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Factors associated with hallux valgus in a population-based study of older women and men: the MOBILIZE Boston Study

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Summary

Objective: To examine potential risk factors for hallux valgus in community-dwelling elders.

Method: Data from 600 MOBILIZE Boston Study participants (386 women and 214 men) were analyzed. Hallux valgus was defined as $>15°$ angular deviation of the hallux with respect to the first metatarsal bone toward the lesser toes. Associations of hallux valgus with age, body mass index (BMI), race, education, pes planus, foot pain, and in women, history of high heel shoe use, were assessed using sex-specific Poisson regression with robust variance estimation for risk ratios (RR) and 95% confidence intervals (CI).

Results: Hallux valgus was present in 58% of women and 25% of men. Higher BMI was inversely associated with presence of hallux valgus in women (P trend = 0.001), with the strongest inverse association observed in those with BMI of 30.0 or more compared to those with normal BMI (RR = 0.7, 95% CI: 0.5, 0.9). Women, who usually wore high-heeled shoes during ages 20–64 years compared to those who did not, had increased likelihood of hallux valgus (RR = 1.2, 95% CI: 1.0, 1.5). Among men, those with BMI between 25.0 and 29.9 had increased likelihood of hallux valgus compared to those with normal BMI (RR = 1.9, 95% CI: 1.0, 3.5). Men with pes planus were more likely to have hallux valgus (RR = 2.1, 95% CI: 1.3, 3.3) compared to men without pes planus.

Conclusion: In women, hallux valgus was associated with lower BMI and high heel use during ages 20–64, while in men, associations were observed with higher BMI and pes planus. Our results suggest that the etiologic mechanisms for hallux valgus may differ between men and women.

Key words: Hallux valgus, Pes planus, Foot pain, BMI, High-heeled shoes, Population-based cohort study.

Introduction

Hallux valgus is a common structural foot deformity in which the angular deviation of the hallux is greater than 15° toward the lesser toes with respect to the first metatarsal bone, and appears as a medial bony enlargement of the first metatarsal head. Several factors have been reported to be associated with hallux valgus including genetic predisposition, structural factors, sex, age, body mass index (BMI), foot pain, pes planus and footwear. Coughlin believes that genetic factors are very important, given the familial patterns of foot structure in general[1,2]. Previous research also suggests that structural factors such as metatarsal length[3], metatarsal head shape[4], first ray hypermobility[5], and hind-foot pronation[6] may be major factors associated with hallux valgus. Clinically, hallux valgus occurs more frequently in women, is more prevalent in older ages[7–9], and is believed to be associated with increased BMI[10,11] and foot pain[10], as well as with pes planus[12,13]. In addition, research from over 40 years ago reported that the prevalence of hallux valgus was much higher in persons wearing shoes than those with unshod feet[14–16] and current research suggests the potential role of shoe types in the development of hallux valgus[17].

The association between race and hallux valgus, however, is not clear. A 2004 study by Dunn and colleagues[7], of urban community-dwelling adults 65 years of age and older, indicated that African Americans had a significantly higher prevalence of hallux valgus than Caucasians. A 1980 study, comparing different groups of South African women 50 years and older, reported that the foot disorder was more common in White than urban or rural Black South Africans[18], but the study did not control for shoe wearing even though the investigators had attributed the differences to footwear.

It is important to understand risk factors for hallux valgus in order to prevent or minimize progression of the disorder since hallux valgus is thought to contribute to impaired balance and gait, and to increased risk of falls[19–22]. Surgical interventions, however, are costly and involve medical risks that could lead to other complications in older adults, and clinicians noted that hallux valgus may also recur[4,5]. Yet many of the previous studies of factors associated with hallux valgus have been limited to clinical populations[8,11] or

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have been descriptive in nature[7,14–16]. The largest study to date by Roddy *et al.*[8], used questionnaires received from 4249 men and women from two general practices in the UK to examine factors associated with self-report hallux valgus. Despite the large sample size and the universal health care system in the UK, the response rate for this study was 32%. The purpose of this current study was to examine potential clinical risk factors for hallux valgus such as age, BMI, race, education, foot pain, and pes planus, as well as past use of high-heeled shoes in women, in a population-based cohort of community-dwelling older adults with clinically assessed foot exams.

