Journal of Pioneering Medical Sciences
Received: August 24, 2026 | Accepted: September 17, 2026 | Published: November 15, 2026
Volume 15, Issue S02, Pages 236-246

DOI https://doi.org/10.47310/jpms202615S0228



Association Between Habitual Footwear Type and Self-Reported Foot Pain Among Adults in Saudi Arabia: A Cross-Sectional Study

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Abstract **Background:** Foot pain is prevalent amongst adults. Mobility and quality of life could be limited by foot pain. Footwear is proposed as one of modifiable factors. Evidence associating footwear worn habitually to foot pain in population studies is lacking. Hence, this research aims to determine three-month foot pain prevalence in the sampled adult and investigate association between footwear worn daily and foot pain. **Methods:** A cross-sectional design recruited convenience sampling of 301 adults in Saudi Arabia through online surveying (17 May-6 June 2026). Adults wearing different types of footwear on a habitual basis were included; the latter was categorised into flexible/athletic, rigid/formal and sandals. Main outcomes were foot pain in the previous three months (yes/no) and pain severity in mm (visual analogue scale). Relationships were established using chi-squared, Kruskal-Wallis tests and binary logistic regression model with odds of being free of pain adjusted to age, occupation, gender, weight, ankle sprain and others. **Results:** 149 (49.5%) out of total participants experienced foot pain within three months prior to conducting a study. Prevalence was not significantly different for different footwear types (48.0, 48.6 and 60.0% for flexible/athletic, rigid/formal and sandals correspondingly; $\chi^2 = 1.75$, $p = 0.417$, Cramér's V = 0.08); so was foot pain severity ($p = 0.632$). Higher comfort was perceived for flexible/athletic footwear. Adjusted comparison of footwear regarding probability of being free of foot pain resulted in wide confidence intervals (rigid/formal OR = 0.90, 95% CI: 0.41-2.00; sandals OR = 0.59, 95% CI: 0.25-1.39). Female sex (OR = 0.28, 95% CI: 0.14-0.57), age of 56 years and older (OR = 0.16, 95% CI: 0.03-0.82) and manual labour occupation (OR = 0.05, 95% CI: 0.004-0.52) correlated with lower probability of being free of pain. Weight 61-70 kg had significantly higher chances (OR = 3.81, 95% CI: 1.36-10.70). **Conclusion:** No significant relationship between footwear and foot pain was identified. Limitations include convenience sampling and self-reports.

Key Words Foot Pain, Footwear, Footwear Comfort, Cross-Sectional Study, Saudi Arabia

INTRODUCTION

Pain in the foot is a common musculoskeletal problem that can potentially adversely influence physical performance, balance, mobility and quality of life. Prevalence of foot pain in adults varies from 17-42% depending on the particular population under study and definitions of foot pain [1]. A number of systematic review articles and large epidemiologic surveys have shown that 24% of people experience frequent foot pain. This pain affects various age groups and not only older adults [2,3]. Being in contact with the ground during standing and gait of the person, foot can get damaged due to any pathological condition that influences mobility, performance and functioning of the body. Therefore, foot pain is an issue of clinical relevance rather than simply local symptom [1].

Footwear is known as a potentially modifiable factor that influences health of the foot throughout the lifespan. Appropriate footwear can give protection and comfort while poor choice of footwear may be associated with pain, deformity, ulcers, impaired mobility, increased risk of falling and so on [4]. Such parameters as fit, heel height, toe box shape and sole hardness of the footwear have been found

to influence comfort and performance of the foot. Of all those parameters, sole hardness is suggested to play an important biomechanical role through its effect on the force delivery from the footwear to the bottom of the foot. Experimental studies have shown that shoe sole hardness increase leads to the increased pressure under the foot. On the contrary, softer shoes provide a buffer and therefore are associated with reduced loads on the foot when walking [5]. However, results of studies remain inconsistent and the question about the relationship between shoe hardness and foot pain needs further investigation.

Several biomechanical investigations revealed the influence of sole hardness on pressure distribution and absorption of shock as well as loading in the lower limbs. Nevertheless, most of the current evidence comes from relatively small sample sizes or special populations such as elderly or people with existing foot problems or even athletes [5]. Those studies focused on biomechanical outcomes of wearing shoes rather than the self-reported foot pain in general population. Most of epidemiological studies about footwear and foot pain examined the relation between fit, type of the shoes, heel height and other footwear design parameters and patient foot complaints while the importance of sole hardness in everyday shoes remains unclear [4].

