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Running head: Hallux valgus, by nature or nurture?

Hallux valgus, by nature or nurture? A twin study

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COMPETING INTERESTS

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work; no other relationships or activities that could appear to have influenced the submitted work.

AUTHORS' CONTRIBUTIONS

SEM, HBM, JDW, BE, and AEW designed the study and obtained project funding.

JC, JDW, and JH were responsible for data collection.

SEM, BE, KJS and MB analysed data.

SEM, HBM, BE, and AEW drafted the manuscript.

JDW, JC, MB, KJS and JLH commented on the manuscript.

All authors read and approved the final manuscript before submission.

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ABSTRACT

Objective:

To evaluate the contributions of shared but unmeasured genetic and environmental factors to hallux valgus (HV).

Methods:

Between 2011-2012, 74 monozygotic (MZ) and 56 dizygotic (DZ) female twin pairs self-reported HV and putative risk factors, including footwear use across their lifespan. Estimates of casewise concordance (P_C), correlation (ρ) and odds ratios (OR) were calculated, adjusting for age and other risk factors, and compared between MZ and DZ pairs using logistic regression, generalised estimating equations and a maximum likelihood-based method, respectively.

Results:

70 participants (27%) reported HV, with 12 MZ and 7 DZ pairs being concordant. After adjusting for age, twins were correlated ($\rho = 0.27$; 95%CI 0.08-0.46) and concordant ($P_C = 0.45$, 95%CI 0.29-0.61 at mean age 58 years) with no difference between MZ and DZ pairs ($p = 0.7$). HV was associated with regularly wearing footwear with a constrictive toe-box during the fourth decade (adjusted OR = 2.73; 95%CI 1.12-6.67). This risk factor was correlated in MZ ($\rho = 0.38$; 95%CI = 0.15-0.60) but not DZ ($\rho = -0.20$; 95%CI = -0.43-0.03) pairs. These correlations were significantly different ($p = 0.002$).

Conclusion:

Twins are correlated for HV but we found no evidence that this was due to shared genetic factors. We identified an environmental risk factor, footwear with a constrictive toe-box, that

is not shared to the same extent by MZ and DZ pairs, contrary to the assumption of the classic twin model. Footwear, and possibly genetic factors and unknown shared environmental factors could contribute to developing HV.

Key words: hallux valgus, twins, genetics, shoes, twin study

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SIGNIFICANCE AND INNOVATIONS

- Twin pairs are more concordant for hallux valgus than unrelated individuals, but given there was no significant difference in concordance between monozygotic (MZ) and dizygotic (DZ) pairs, this could not be attributed to genetic factors. This raises the possibility that environmental risk factors shared by twins contribute to the development of hallux valgus.
- The regular use of footwear with a constrictive toe-box in the fourth decade of life was associated with increased presence of hallux valgus and is an environmental factor for this condition that was shared by MZ, but not DZ, pairs.
- Given that footwear choices are modifiable, identification of the most appropriate footwear during the life course may be able to reduce the prevalence of hallux valgus.

Hallux valgus (HV) is a common condition of the foot affecting 23% of people aged 18-65 years, and 36% of those over 65 years, and is more prevalent in females (1). It causes substantial foot pain, is related to reduced health-related quality of life (2-5), impaired balance (6), altered gait patterns (7), an increased risk of falls (8, 9), and is costly to treat (10).

HV is characterised by the progressive subluxation of the first metatarsophalangeal joint resulting in lateral deviation of the hallux and medial deviation of the first metatarsal. As the deformity progresses, the lateral deviation of the hallux compresses against the second toe, leading to lesser toe-deformity, keratotic lesions and difficulties finding comfortable footwear (11). This is often accompanied by a painful prominence on the medial aspect of the first metatarsal head, commonly referred to as a “bunion” (12).

The aetiology of HV is assumed to be multifactorial but is poorly understood (13). Because it evolves over decades, no prospective risk factor studies have been performed. Proposed risks can be classified as environmental or genetic (12, 14). Of the proposed environmental risks, footwear is considered important, particularly for females (10, 15-17). This is based on the prevalence of HV being lower in unshod populations and increasing when shoes are introduced into a previously-unshod population (2, 10, 15). Footwear with an elevated heel or that is ill-fitting (too narrow/constrictive toe-box) has been associated with hallux valgus in cross-sectional studies (10, 17-21). Recently, Menz (22) found that self-reported use of footwear with a constrictive toe-box during the third and fourth decades was associated with hallux valgus in females aged 50-89 years. No association was identified for the footwear heel height. Although these findings suggest shoe width and/or heel height affect the risk of hallux valgus, their relative contributions to this requires further investigation.