Methods

STUDY PARTICIPANTS

Participants in the current study are members of the first wave of participants from the MOBILIZE Boston Study (Cycle 1), an on-going longitudinal study to examine mechanisms and novel risk factors for falls in a population-based sample of older persons living around Boston, Massachusetts, USA. Details of the MOBILIZE Boston Study cohort have been previously reported[23,24]. In brief, between 2005 and 2008, the study enrolled 765 participants 70 years or older, including 16 of their spouses 64–69 years of age. Inclusion criteria were comprised of: ability to communicate in English, living within the Boston area, planning to remain in the area over the next 2 years, and ability to walk 20 feet unassisted.

Enrollment involved a two-step process: first, a door-to-door recruitment, followed by a telephone screening. From 5655 sampled households, 4303 people of age 70 years and older were identified. Of the 4303 people, 1581 were not eligible and 1973 either refused to participate or were unable to be contacted. As expected in a population-based study of older persons, the standard Council of American Research Organization (CASRO) response rate was 52% after screening for eligibility criteria. The CASRO response rate was 30% for the door-to-door phase. In comparison with US Census data for the population aged 65 and older in the Boston area, the study sample was representative of Boston area elders in terms of age, sex, race and ethnicity[23].

The participants were interviewed in their homes by trained staff and were examined within 4 weeks of the home visit by research nurses at the study clinic in the Hebrew Rehabilitation Center, a research and long-term care facility in Boston. Institutional Review Boards at the Hebrew Rehabilitation Center and collaborating institutions approved the study and all participants provided informed consent. For the current analyses, we included the first wave of 600 participants whose baseline data have been entered and verified.

DATA COLLECTION OF HALLUX VALGUS AND POTENTIAL RISK FACTORS

During the in-home interview, information was collected *via* standardized questionnaire on several factors of interest including age (age at examination was recorded), sex, race, and educational attainment (the number of years of completed education), as well as information on types of shoes usually worn during specific ages. Race was self-defined by each participant using the categories of white, black, Asian or other. Use of high-heeled shoes (2 inch or higher) by women was identified by questionnaire if the women listed high heels as the type of shoes they usually wore at ages 20–29, 30–44, and 45–64 years. Height (in millimeters) and weight (in pounds, recorded to the nearest pound) were measured using a calibrated stadiometer and standardized balance beam, respectively, and a physical examination of a participant's feet was completed at the clinic visit. For each participant, BMI was calculated as weight (in kg) divided by height in squared meters.

A validated foot evaluation was performed by trained nurse examiners using a standardized, weight-bearing clinical examination of the foot to assess the presence of several common foot conditions. While Couglin and Jones[9] have defined moderate to severe hallux valgus based upon observing a hallux valgus angle $> 20°$, we were less stringent. We defined hallux valgus as present if the angular deviation of the hallux with respect to the first metatarsal bone toward the lesser toes was observed to be similar to photos that show this angle to be greater than 15°. Pes planus was defined using a weight-bearing ratio of arch width to rear-foot width from a bipedal stance on a computerized pressure mat.

Specifically, foot pressure data were collected *via* a computerized mat (MatScan pedobarographic device, Tekscan Inc., Boston, MA) with the participant standing quietly on the pressure-sensing device with their body weight distributed equally over their two feet. For each foot, a high-resolution digital recording of the footprint was made and the ratio of arch width to rear-foot width was calculated from the dimensions of the acquired footprints. From the most distal extent of the forefoot to the most proximal extent of the heel, each footprint was divided into thirds in order to define the forefoot, arch (mid-foot), and heel regions. The ratio of arch width to rear-foot width was calculated as the ratio of the smallest medial to lateral width of the arch region divided by the largest medial to lateral width of the heel region (measurements recorded to the nearest 0.01 centimeter). The ratio of arch width to rear-foot width value increases with an increasingly planus foot. We defined pes planus for a person as having a ratio of arch width to rear-foot width of more than 75% (arch width of 75% or more of the heel width), on either foot, identified by the ratio of the arch of the foot. We chose the $>75\%$ cut-point for the weight-bearing ratio of arch to rear-foot widths based upon our unpublished previous work from the Framingham Foot Study which has shown that the $>75\%$ arch to rear-foot ratio incorporates all of the persons thought to have a clinical impression of pes planus and none of those without the clinical impression of pes planus. We do not have the clinical impression data in the current Mobilize Boston Study population but the arch to rear-foot ratio variable is fairly normally distributed and similar in both our Framingham Study data and in our Mobilize Boston Study data.