This way, community survey data can reveal possible association between broad categories of regularly worn footwear and self-reported foot pain. Various categories may vary in design.

Thus, the purpose of this cross-sectional study is the examination of the relationship between habitual footwear category and self-reported foot pain in the last three months.

METHODS

Study Design and Setting

This is an online cross-sectional survey conducted to investigate the association between type of footwear routinely worn and foot pain in Saudi Arabian adults. Cross-sectional designs are very popular in musculoskeletal epidemiology for estimation of the prevalence rate and determination of features associated with particular conditions in the population at a specific moment in time [6]. A cross-sectional design was selected as it provides an opportunity to measure the exposure and the outcome variables at once, is cost-effective and suitable methodological basis for such kind of study [6,7]. Data were collected during 17 May-6 June 2026 through an online structured self-administered questionnaire completed by the adult Saudi Arabian population members. The study was carried out following the ethical provisions outlined in the Declaration of Helsinki [8].

Study Population and Sample

Target Population: The target population comprised all adult persons, aged 18 and above, who were living or located at the moment of data gathering in or within Saudi Arabia. No geographical limitations were set to be imposed and regional representation is unknown.

Inclusion/Exclusion Criteria

Inclusion/exclusion criteria used in this study are presented in the Table 1. They were used in order to select the proper study sample and reduce the effect of independent foot health affecting diseases on research results.

Sample Size

Sample size needed was determined at the start of data collection using a projected prevalence of foot pain among the adult general community at 25%, based on previous population studies [9,10]. The estimation of sample size was done using the following equation:

$$n = (Z^2 \times p \times (1-p))/d^2 = (1.96^2 \times 0.25 \times 0.75)/0.05^2 \approx 289$$

It used 95% confidence interval and ±5% margin of error (Z = 1.96). It is based on estimating precision for a single proportion prevalence. The number is increased to 300 to accommodate incomplete response rate. The precision of the modified model will depend on the relationship between the number of outcome events and the number of the parameters estimated [11]. Finally, a total of 301 participants joined the study exceeding the target value set.

Sampling and Recruitment

Convenient sampling was utilized since the same is widely used in community-based health surveys that cannot use probability sampling [12]. Respondents in the study were recruited through an online self-administration of a questionnaire posted on Google Forms that could be accessed through social media and other messaging applications. Survey administration was without geographical restriction within Saudi Arabia. Participation in the survey was completely voluntarily without any incentive. To minimize chances of over-sampling any certain social or professional class, the survey link was circulated through several independent channels.

Data Collection Instrument

Questionnaire Development: A self-administered structured questionnaire specific to this study was developed by referring to literature on footwear, foot pain and musculoskeletal health in addition to the research objectives [9,10,13]. The questionnaire was prepared in Arabic in order to make it easy and understandable by the target study population. It consisted of 35 questions divided into seven themed groups:

- Informed consent-participants consented before proceeding to answer the survey questions
- Socio-demographics of participants-age group, gender, nationality, height, weight and marital status

Table 1: Participant Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
Adults aged 18 years or older	History of major foot or ankle surgery
Able to read and understand the questionnaire	Known inflammatory or systemic rheumatological disease affecting the foot (e.g., Rheumatoid Arthritis)
Willing to provide voluntary informed consent	Acute foot or ankle trauma in the preceding three months
Resident or present in Saudi Arabia during the data collection period	Incomplete questionnaire responses (more than 20% of items missing)

Participants who indicated a history of major foot or ankle surgery or an active systemic rheumatological condition were excluded from the analysis, Incomplete responses were defined as missing more than 20% of questionnaire items

- Occupational and lifestyle details-occupation, working field, number of hours in a working day, standing and walking hours in a day, frequency and type of exercise performed
- Footwear details-the most frequently used footwear type, average hours per day spent wearing, tight or narrow shoes and high heeled shoes worn regularly, use of orthopedic insoles and the level of comfort felt in the shoes ranging from 1 to 10
- Foot pain-foot pain ever experienced in last 3 months (Yes/No), the duration and the anatomical site (Heel, arch or plantar surface, forefoot and toes and ankle, multiple options allowed), foot pain intensity as scored on a Visual Analogue Scale (0 for no pain and 10 for the most severe pain possible), pain patter, effects of foot pain on walking and working and use of any pain medication
- Foot and ankle health history-ankle sprain and recurrent ankle instability, previously diagnosed foot deformities (flat foot, plantar fasciitis and hallux valgus) and family history of foot deformity and
- Perception of risk factor-whether respondents considered their footwear to contribute to their foot pain and willingness to change the footwear as suggested by a health care professional

In order to help in properly categorizing respondents' footwear, clear descriptions were added to every footwear type along with pictures as illustration. Flexibile or athletic footwear included running shoes, cushioned walking shoes and padded athletic footwear. Rigid or formal shoes consisted of dress shoes, flats without any cushion and occupational shoes without any cushion. Sandals refer to open toe footwear with or without heels. Categories of footwear used were according to self-reporting and may consist of various soles [13].