A genetic risk for HV has been proposed as 58-90% of people with HV report a family history of the condition (23-25). Pedigree studies found familial associations across three to seven generations (25, 26). Two recent studies, the Framingham Foot Study and a Korean twin and family member study, found familial associations that were attributed, at least partially, to unmeasured genetic factors (27, 28). Neither assessed the role of specific environmental factors that could be correlated in relatives.

We thus hypothesised that the occurrence of HV in women is affected by genetic factors as well as footwear use. The primary objective of this study was to examine the familial (i.e. genetic and/or shared environmental) factors involved with HV by documenting its prevalence in monozygotic (MZ) and dizygotic (DZ) Australian female twin pairs. Under the assumptions of the classical twin model, the non-genetic factors relevant to HV variance are assumed to be shared to the same extent within MZ pairs as within DZ pairs. Therefore, a greater age-adjusted concordance/correlation for MZ compared with DZ pairs is evidence consistent with, but not proving, genetic factors influencing prevalence: a lack of difference between MZ and DZ pairs in within-pair concordance suggests shared environmental factors influence prevalence. The second objective of the study was to determine the association between HV and self-reported previous use of inappropriate footwear by these participants across their lifespan. The third objective was to assess the extent to which familial associations in risk factors might influence our conclusions for the first objective. Developing a better understanding of these issues may enable focused interventions to be developed to prevent HV.

METHODS

Study design and data collection

We performed a classical twin study. A cross-sectional postal survey was conducted between April-October 2011 of female twins in Victoria, Australia. The study was approved by the Melbourne Health HREC (2010.206), and Monash University, Australia (2011000406).

Participants

Participants were 74 monozygotic (MZ) and 56 dizygotic (DZ) female twin pairs aged 31-87 years (mean [SD] age = 57.9 [12.8]), registered with the Australian Twin Registry and the Twin Research Program at the Royal Melbourne Hospital (Melbourne, Australia) and had participated in research investigating genetic and environmental determinants of bone health and balance performance (29, 30). These women were initially recruited through community outreach. They were approached by the Australian Twin Registry on behalf of the researchers to participate in this study. The zygosity of twin pairs was determined previously (29, 30) through a self-report questionnaire designed by the Australian Twin Registry (31), that accurately identifies true zygosity in 95 percent of twin pairs (32). To be eligible for inclusion, participants were (i) members of a twin pair (MZ or DZ), (ii) female, and (iii) older than 30 years at the time of the postal survey. Participants were excluded if they reported inflammatory arthritis (including rheumatoid arthritis or gout), or any lower limb amputation.

Medical history and anthropometric information

Participants completed a questionnaire to obtain information concerning their age, medical history and weight (kg). Height was determined from previous study data (29). Body mass index (BMI, kg/m²) was calculated.

Assessment of HV

The severity of HV was determined by self-assessment using the Manchester scale (33), a standardised collection of four photographs which encompass the range of severity of HV.

HV is graded as no deformity (grade 1), mild deformity (grade 2), moderate deformity (grade 3) or severe deformity (grade 4). Participants were asked to remove their shoes and socks and stand with weight distributed evenly on both feet, then to compare each of their feet to the scale photos and determine which image best matched each of their feet. Results for the Manchester scale were dichotomised; grades 1 and 2 were categorised as absent for HV, and grades 3 and 4 categorised as present (34). Participants were categorised as having HV if either foot had HV present. This scale has been validated against radiographic measures (34). Self-assessment of HV using this scale is reliable ($\kappa = 0.78$, percentage agreement = 95.8%), and shows agreement with grading by a trained examiner ($\kappa = 0.76$, percentage agreement = 95.6%) (35). Participants reporting a history of surgery for HV were classified as having HV.

Assessment of footwear

Past footwear use was determined by self-report using a series of drawings depicting 4 heel heights (A = flat, B = low, C = medium, and D = high) and 4 toe-box shapes (A = very wide, B = wide, C = narrow, and D = very narrow) (Figure 1) (36). The heel height and degree of toe-box constriction were assessed as these footwear features have been associated with HV (10, 17-20, 22). For each period of their life (divided into decades, commencing with 20-29 years of age), participants were asked to indicate which heel height and toe-box shape they

wore most of the time. For each participant, data were included for the corresponding decade of life if their age was greater than the mid-point (fifth year) of that decade. The footwear features were dichotomised by classifying the two most 'inappropriate' grades (eg: for heel height, medium and high, and for toe-box shape, narrow and very narrow). The classification was determined by using expert opinion from two experienced podiatrists (SEM and HBM).