The presence of foot pain was identified based on a participant's response to the question: ''On most days do you have pain, aching or stiffness in either of your feet?'' Reliability of the standardized foot exam has been previously tested in elderly persons and both inter-observer and intra-observer tests had good reliability (kappas > 0.85, all $P < 0.01$)[25], including the assessment of hallux valgus and pes planus. Validity of the hallux valgus and other foot conditions was examined in 56 older adults where the foot examination findings were compared to independent clinical podiatry notes, and 100% of the foot conditions present on the foot examination were also noted in the podiatry notes[26].

DATA ANALYSIS

We investigated the possible associations between hallux valgus and clinical variables thought to be linked with this structural foot disorder, including age (years), BMI, race (white vs non-white), education (college vs no college), presence of foot pain (yes vs no), pes planus (yes vs no), and in women, use of high-heeled shoes in the past.

For women, past use of high-heeled shoes was classified into three mutually exclusive groups: (1) those who wore high-heeled shoes as their one usual shoe type for the duration between the ages of 20 and 64 years; (2) those who wore high heels as their usual type of shoes at some ages between 20–29, 30–44, and 45–64 but not continuously across the age groups; and (3) those who did not wear high-heeled shoes as their usual type of shoes between ages 20 and 64 years.

We used SAS Gemod for Poisson regression with robust variance estimation for binary data[27–29] to calculate risk ratios (RR) and 95% confidence intervals (CI) for the associations of the possible risk factors above with hallux valgus, both considering potential confounders and without adjusting for potential confounders. Age and BMI were first modeled as continuous variables. We then analyzed BMI as a categorical variable since the association with hallux valgus appeared to be non-linear. BMI was categorized as: 16.7–24.9 (normal), 25.0–29.9 (overweight), and 30.0–49.2 (obese). To test for linear trend, we modeled BMI as well as past use of high-heeled shoes in the multivariable model with ordinal data representing their respective categories. We also tested for interaction of sex with BMI, foot pain, and pes planus. Literature suggested and we found that there were significant differences in associations of these factors with hallux valgus between men and women, thus all analyses are presented stratified by sex.

Results

The distribution of the study characteristics for the 386 women and 214 men is presented in Table I. Over half of the women had hallux valgus, and the prevalence was more than twice as high in women (58%) as in men (25%). The age distribution for women and men was similar. Slightly more women than men were obese. Also, women had slightly higher prevalence of foot pain and pes planus than men. Among women, the proportion of women who wore high-heeled shoes as their usual type of shoes during ages 20–64 years was slightly less than 25%.

The associations of hallux valgus with BMI, foot pain, and pes planus were significantly different between the women and men. Formal tests for interaction of these risk factors with sex revealed significant interactions with the overweight (25.0–29.9) and obese BMI groups (30.0–49.2), $P = 0.003$ and $P = 0.02$, respectively. In addition, interactions were found between sex and presence of foot pain ($P = 0.03$), as well as pes planus ($P = 0.04$). The associations between

Table I
Sample characteristics by sex: the MOBILIZE Boston Study

	Women $n = 386$	Men $n = 214$
Hallux valgus	223 (58%)	54 (25%)
Age in years, mean (SD)	77.8 (5.7)	78.1 (5.3)
BMI		
16.7–24.9 (normal)	125 (33%)	67 (32%)
25.0–29.9 (overweight)	147 (39%)	98 (47%)
30.0–49.2 (obese)	105 (28%)	43 (21%)
Race-white	290 (76%)	176 (82%)
College education	232 (60%)	154 (72%)
Foot pain	100 (26%)	43 (20%)
Pes planus	76 (20%)	37 (17%)
High-heeled shoes worn as usual shoe type (women only)		
Worn as usual shoe type during ages 20–64 years	89 (23%)	NA
Worn at some but not all age groups during ages 20–64 years	144 (38%)	NA
Not worn as usual shoe type during ages 20–64 years	148 (39%)	NA

hallux valgus and each risk factor under study are presented in Table II for men and women separately.

Compared with women of normal BMI (16.7–24.9), overweight (adjusted RR = 0.8, 95% CI: 0.7, 1.0) and obese (adjusted RR = 0.7, 95% CI: 0.5, 0.9) women were significantly less likely to have hallux valgus, with the strongest inverse association observed in obese women (P trend = 0.001). Age, race, college education, presence of foot pain, and presence of pes planus had no statistical association with hallux valgus in women.