Outcome Measurement

The primary outcome measure was the foot pain in the last 3 months (Yes/No) prior to completing the survey. The 3 months recall period was used based on existing epidemiological surveys done on foot pain [9,10]. Possible recall bias can be observed during the process. The secondary outcome was the pain severity in form of Visual Analogue Scale (VAS) that is extensively used in the clinical and population research settings to measure pain severity [14].

Validation of Questionnaire

Questionnaire went through a pre-test before distribution to assess the instrument's clarity, face validity and reliability. Cronbach's alpha was used for the assessment of reliability because the latter is the most popular measure of the former for multi-items questionnaires [15]. The preliminary test resulted in alpha of 0.624 that is lower than acceptable threshold value of 0.70 [15,16]. Item-wise examination showed that five items of Height, Number of working hours, Frequency of exercise, Frequency of changing shoes and footwear comfort rating had negative correlation with the total scale. They all measured different things; therefore, alpha score is descriptive in nature. Items wording and response sequence order have been checked before distributing the questionnaire.

Data Collection Procedure

Survey was carried out through Google Forms. It was distributed among the potential respondents across Saudi Arabia through social media and messaging applications. Prior to asking any question, the respondent was required to read the description about the survey and understand the purpose of it and what he or she would have to do as participation. Respondents had to give the agreement of participating through clicking on one of the informed consent options. Those who did not agree were redirected to closing page and data collection was not done from those persons.

All questions were provided in Arabic. Survey could be completed by using any smartphone, computer or tablets without signing up for an account or installing any software. Normally, it took around 5-8 minutes for the respondent to complete the survey. None of the participants were required to give their name or national ID and any other personal identifier. All the responses were stored in the password protected database of Google Forms only accessible by the principal investigator and the supervision committee.

The data collection lasted for 3 weeks from 17th May until 6th June 2026. Research team reviewed the recruitment status on weekly basis and once the target number of 300 was reached and exceeded, the survey was closed. The final sample size was 301 respondents. Duplicates were detected and removed before the finalization of the database.

Study Variables

The Table 2 gives an outline of the independent variable, outcome variables and covariates with measures of them.

Table 2: Study Variables, Definitions and Measurement Approaches

Variable Type	Variable	Measurement
Primary Independent Variable	Primary footwear type	Self-reported: Flexible/Athletic, Rigid/Formal or Sandals
	Daily footwear hours	Self-reported: <2, 2-5, 5-8 or >8 hours per day
Primary Dependent Variables	Foot pain presence (primary outcome)	Self-reported yes/no: foot pain in the preceding three months
	Pain severity (secondary outcome)	Visual Analogue Scale (VAS): 0 = no pain, 10 = worst imaginable pain
Covariates/Confounders	Age group	Ordinal: 18-25, 26-35, 36-45, 46-55, 56-65, >65 years
	Gender	Male/Female
	Nationality	Saudi/Non-Saudi
	Body weight	Ordinal: <50 to >110 kg (eight categories)
	Occupation type	Student, Office Job, Standing Job, Manual Labor, Not Working, Retired
	Daily physical activity	Standing time, walking time and exercise frequency (ordinal categories)
	Foot and ankle history	Ankle sprain, recurrent instability and diagnosed conditions (flat foot, plantar fasciitis, hallux valgus)

VAS: Visual Analogue Scale, The adjusted analysis included demographic, occupational, activity and ankle-history covariates as potential confounders

Table 3: Statistical Analysis Plan

Research Objective	Statistical Test	Variables
Describe participant characteristics	Descriptive statistics-frequencies, percentages, Mean±SD or median (IQR)	All demographic and lifestyle variables
Test normality of continuous variables	Shapiro-Wilk test; histograms; Q-Q plots	Pain Severity (VAS), Footwear Comfort Rating
Primary: footwear type vs foot pain	Pearson Chi-square; Cramer's V for effect size	Footwear Type×Foot Pain (yes/no)
Footwear type vs pain severity	Kruskal-Wallis H-test; DSCF pairwise post-hoc	Footwear Type×Pain Severity (VAS)
Footwear type vs comfort rating	Welch's One-way ANOVA; Tukey HSD post-hoc	Footwear Type×Comfort Rating
Other factors vs foot pain (bivariate)	Chi-square (categorical); Mann-Whitney U (continuous)	Multiple predictors×Foot Pain
Independent predictors of foot pain	Binary logistic regression-OR with 95% CI	All covariates → Foot Pain