Statistical analyses

Logistic and linear regression models were used to test for differences in anthropometric and demographic characteristics between MZ and DZ participants or those with and without HV. To accommodate the correlation structure within twin pairs for both methods, we used generalised estimating equations (GEE) to estimate parameters, the Huber-White method to estimate robust standard errors of these parameters, and Wald tests to obtain *p*-values. Logistic regression models estimated by GEE were fitted using STATA software, version 13 (StataCorp. 2013. *Stata Statistical Software: Release 13*. College Station, TX: StataCorp LP).

Correlations and casewise concordances were estimated to examine whether HV and its' measured risk factors were influenced by genetic and/or environmental factors. Under the assumptions of the classical twin model, non-genetic factors relevant to trait variance are shared to the same extent within MZ and DZ pairs. Therefore, a greater correlation or concordance among MZ twins than the DZ twins is evidence against a non-genetic influence hypothesis and in favour of a genetic influence hypothesis. The casewise concordance P_C is the conditional probability of a twin being affected given that the co-twin is also affected and was also estimated. However, concordance depends the prevalence of the condition, which is

expected to increase with age. In order to adjust for this, the flexible maximum likelihood method described by Hannah (37), which is based on a logistic regression model and allows concordance to depend on age (and other measured covariates), and which also provides an estimate of the “intrinsic correlation” ρ independent of age, was applied to these data. Models were fitted and the likelihood maximized using the *optim* function in the R software package (<http://www.R-project.org/>). Code to fit these models is available from the authors on request.

The twin odds ratio (OR), was used to examine whether HV was influenced by genetic and/or environmental factors. The twin OR is the ratio of the odds of having HV given that the co-twin has HV to the odds of having HV given that the co-twin does not have HV.

Logistic regression models fitted using GEEs were used to determine the association between the presence of HV and use of inappropriate footwear and other covariates. An interaction term (between zygosity and a predictor) was used to assess differences in ORs between MZ and DZ twins. The *p*-value for this term was obtained from a Wald test. The maximum likelihood method described above (37) was then applied to estimate concordances and correlations for the use of inappropriate footwear, and to adjust concordances, correlations and twin ORs of HV for additional covariates found to be significantly associated with presence of HV. Age was included as a covariate in all these models.

RESULTS

One hundred and fifty-two twin pairs were approached, and 130 complete pairs (86%; 74 MZ, 56 DZ) participated. The demographic and anthropometric characteristics of participants are shown in Table 1. The MZ and DZ twins were well matched for age and physical characteristics (all $p > 0.1$).

HV was reported by 70 participants (27%); 42 from MZ pairs (28%) and 28 from DZ pairs (25%). These proportions did not differ by zygosity ($p = 0.6$). Of the participants with HV, 33 had unilateral and 37 bilateral conditions. Participants with HV were older than unaffected individuals (mean [SD] = 65.6 [10.0] versus 55.2 [12.4] years, $p < 0.001$) but similar regarding the proportion who were obese (OR = 0.44; 95% CI = 0.17 to 1.14; $p = 0.09$).

Concordance and correlation of HV unadjusted and adjusted for age

Of the 130 twin pairs, 19 (15%) were concordant for HV; 12 (16%) for MZ pairs and 7 (12.5%) for DZ pairs. The expected concordance under no familial association was 7% (standard error = 2%). The unadjusted casewise concordance for MZ pairs was 0.57 (95% CI = 0.39 to 0.75) and for DZ pairs was 0.50 (95% CI = 0.27 to 0.73). Both were greater than the expected casewise concordance under no familial association of 7%: they did not differ significantly ($p = 0.6$). The correlation for MZ pairs was 0.40 (95% CI = 0.16 to 0.60) and for DZ pairs was 0.33 (95% CI = 0.06 to 0.58): this difference was not statistically significant ($p = 0.7$).

After adjusting the prevalence of HV for age, twin pairs were correlated and concordant (MZ: $\rho = 0.30$; 95% CI = 0.06 to 0.55; DZ: $\rho = 0.23$; 95% CI = 0.08 to 0.54), but not significantly

different ($p = 0.7$). The combined correlation was 0.27 (95% CI = 0.08 to 0.46). For MZ pairs, concordance at the mean age of 58 years was 0.46 (95% CI = 0.26 to 0.66) and for DZ pairs was 0.41 (95% CI = 0.16 to 0.66). The estimated concordance for all twin pairs combined was 0.45 (95% CI = 0.29 to 0.61).