As shown in Table II, there was no statistically significant association between age and hallux valgus in men ($P = 0.21$). Also, the association of hallux valgus with BMI appeared to be non-linear in men. Compared with men of normal BMI, overweight (adjusted RR = 1.9, 95% CI: 1.0, 3.5) and obese men (adjusted RR = 1.4, 95% CI: 0.7, 3.1) were more likely to have hallux valgus. White men had a 40% reduced likelihood of having hallux valgus compared to non-white men, and college educated men were 50% times more likely to have hallux valgus than men who were not college educated, but the associations were not statistically significant.

Among the men in our study, a significant positive association was observed between pes planus and hallux valgus. Men with pes planus had two times the likelihood of having hallux valgus compared with men without pes planus (95% CI: 1.3, 3.3). Foot pain, however, was inversely associated with hallux valgus ($P = 0.05$). Men with foot pain had a 50% reduced likelihood of having hallux valgus compared to men without foot pain.

Figure 1 presents the association of hallux valgus across the three categories of past use of high-heeled shoes. Women who reported wearing high-heeled shoes as their usual type of shoe for the entire period between 20 and 64 years of age had a 20% increased likelihood of having hallux valgus compared with women who did not report wearing high heels as their usual shoe type between 20 and 64 years of age (95% CI: 1.0, 1.5), $P = 0.04$. There was a borderline significant linear trend for hallux valgus across the categories of duration of high-heeled use (P trend = 0.06).

Discussion

Despite previous reports that hallux valgus worsens with age, our population-based sample of community-dwelling older adults showed no significant association across the age groups that we examined. It is possible that associations of hallux valgus with age may be more apparent when younger persons are included in a study. We did observe, however, that the prevalence of hallux valgus was twice as high in women as in men. The patterns of results were notably different between the sexes, especially in the associations of hallux valgus with BMI and pes planus, and possibly with the presence of foot pain.

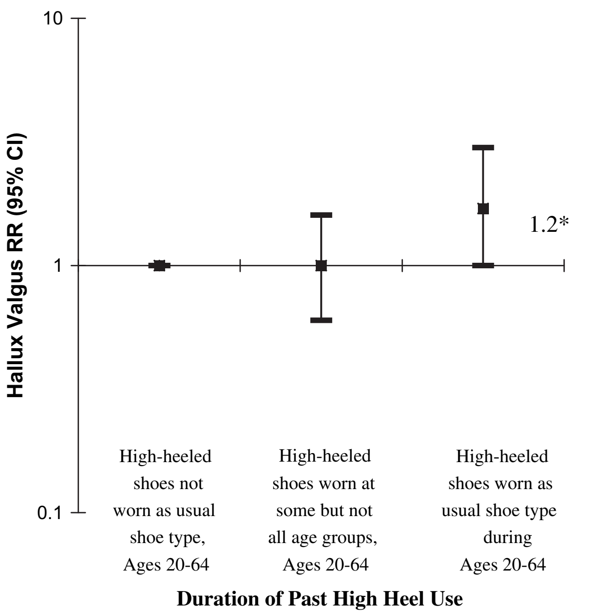
Increased BMI was associated with decreased prevalence of hallux valgus in women (P trend = 0.001), while BMI was positively associated with hallux valgus in men. Furthermore, pes planus showed no statistical association in women, but was strongly associated with a 2-fold increased likelihood of having hallux valgus in men. Similarly, we observed a borderline negative association of hallux valgus with foot pain but only among the men in our study. The different pattern of results between women and men imply potentially different pathways to the presence of hallux valgus in older women and men. To our knowledge, this has

Table II
Associations of potential risk factors with hallux valgus by sex: the MOBILIZE Boston Study