DSCF: Dwass-Steel-Critchlow-Fligner pairwise comparison test, OR: Odds Ratio, CI: Confidence Interval, IQR: Interquartile Range, All tests were two-tailed with statistical significance set at $p<0.05$

Statistical Analysis

All analyses were conducted using Jamovi (version 2.6; The jamovi project, 2024). The methodological approach for testing each research hypothesis is outlined in Table 3.

Descriptive Statistics

Frequency distributions and percentages were used to describe categorical variables. Normality of the continuous variables Pain Severity (VAS 0-10) and Footwear Comfort Rating (1-10) was checked using the Shapiro-Wilk test [17]. Visual inspection of the histograms and Q-Q-plots was performed as an additional verification step. Both continuous variables were not normally distributed ($p<0.001$ for both), hence median and interquartile range were calculated and rank test statistics were used for all comparisons below. The difference in footwear comfort among groups of footwear types was compared using the Welch's ANOVA.

Bivariate Analysis

Associations between categorical predictors and foot pain status (yes/no) were evaluated using the Pearson Chi-square test of independence [18]. Cramer's V statistic was computed as the measure of effect size (values around 0.1, 0.3 and 0.5 were considered to represent small, medium and large effect sizes correspondingly) [19]. Caution should be exercised when interpreting results obtained for sparse categories. Throughout the bivariate analyses the row percentage of respondents falling into each predictor value/category was provided in order to clarify the association direction.

Mann-Whitney U-test [20] was applied to assess the difference in comfort ratings and pain severity of those who suffer from foot pain and those who do not as these continuous variables had non-normal distribution. Rank biserial correlation coefficient was used as an effect size measure. Pain severity differences among the three groups of footwear types were estimated using the Kruskal-Wallis H-test [21]. In addition, Dwass-Steel-Critchlow-Fligner post-hoc procedure was used to conduct pairwise comparisons. The comparison of Footwear comfort rating between groups of footwear types was done using the Welch's one-way ANOVA (and not the standard ANOVA) since Levene's test showed different variances across groups [22]. Tukey's Honest Significant Difference (HSD) post-hoc test was applied to conduct pairwise comparisons.

Multivariable Analysis

The adjusted association of predictors with being pain-free was assessed using binary logistic regression analysis [23]. The modeled event is 'Foot Pain = No'. As a predictor of primary interest the footwear type was used, flexible/athletic type of footwear was defined as the reference. Other predictors included in the model were gender, body weight category, age group, daily standing time, frequency of exercise, history of ankle sprain and occupational category. To reduce the sparseness of categories in old age groups, age variable was recoded into three broader age categories: 18-35 years, 36-55 years and over 55 years. In addition, retired respondents (n = 2) were combined with the not working respondents based on the recommendations for dealing with sparse data in logistic regression [11]. OR and 95% CI were used to report the regression coefficients. The model fit was assessed using the pseudo R^2 (Nagelkerke) statistic, Likelihood-ratio, AIC and classification accuracy table. Throughout the whole study two-tailed alpha level of significance was set at 0.05 [18].

Ethical Considerations

Ethical approval for this study was received from the Institutional Review Board of King Faisal University, Saudi Arabia (Approval Reference: KFU-REC-2026-MAY-ETHICS4288). Prior to data collection, no ethical approval was received. This research study adhered to the code of ethics as stated in the declaration of Helsinki [8].

Participation in the study was voluntary. Prior to conducting the study by providing access to the questionnaire, all potential participants were informed about the purpose of the study, its nature and the uses of the data as well as their option to withdraw from the study without facing any consequences. Obtaining electronic consent from the participants was a necessary step-all the participants had to agree actively to participate in the study. Those who decided not to consent were provided with an exit page and no data of theirs were kept.

Confidentiality and anonymity of the participants were protected. The participants' personal information was not collected through the questionnaire and included no names, national identity card numbers, dates of birth or other contact information of any sort. Data collected was placed into the password-protected database to which only the primary investigator had access, as well as the supervisor's team.

There was no physical risk to any participant in this study as the sole risk associated with participating in it was limited to the time that would be spent filling the questionnaire (approximately 5-8 minutes), the benefits of finding out more about the modifiable risk factor in a commonly occurring musculoskeletal disorder clearly outweighing it.

