category. Horizontal line representing an odds ratio of 1 indicates the reference category of normal BMI within each model.

Table I

Description of study participants' feet from the Framingham Foot Study (2002–2008)

	All N=4888 feet	Men N=2150 feet	Women N=2738 feet
Age 36–100	68.00 ± 10.92	67.74 ± 10.41	68.21 ± 11.31
Female	2738 (56.0%)		
BMI (range 14.22–57.16)	28.34 ± 5.41	29.02 ± 4.78	27.80 ± 5.80
<25.00	1379 (28.2%)	419 (19.5%)	960 (35.1%)
25.00–29.99	1872 (38.3%)	924 (43.0%)	948 (34.6%)
30.00–34.99	1147 (23.5%)	597 (27.8%)	550 (20.1%)
35.00+	486 (10.0%)	208 (9.7%)	278 (10.2%)
Foot pain	871 (17.8%)	302 (14.1%)	569 (20.8%)
Hallux valgus	1242 (25.4%)	323 (15.0%)	919 (33.6%)
Claw toes	109 (2.2%)	44 (2.1%)	65 (2.4%)
Hammer toes	871 (17.8%)	369 (17.2%)	502 (18.3%)
Overlapping toes	324 (6.6%)	112 (5.2%)	212 (7.7%)
Foot Posture (MAI)			
Normal	2595 (59.3%)	1124 (58.2%)	1471 (60.1%)
Cavus	931 (21.3%)	392 (20.3%)	539 (22.0%)
Planus	853 (19.5%)	416 (21.5%)	437 (17.9%)
Dynamic Foot Function (CPEI)			
Normal	2456 (60.0%)	1121 (60.3%)	1335 (59.6%)
Pronated	798 (19.5%)	242 (13.0%)	556 (24.8%)
Supinated	843 (20.6%)	495 (26.6%)	348 (15.5%)

Age-adjusted associations between BMI categories and foot pain and foot disorders in men and women from the Framingham Foot Study (2002–2008)

Table II

	Men			Women		
	OR (95% CI)	p-value		OR (95% CI)	p-value	
Foot pain	25 – 29.99 vs <25	1.06 (0.67,1.67)	0.8182	1.49 (1.09,2.03)	0.0116	
	30 – 34.99 vs <25	1.17 (0.71,1.91)	0.5358	2.01 (1.43,2.81)	<.0001	
	35+ vs <25	2.44 (1.38,4.33)	0.0022	3.21 (2.15,4.79)	<.0001	
Hallux valgus	25 – 29.99 vs <25	1.01 (0.68,1.50)	0.9693	0.97 (0.76,1.24)	0.7974	
	30 – 34.99 vs <25	0.84 (0.54,1.31)	0.4358	0.81 (0.61,1.09)	0.1692	
	35+ vs <25	0.61 (0.31,1.18)	0.1432	0.61 (0.40,0.93)	0.0207	
Claw toes	25 – 29.99 vs <25	1.23 (0.46,3.27)	0.6764	1.05 (0.49,2.24)	0.9086	
	30 – 34.99 vs <25	1.89 (0.65,5.49)	0.2430	0.97 (0.38,2.45)	0.9402	
	35+ vs <25	3.37 (1.06,10.66)	0.0387	1.14 (0.33,3.91)	0.8351	
Hammer toes	25 – 29.99 vs <25	0.93 (0.64,1.35)	0.7002	0.78 (0.58,1.05)	0.1028	
	30 – 34.99 vs <25	1.11 (0.74,1.66)	0.6160	0.94 (0.66,1.33)	0.7269	
	35+ vs <25	1.37 (0.79,2.37)	0.2597	1.13 (0.72,1.76)	0.5986	
Overlapping toes	25 – 29.99 vs <25	0.86 (0.47,1.57)	0.6255	0.97 (0.65,1.44)	0.8701	
	30 – 34.99 vs <25	1.03 (0.53,1.99)	0.9369	1.15 (0.70,1.88)	0.5891	
	35+ vs <25	1.06 (0.43,2.62)	0.9018	0.87 (0.40,1.88)	0.7178	