	Women ($n = 386$)			Men ($n = 214$)		
	Proportion with hallux valgus	Unadjusted RR (95% CI)	Adjusted† RR (95% CI)	Proportion with hallux valgus	Unadjusted RR (95% CI)	Adjusted† RR (95% CI)
Age, each 10-year increase	NA	1.1 (1.0, 1.3)	1.0 (0.9, 1.2)	NA	1.1 (0.7, 1.7)	1.3 (0.8, 2.1)
BMI						
16.7–24.9 (normal)	67%	1.0	1.0	16%	1.0	1.0
25.0–29.9 (overweight)	56%	0.8 (0.7, 1.0)§	0.8 (0.7, 1.0)*	33%	2.0 (1.1, 3.7)*	1.9 (1.0, 3.5)*
30.0–49.2 (obese)	49%	0.7 (0.6, 0.9)**	0.7 (0.5, 0.9)**	26%	1.6 (0.7, 3.3)	1.4 (0.7, 3.1)
White race-no	54%	1.0	1.0	34%	1.0	1.0
White race-yes	59%	1.1 (0.9, 1.3)	1.0 (0.8, 1.3)	23%	0.7 (0.4, 1.1)	0.6 (0.4, 1.1)§
College education-no	56%	1.0	1.0	20%	1.0	1.0
College education-yes	59%	1.1 (0.9, 1.3)	1.0 (0.8, 1.2)	27%	1.4 (0.8, 2.4)	1.5 (0.9, 2.6)
Foot pain-no	58%	1.0	1.0	27%	1.0	1.0
Foot pain-yes	59%	1.0 (0.8, 1.2)	1.1 (0.9, 1.3)	16%	0.6 (0.3, 1.2)	0.5 (0.3, 1.0)§
Pes planus-no	57%	1.0	1.0	20%	1.0	1.0
Pes planus-yes	61%	1.1 (0.9, 1.3)	1.2 (0.9, 1.4)	49%	2.4 (1.5, 3.7)	2.1 (1.3, 3.3)**

*$0.01 < P < 0.05$; **$0.001 < P < 0.01$; §$0.05 < P < 0.1$.

†Each risk factor adjusted for the other risk factors (and for past use of high-heeled shoes in women).



[1]Adjusted for age, BMI, race, college education, presence of foot pain, and pes planus

*p=0.04

Fig. 1. Risk of hallux valgus according to past duration of high-heeled shoe wearing.

not been previously described in the literature and would require confirmation in other samples.

Our findings that the associations between BMI and hallux valgus were opposite in men and women were unexpected. There may be many possible explanations for this difference between men and women. One plausible explanation is that women of normal BMI may have been more likely to wear more fashionable shoes with tighter or narrower toe box than overweight and obese women. Research by Menz and Morris[17] found that women were more likely than men to wear shoes that were much smaller in length, width, and total area relative to their foot size. Unfortunately, there were no data on the association between shoe wear and hallux valgus by BMI status in men and women. While Roddy *et al.*[8] reported no association between dichotomized BMI ($>$30 kg/m^2) and age-adjusted hallux valgus in both women and men, work by Cho *et al.*[10] in a rural community of Koreans found that those with hallux valgus had significantly higher mean BMI than those without hallux valgus but there were no sex-specific data. Moreover, Frey and Zamora[11] found that individuals of normal weight in an orthopaedic foot and ankle practice (62% women) had an increased likelihood of hallux valgus compared to overweight or obese individuals. Clearly, further research is needed to examine the prospective relation between BMI and hallux valgus and whether they differ in men and women.

Also, footwear for men and women are often thought to have different characteristics such as support or toe box, and different quality. Most of the original anthropometric foot data from which ‘shoe lasts’ (the positive molds from which shoes are made) were designed were based upon military studies and hence predominantly men[30,31]. More recent military studies have included women in their anthropometric assessments[32]. Parham *et al.*[32] found differences in several of the pedal anthropometric variables (e.g., heel width and forefoot breadth) whereby women were substantially smaller than men. The differences could not be explained only by foot length, suggesting that women needed their own shoe lasts from which to base their shoe designs. Furthermore, many believe, and it is well appreciated in the shoe wear industry, that most women’s shoes (especially in the past) were constructed in an inferior manner compared to that of men. Men’s shoes were marketed to be sturdy while women’s shoes were marketed to be replaced more frequently in order to be consistent with current fashions. Women’s ‘fashionable dress shoes’ were more likely to have pointed toe boxes than that of men. This is especially true for the age groups of older adults included in our study. Unfortunately, we do not have measures of shoe width, shoe length, or shoe quality available to further explore these sex-differences in the associations of BMI with hallux valgus.

We also found, even after adjusting for BMI and other potential risk factors of hallux valgus, that women who wore high-heeled shoes as their major shoe type between 20 and 64 years of age had an increased prevalence of hallux valgus compared with women who did not wear high-heeled shoes as their major shoe type during ages 20 and 64 years. It is possible that wearing high-heeled shoes as one’s usual shoe type between ages 20 and 64 years may create heightened forefoot pressure over a prolonged period that put these women at increased risk for hallux valgus. Interestingly, Menz and Morris[17] found a significant association between heel height $>$25 mm with hallux valgus but no significant association between foot problems and past history of wearing high heels. It is possible our definition of high heels (2 inches or above) or assessment of past use of high heels over a longer period of a woman’s life that may explain the difference between our results and those of Menz and Morris.