RESULTS

The total number of adults who participated in this study was 301. Among them, 50.2% were women (151) while 49.8% of them (150) were men. The biggest proportion of the sample was young adults as 49.8% of them (n = 150) were 18-25 years old. Also, 69.1% (n = 208) were under 36 years of age. Almost the entirety of the sample was comprised of Saudi nationals (n = 247, 82.1%) with the majority having a fairly narrow range of body weights (from 50-80 kg). A significant portion of the sample included students (n = 143, 47.5%), workers whose job involves standing (n = 56, 18.6%) and workers doing office work (n = 50, 16.6%). The full characteristic of the sample is given in Table 4.

Foot pain during the past 3 months was experienced by 149 individuals (49.5%; 95% CI 43.9-55.2%). Out of the 149 individuals experiencing foot pain, the average pain intensity was 4.32 (SD = 1.95); whereas in case of all the 301 subjects, the VAS score was 2.41 (SD = 2.61; Median = 2.00). Prevalence of foot pain did not show marked variation among the 3 categories of shoes (Table 5 and Figure 1): 48.0% among the participants using flexible/athletic shoes (95% CI 41.6-54.5%), 48.6% in the participants wearing rigid/formal shoes (95% CI 32.5-64.7%) and 60.0% among those using sandal shoes (95% CI 43.8-76.2%). Difference between these proportions was not statistically significant ($\chi^2 = 1.75$, df = 2, p = 0.417; Cramér's V = 0.08). Width of the confidence intervals obtained for rigid/shoes and sandal shoe groups is due to their small sample size.

Table 4: Sociodemographic and Lifestyle Characteristics of the Study Population (N = 301)

Characteristic	No.	Percentage
Age (years)		
18-25	150	49.8
26-35	58	19.3
36-45	46	15.3
46-55	30	10.0
56-65	10	3.3
>65	7	2.3
Gender		
Male	150	49.8
Female	151	50.2
Nationality		
Saudi	247	82.1
Non-Saudi	54	17.9
Weight		
<50 kg	28	9.3
50-60 kg	63	20.9
61-70 kg	70	23.3
71-80 kg	67	22.3
81-90 kg	37	12.3
91-100 kg	21	7.0
101-110 kg	6	2.0
>110 kg	9	3.0
Occupation		
Student	143	47.5
Office job	50	16.6
Standing job	56	18.6
Manual labour	8	2.7
Not working	42	14.0
Retired	2	0.7
Main daily footwear		
Flexible/Athletic	229	76.1
Rigid/Formal	37	12.3
Sandals	35	11.6

Values are reported as the count and column percentage for each category

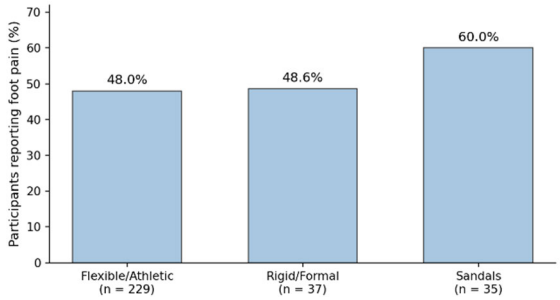


Figure 1: Prevalence of Self-Reported Foot Pain Across the Three Main Daily Footwear Categories (N = 301)

Precision of Footwear Comparisons

The obtained group sizes varied considerably, namely 229 flexible/athletic, 37 rigid/formal and 35 sandals groups. The small sample size reduces the accuracy and, consequently, leads to an inconclusive conclusion about the potential association between the factors considered.

Table 5: Prevalence of Foot Pain by Main Daily Footwear Type, with 95% Confidence Intervals

Main daily footwear	Foot pain: Yes	Foot pain: No	Total	Prevalence (95% CI)
Flexible/Athletic	110 (48.0%)	119 (52.0%)	229	48.0% (41.6-54.5%)
Rigid/Formal	18 (48.6%)	19 (51.4%)	37	48.6% (32.5-64.7%)
Sandals	21 (60.0%)	14 (40.0%)	35	60.0% (43.8-76.2%)
Total	149 (49.5%)	152 (50.5%)	301	49.5% (43.9-55.2%)

Values are presented as n (row %), Confidence intervals were calculated using the normal approximation to the binomial distribution, The association between footwear type and foot pain was tested with the chi-square test ($\chi^2 = 1.75$, df = 2, p = 0.417; Cramér's V = 0.08)