These correlations and concordances are equivalent to an age-adjusted OR for having HV of 4.27 (95% CI = 1.27 to 14.3) and 3.40 (95% CI = 0.74 to 12.4) for MZ and DZ pairs respectively. These were not significantly different ($p = 0.7$).

Analysis of prevalence of HV as a function of footwear

Unadjusted associations of HV with footwear with a narrow or very narrow toe-box and medium or high heel for MZ twins and DZ twins separately, and using combined data are presented (Table 2). HV was significantly associated with the use of footwear with a narrow or very narrow toe-box during the third and fourth decades for MZ twins ($p = 0.007$ and <0.001 respectively) and when combined ($p = 0.002$ and <0.001 respectively), and in the fourth decade for DZ twins ($p = 0.03$). HV was significantly associated with the use of footwear with a medium or high heel during the fourth decade for MZ twins ($p = 0.03$) and for the total sample ($p = 0.02$).

The association between HV and the use of specific footwear styles adjusted for age and BMI in the combined data using multiple logistic regression is presented (Table 3). As height was not significantly associated with HV in unadjusted analysis, it was not included in multiple regression modelling. The use of footwear with a narrow or very narrow toe-box worn during

the fourth decade was the only variable significantly associated with HV when adjusted for all other factors ($p = 0.028$).

Correlation of constrictive toe-box unadjusted and adjusted for age

The risk factor for HV, narrow or very narrow toe-box worn during the fourth decade, was correlated in MZ ($\rho = 0.42$; 95% CI = 0.19 to 0.61) but not DZ ($\rho = -0.13$; 95% CI = -0.38 to 0.13) pairs. These correlations differed significantly ($p = 0.002$). Adjustment for age did not substantially change the correlation in MZ ($\rho = 0.38$; 95% CI = 0.15 to 0.60) or DZ pairs ($\rho = -0.20$; 95% CI = -0.43 to 0.03).

Concordance and correlation of HV adjusted for age and toe box

A larger difference between MZ and DZ correlations was observed when presence of HV was adjusted for narrow or very narrow toe-box worn during the fourth decade, regardless of whether or not adjustment for age was made. The correlation for MZ twins ($\rho = 0.35$; 95% CI = 0.08 to 0.62) was approximately double that for DZ twins ($\rho = 0.17$; 95% CI = 0.13 to 0.46). However, this difference was not statistically significant ($p = 0.4$).

DISCUSSION

We have confirmed a familial component to the prevalence of HV, with about a 4-fold increased risk for having an affected twin. Our analysis suggested that this familial observation could be attributed to shared environmental factors, not to shared genes. Moreover, the use of footwear with a constrictive toe-box during the fourth decade was associated with increased prevalence of HV. Use of inappropriate footwear was correlated in

MZ, but not DZ pairs, but when we took this into account it did not change our general conclusion.

A strong familial tendency for HV has commonly been reported, but existing evidence was largely based on pedigree studies from which it is difficult to differentiate between the effects of shared environment and shared genes (23-25). An analysis of non-twin first-degree relatives from the Framingham Foot study concluded that HV was heritable (heritability of liability 0.29 to 0.89), but no environmental risk factors were considered (28). Lee (27) analysed the Healthy Twin Study in Korea, concluding that variation in liability had moderate to high heritability. However, their findings relating to parent-offspring concordance were not consistent with this postulate. One interpretation of their analyses is that there is a shared environment effect, and a generational effect, due to parent-offspring concordance being less than half that for MZ twin pairs. Whilst our study confirmed a familial tendency, we were unable to identify evidence for a genetic component.

Our secondary objective was to examine the association between HV and self-reported use of inappropriate footwear, a commonly considered risk factor. We examined the association between HV and self-reported use of footwear with an excessive heel height or constrictive toe-box across participants' adult life, as these features have been associated with HV (18-20). We found that the self-reported use of footwear with a narrow or very narrow toe-box during the fourth decade was associated with an increased prevalence of HV (OR, 95% CI = 2.73, 1.12 to 6.67), suggesting a role for footwear with a narrow or very narrow toe-box in the aetiology of HV. In contrast, the self-reported use of footwear with a medium or high heel

was not independently associated with an increased prevalence of HV once the use of footwear with narrow or very narrow toe-box was accounted for.