Additionally, we found that pes planus was highly associated with hallux valgus in men but not in women. Among persons without pes planus, however, hallux valgus was much more common among women than among men in our study. Thus, the magnitude of the relative measure of association of hallux valgus and pes planus was much higher in men than in women. Another possible explanation for the differences in the association seen with pes planus and hallux valgus may be that men and women have different foot structures or different weight-bearing foot pressure that could modify the effect of pes planus on hallux valgus[13,33]. Ferrari *et al.*[33] found that male foot bones were larger than those of females which may affect weight bearing differently, and that female bones had the potential for more movement. In addition, James[34] suggested that footwear and physical ill-treatment of the feet may explain the flat-feet condition since natives from Solomon Island who did not wear shoes were free of flat-feet. Taken together, it is possible that structural differences or constricted shoe wear may explain differences in association between pes planus and hallux valgus in men and women.

It merits noting that foot pain was inversely associated with hallux valgus in men. It is possible that men with hallux valgus had already modified their foot support or shoe wear; thus, affecting the occurrence of foot pain in the presence of hallux valgus.

It is interesting to note that race and education were not associated with hallux valgus in women, but may be associated with hallux valgus in men. It is possible that racial and educational differences in men may greatly affect choices of occupations requiring prolonged periods of performing weight-bearing activities on their feet or jobs requiring the use of specific shoe type that may affect their risk for hallux valgus differently. We do not have sufficient data on these factors, however, to examine these possibilities.

There were several limitations to our study. First, we lacked data on genetics and structural factors such as metatarsal length, metatarsal head shape, first ray hypermobility, and hind-foot pronation so our study was not able to examine these factors. Furthermore, our analyses were cross-sectional; thus, causal inference was limited, especially for determining whether BMI differences lead to hallux valgus or whether hallux valgus contributes to changes in BMI over time. In addition, information on past use of high-heeled shoes relied on self-report and may have been subject to recall bias even though the participants were not aware of the current research questions at the time they responded to the queries on past high-heeled shoes. Another difficulty was that we could not determine whether differences observed in magnitude and/or direction of association for some of these factors under study with hallux valgus were due to structural foot differences or behavioral differences between men and women, including choice of shoe wear. Also, hallux valgus was determined during a foot exam by a trained clinician for the presence or absence of the foot disorder and not from a tool such as the Manchester scale[35]. However, any possible misclassification of hallux valgus would have been non-differential with regard to the potential risk factors examined; thus, had we used a more stringent instrument to classify hallux valgus free of measurement error, our estimates of effect would have been even stronger in magnitude.

Despite the limitations, our study has several strengths. A notable strength of the study is that information on foot disorders was based on foot examinations conducted by trained clinical nurses using a validated foot evaluation, which may reduce measurement errors associated with self-report of foot problems. Also, our study population was a sample of community-dwelling elderly men and women, and may be more representative of elders than clinic-based samples.

Our results indicate intriguing sex-differences in the association of certain study factors in relation to hallux valgus. Further investigations are needed, particularly to look at shoe width, toe box, or other factors in addition to heel height in relation to hallux valgus. Should future research confirm that use of high-heeled shoes or narrow toe-boxed shoes that put wearers at increased risk for hallux valgus, then minimizing the use of high heels or avoiding certain types of shoes could prevent the structural foot disorder.

Conclusion

To our knowledge, this study is one of few studies to examine multiple potential risk factors for hallux valgus in a population-based sample of community-dwelling older women and men. This study found that hallux valgus was twice as prevalent in elderly women as in men, and that there may exist intriguing differences in the etiologies of hallux valgus between women and men. The roles of BMI, high-heeled shoes, pes planus, foot pain and other clinical factors in the presence of hallux valgus are very likely to differ between the sexes. These patterns may reflect the biological, structural and behavioral differences in men and women. Future studies should further evaluate BMI, shoe types and width, pes planus, and foot pain on incident risk of hallux valgus in both men and women.

Conflict of interest

The authors have no financial or personal relationships with other people or organizations that could bias our research.

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