Table 6: Footwear Comfort Analyses

Comparison	Statistic	p-value	Effect size
Comfort by footwear type (Welch's ANOVA)	F(2, 61.1) = 17.4	<0.001	-
Tukey HSD: Flexible/Athletic vs Rigid/Formal	Mean diff = 1.74	<0.001	-
Tukey HSD: Flexible/Athletic vs Sandals	Mean diff = 1.45	<0.001	-
Tukey HSD: Rigid/Formal vs Sandals	Mean diff = -0.29	0.820	-
Comfort by pain status (Mann-Whitney U)	U = 8177	<0.001	Rank-biserial r = 0.278
Pain severity by pain status (Mann-Whitney U)	U = 1289	<0.001	Rank-biserial r = -0.886

The level of pain, indicated by the VAS, did not show significant differences among footwear groups (Kruskal-Wallis chi2 = 0.917, df = 2, p = 0.632; epsilon-squared $\varepsilon^2 = 0.003$, hence, very small effect). All pairwise comparisons between the groups, performed using the Dwass-Steel-Critchlow-Fligner test (Flexible/Athletic vs. Rigid/Formal: W = -0.252, p = 0.983; Flexible/Athletic vs. Sandals: W = 1.294, p = 0.631; Rigid/Formal vs. Sandals: W = 1.124, p = 0.706), were non-significant.

Comfort of Footwear

The self-assessed comfort of footwear (the scale from 1-10) showed significant differences between footwear groups (Welch's F(2, 61.1) = 17.4, p<0.001). Post hoc Tukey's HSD test revealed that flexible/athletic footwear was significantly more comfortable compared to rigid/formal footwear (mean difference = 1.74, p<0.001) and sandals (mean difference = 1.45, p<0.001); while the level of comfort did not differ for rigid/formal footwear and sandals (mean difference = -0.29, p = 0.820).

Besides, the comfort of footwear differed significantly for those with foot pain and without it (Mann-Whitney U = 8177, p<0.001, rank-biserial r = 0.278; without foot pain group rated their footwear as more comfortable). However, there was no relation between comfort advantage of footwear and its lower prevalence among this footwear group (Table 6).

Bivariate Associations with Other Covariates

The unadjusted relationships between foot pain and the other covariates are provided in Table 7. There were significant relationships between foot pain and gender ($\chi^2 = 5.59$; df = 1; p = 0.018); occupation ($\chi^2 = 14.1$; df = 5; p = 0.015); time per day of wearing footwear ($\chi^2 = 8.35$; df = 3; p = 0.039) and past diagnosed flat foot ($\chi^2 = 6.37$; df = 1; p = 0.012). There were no significant relationships between foot pain and age group (p = 0.081); tight/narrow shoe (p = 0.074); ankle instability (p = 0.069) and family history of foot deformity (p = 0.055). There were no significant relationships with nationality, high heel use, orthopaedic insoles use, exercise frequency, hours per day standing or walking, history of ankle sprain and plantar fasciitis diagnosis (p>0.10 for all variables).

Logistic Regression: Odds of Being Pain-Free

Freedom from foot pain was considered as the outcome and the odds were considered for various types of footwear while adjusting for gender, weight, time spent standing per day, physical exercise habits, prior ankle sprain incidence, age and occupation (Table 8). In other words, odds ratio less than 1 implies that one is less likely to have no pain. Neither footwear compared with the flexible/athletic footwear category has been significantly linked to having no pain, the corresponding odds ratios being 0.90 (CI 95% 0.41-2.00, p-value = 0.805) and 0.59 (CI 95% 0.25-1.39, p-value = 0.229) for rigid/formal footwear and sandals respectively. Various independent variables have shown adjustment odds for being pain free: Women were less likely to be pain free than men (Odds Ratio = 0.28, CI 95% 0.14-0.57, p<0.001), adults aged 56 years or above are less likely to be pain free than adults aged 18-35 years (Odds Ratio = 0.16, CI 95% 0.03-0.82, p-value = 0.027) and manual laborers are less likely to be pain free than students (Odds Ratio = 0.05, CI 95% 0.004-0.52, p-value = 0.013). However, those people who belong to the 61-70 kg category are more likely to be pain free than those in the reference weight category (Odds Ratio = 3.81, CI 95% 1.36-10.70, p-value = 0.011) (Table 8, Figure 2).