Previous cross-sectional studies have suggested an association between HV and footwear that has a constrictive toe-box/inadequate width (18, 19), or an excessive heel height (17, 19-21).

The relative contribution of these two features across each decade of life has not been thoroughly investigated. A recent study of females aged 50-89 years in the United Kingdom by Menz (22) that used the same footwear assessment tool as our study, reported that compared with women who had worn shoes with a very wide toe-box, the likelihood of HV increased in those who had worn shoes with a narrow (OR = 2.4; 95% CI = 1.3 to 4.4) and very narrow (OR = 2.7; 95% CI = 1.5 to 5.0) toe-box between 20 and 29 years of age, and those who wore shoes with a very narrow toe-box (OR = 1.9; 95% CI = 1.1 to 3.4) between 30 and 39 years of age. There was no association with the self-reported height of the heel of the footwear. Therefore, our findings are in general agreement with Menz (22). It is believed that the use of constrictive shoes may lead to progressive lateral displacement of the hallux by exerting a laterally-directed force against the hallux medial aspect of the hallux (12). However, it is not clear why the fourth decade of life is important. It may be that females spend a greater proportion of time weightbearing in inappropriate footwear during this period. There may also be more complex reasons including changes to foot shape or function during this time period due to changes associated with life events such as pregnancy (38) that amplify the deforming effects of constrictive footwear. It is also possible that a birth cohort effect exists as shown by Menz (22) where females in the United Kingdom born between 1942 and 1952 were more likely than other birth cohorts to wear shoes that had a narrow toe-box or high heel when aged in their twenties and thirties. The specificity of our finding for the fourth decade could be in part due to lack of power to detect associations with other

decades. There are also likely to be other important environmental or lifestyle factors that are unknown; these could include diet, physical activity or general health.

From the viewpoint of twin study methodology, our finding that the environmental determinant of HV, a narrow or very narrow toe-box in the fourth decade, was substantially correlated for MZ pairs but not correlated for DZ pairs, is noteworthy. The 'equal environments' assumption of the classic twin model assumes that the twin pair correlation for the combined effects of shared environmental effects is the same for MZ pairs as it is for DZ pairs (39). This clearly was not the case for this risk factor. Therefore one cannot presume that the equal environments assumption applies to HV.

The observation that HV in females is associated with, at least in part, the use of footwear with a constrictive toe-box as the usual footwear during the fourth decade of life has potentially-important clinical implications. Given that footwear choices are modifiable, identification of the most appropriate footwear during the life course may be able to reduce the risk of HV. This argument is supported by the association of reduced prevalence of HV in males and that men are more likely to wear footwear with a wider toe-box (2, 10, 15, 40).

Identification of other modifiable risk factors for HV may aid prevention.

The findings of this study must be interpreted in the context of its limitations. First, the study participants were volunteers registered with the Australian Twin Registry Program, so there was potential for the studied pairs not being sampled independently of their status for HV. However, these women were recruited from the previous study, which investigated genetic

influences on variation in bone health and balance, unselected for foot pathology (29). Further, the participation of twins was very high (86%) for this study. Second, as we used a self-administered questionnaire, we cannot exclude the possibility that some sibling pairs did not complete the questionnaire independently. Also, the use of footwear was based on participant recall. The reliability and validity of the instrument used to determine the self-reported use of footwear across decades is unknown, and could have been influenced by recall bias. However, if recall bias were present we would have expected participants to have also associated their HV with high-heeled footwear, which was not observed. Third, we were unable to examine the effect of footwear or socioeconomic status in childhood, a life stage that has major influence on musculoskeletal development and where there is evidence of incorrectly fitting footwear being associated with HV (41). Additionally, the duration of weightbearing may increase the risk of HV (42), but we do not have the relevant data to examine this possibility. Fourth, we could not ascertain the age of onset of HV. Thus it is possible that earlier onset may have influenced footwear choices. Fifth, HV is a progressive deformity so it is possible that participants classified as not having HV, may develop it in the future. Finally, whilst no effect of genetic factors was identified, and adjustment for toe-box did not reduce the difference in association seen in MZ and DZ twins which was unexpected, the confidence intervals show that the study had limited power. Further studies with larger sample sizes are required to exclude a genetic effect on variation in prevalence.