Pain in foot arch was the most common area affected, with 70 respondents (47%) indicating foot pain there, while pain on heels, toes, forefoot and ankle were less prevalent, respectively (Table 9). Pain occurring recently was the most common category: 89 subjects (59.7%) said their pain was new over the past month, while 39 people (26.2%) indicated that their pain occurred over three months prior to survey. The period of the last three months accounts not only for new pain but also covers older pain during that period. There were 67 respondents (45%) who felt pain when active. Pain most often had a minor impact on patients' ability to walk and affected their work for 47 respondents (31.5%). No significant difference was found for limitation of walking in three types of footwear ($\chi^2 = 6.99$, df = 6, p = 0.322).

Table 7: Bivariate Associations Between Foot Pain and Sociodemographic, Occupational and Foot-History Covariates

Variable	Category	Pain: Yes	Pain: No	N	χ^2	df	p-value	Cramér's V
Gender	Male	64 (42.7%)	86 (57.3%)	150	5.59	1	0.018	0.136
	Female	85 (56.3%)	66 (43.7%)	151				
Age group	18-25	66 (44.0%)	84 (56.0%)	150	9.80	5	0.081	0.180
	26-35	31 (53.4%)	27 (46.6%)	58				
	36-45	24 (52.2%)	22 (47.8%)	46				
	46-55	14 (46.7%)	16 (53.3%)	30				
	56-65	8 (80.0%)	2 (20.0%)	10				
	>65	6 (85.7%)	1 (14.3%)	7				
Nationality	Saudi	125 (50.6%)	122 (49.4%)	247	0.673	1	0.412	0.047
	Non-Saudi	24 (44.4%)	30 (55.6%)	54				
Occupation	Student	61 (42.7%)	82 (57.3%)	143	14.1	5	0.015	0.217
	Office job	21 (42.0%)	29 (58.0%)	50				
	Standing job	31 (55.4%)	25 (44.6%)	56				
	Manual labour	7 (87.5%)	1 (12.5%)	8				
	Not working	28 (66.7%)	14 (33.3%)	42				
	Retired	1 (50.0%)	1 (50.0%)	2				
Daily footwear hours*	<2 h	- (43.5%)	- (56.5%)	-	8.35	3	0.039	0.167
	2-5 h	- (40.6%)	- (59.4%)	-				
	5-8 h	- (54.9%)	- (45.1%)	-				
	>8 h	- (63.4%)	- (36.6%)	-				
Tight/narrow shoes*	Never	- (45.7%)	- (54.3%)	-	8.55	4	0.074	0.168
	Rarely	- (42.1%)	- (57.9%)	-				
	Sometimes	- (57.6%)	- (42.4%)	-				
	Often	- (64.5%)	- (35.5%)	-				
	Always	- (66.7%)	- (33.3%)	-				
High heel use*	Yes	- (56.1%)	- (43.9%)	-	3.86	2	0.145	0.113
	No	- (50.0%)	- (50.0%)	-				
	Not applicable	- (41.9%)	- (58.1%)	-				
Orthopaedic insoles*	Yes	- (54.0%)	- (46.0%)	-	1.00	1	0.317	0.058
	No	- (47.7%)	- (52.3%)	-				
Exercise frequency	None	54 (54.5%)	45 (45.5%)	99	2.17	3	0.539	0.085
	1-2/week	49 (46.2%)	57 (53.8%)	106				
	3-4/week	32 (50.8%)	31 (49.2%)	63				
	>4/week	14 (42.4%)	19 (57.6%)	33				
Daily standing hours	<2 h	44 (46.3%)	51 (53.7%)	95	1.64	3	0.650	0.074
	2-5 h	80 (52.6%)	72 (47.4%)	152				
	5-8 h	16 (43.2%)	21 (56.8%)	37				
	>8 h	9 (52.9%)	8 (47.1%)	17				
Daily walking hours	<2 h	82 (49.7%)	83 (50.3%)	165	0.198	3	0.978	0.026
	2-5 h	56 (50.0%)	56 (50.0%)	112				
	5-8 h	8 (44.4%)	10 (55.6%)	18				
	>8 h	3 (50.0%)	3 (50.0%)	6				
Ankle sprain history*	Yes	- (56.1%)	- (43.9%)	-	1.96	1	0.161	0.081
	No	- (47.0%)	- (53.0%)	-				
Ankle instability*	Yes	- (68.2%)	- (31.8%)	-	3.31	1	0.069	0.105
	No	- (48.0%)	- (52.0%)	-				
Diagnosed flat foot*	Yes	- (71.0%)	- (29.0%)	-	6.37	1	0.012	0.145
	No	- (47.0%)	- (53.0%)	-				
Diagnosed plantar fasciitis*	Yes	- (54.5%)	- (45.5%)	-	0.116	1	0.733	0.020
	No	- (49.3%)	- (50.7%)	-				
Family history of deformity*	Yes	- (63.4%)	- (36.6%)	-	3.68	1	0.055	0.111
	No	- (47.3%)	- (52.7%)	-				