In conclusion, we confirmed that HV is a familial condition, but found no evidence that this was due to genetic factors. We also found that the key 'equal environments' assumption of the classic twin model did not apply to a newly-identified risk factor for this condition, bringing into doubt previous estimates of heritability based on that model. Our finding that shared environmental factors are important in the risk of HV, and that the use of footwear

with a constrictive toe-box during the fourth decade of life is a specific environmental risk factor, could be particularly important. These findings suggest that HV may be preventable, and the selection of appropriate footwear with a toe-box that is not constrictive may be a useful intervention in future preventative strategies.

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TABLES

Table 1. Characteristics of MZ and DZ twins examined as individual participants.

Variable	From MZ pairs			From DZ pairs			<i>p</i> **
	n	Mean	SD	n	Mean	SD	
Age (at questionnaire), years	148	57.3	13.0	112	58.8	12.6	0.5
Height, cm	146	1.61	0.063	108	1.62	0.05	0.4
Weight, kg	146	64.8	11.0	108	67.8	14.7	0.1
BMI, kg/m ²	146	25.3	4.56	108	25.9	5.45	0.4
Obesity (BMI>30)	146	0.137*	0.0008	108	0.194*	0.0014	0.3
Hallux valgus	148	0.284*	0.0014	112	0.250*	0.0017	0.6

*Values are proportions; **A generalised estimating equation method was used to compute *p*-values (*p*) comparing means or proportions between MZ and DZ twins.

Table 2. Simple logistic regression to examine the associations of hallux valgus with inappropriate footwear.

<i>P-value for difference in ORs between MZ and</i>							Combined			
MZ			DZ			<i>DZ twins</i>			data	
Use of inappropriate footwear per decade*										
N	OR (95% CI)	<i>p</i>	N	OR (95% CI)	<i>p</i>	<i>p</i>	N	OR (95% CI)	<i>p</i>	
Narrow or very narrow toe-box										
20 to 29	14	3.33	0.007	11	2.35	0.07	0.6	25	2.77	0.002
	8	(1.38, 8.02)		1	(0.92, 5.97)	3		9	(1.47, 5.23)	
30 to 39	14	4.41	<	10	3.07	0.02	0.5	24	3.52	<
	0	(2.05, 9.51)	0.001	7	(1.13, 8.31)	8		7	(1.88, 6.59)	0.001

40 to 49	13	1.84	0.15	93	0.98	0.97	0.3	22	1.43	0.259
	0	(0.79, 4.29)			(0.38, 2.51)	1		3	(0.77, 2.65)	
50 to 59	85	1.68	0.4	73	0.64	0.51	0.3	15	1.26	0.589
		(0.51, 5.48)			(0.17, 2.44)	5		8	(0.55, 2.90)	
60 to 69	46	0.78	0.8	41	0.58	0.56	0.8	87	0.79	0.750
		(0.09, 7.03)			(0.09, 3.65)	3			(0.19, 3.30)	
Medium or high heel										
20 to 29	14	1.40	0.4	11	1.56	0.35	0.9	25	1.49	0.186
	8	(0.66, 2.97)		1	(0.61, 3.97)	0		9	(0.83, 2.70)	
30 to 39	14	2.24	0.03	10	1.84	0.16	0.7	24	2.01	0.015
	0	(1.06, 4.70)		7	(0.78, 4.32)	3		7	(1.15, 3.53)	

40 to 49	13	1.63	0.2	93	1.09	0.83	0.5	22	1.38	0.232
	0	(0.79,			(0.49,	8		3	(0.81, 2.35)	
		3.36)			2.38)					
50 to 59	82	0.68	0.5	73	NA	NA	NA	15	0.70	0.539
		(0.19,						5	(0.23, 2.17)	
		2.39)								

NA = unable to calculate;

*Insufficient data for analysis of variables toe-box 70 to 79, 80+, as well as heel height 60 to 69, 70 to 79, and 80+ decades.

Table 3. Multiple logistic regression to examine the associations of hallux valgus with age, BMI and inappropriate footwear.

Variable	OR (95% CI)	<i>P</i>
Age	1.07 (1.03, 1.10)	< 0.001
BMI	0.95 (0.89, 1.02)	0.15
Narrow or very narrow toe-box 20 to 29	1.45 (0.60, 3.50)	0.4
Narrow or very narrow toe-box 30 to 39	2.73 (1.12, 6.67)	0.03
Medium or high heel 20 to 29	0.91 (0.44, 1.86)	0.8

FIGURE LEGENDS

Figure 1. Footwear assessment drawings. Figure from Roddy (36).

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Figure 1. Footwear assessment drawings. Figure from Roddy et al. (38).
Figure 1
1539x1054mm (72 x 72 DPI)

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