Dashes indicate unavailable cell counts

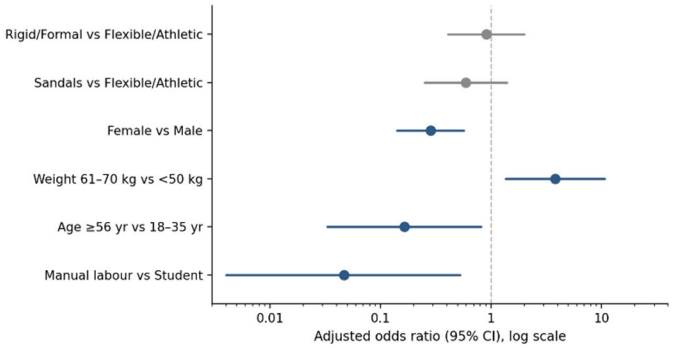


Figure 2: Adjusted Odds Ratios (95% CI) for Selected Covariates in the Pain-Free Model From the Binomial Logistic Regression

Table 8: Adjusted Binomial Logistic Regression for the Odds of Being Pain-Free (N = 301)

Predictor	Adjusted OR (95% CI)	p-value
Main daily footwear (ref: Flexible/Athletic)		
Rigid/Formal	0.90 (0.41-2.00)	0.805
Sandals	0.59 (0.25-1.39)	0.229
Gender (ref: Male)		
Female	0.28 (0.14-0.57)	<0.001
Weight (ref: <50 kg)		
50-60 kg	1.89 (0.72-4.98)	0.196
61-70 kg	3.81 (1.36-10.70)	0.011
71-80 kg	1.38 (0.49-3.90)	0.546
81-90 kg	1.09 (0.33-3.57)	0.892
91-100 kg	0.45 (0.11-1.89)	0.274
101-110 kg	0.29 (0.04-2.24)	0.233
>110 kg	0.30 (0.05-1.86)	0.196
Daily standing hours (ref: <2 h)		
2-5 h	0.76 (0.41-1.39)	0.371
5-8 h	0.92 (0.37-2.29)	0.863
>8 h	0.73 (0.21-2.57)	0.625
Exercise frequency (ref: None)		
1-2/week	0.95 (0.50-1.80)	0.878
3-4/week	0.70 (0.33-1.46)	0.342
>4/week	0.99 (0.39-2.51)	0.987
Ankle sprain history (ref: Yes)		
No	1.70 (0.95-3.03)	0.072
Age group (ref: 18-35 yr)		
36-55 yr	1.49 (0.69-3.23)	0.310
≥56 yr	0.16 (0.03-0.82)	0.027
Occupation (ref: Student)		
Not working/Retired	0.53 (0.20-1.37)	0.190
Office job	1.09 (0.48-2.48)	0.840
Standing job	0.44 (0.19-1.03)	0.057
Manual labour	0.05 (0.004-0.52)	0.013

All odds ratios are adjusted for the variables listed, entered together in a single model, Estimates are expressed as the odds of 'Foot Pain = No' relative to 'Foot Pain = Yes', so an odds ratio below 1.00 reflects lower odds of being pain free (i.e., greater odds of pain), For the model as a whole, $\chi^2 = 57.6$, df = 23, p<0.001, Nagelkerke $R^2 = 0.232$, overall classification accuracy = 68.1%. The significance threshold was p<0.05. CI = confidence interval; ref = reference category

Table 9: Characteristics of foot pain among symptomatic participants (n = 149)

Characteristic	No.	Percentage
Anatomical location of pain*		
Arch	70	47.0
Heel	46	30.9
Toes	44	29.5
Forefoot	42	28.2
Ankle	41	27.5
Pain duration		
<1 month	89	59.7
1-3 months	21	14.1
>3 months	39	26.2
Pain pattern		
During activity	67	45.0
Worse in evening	22	14.8
Worse in morning	19	12.8
Continuous	13	8.7
Continuous+activity	12	8.1
Evening+activity	8	5.4
Morning+evening	2	1.3
Not reported/missing	6	4.0
Effect on walking		
None	23	15.4
Mild	75	50.3
Moderate	42	28.2
Severe	9	6.0
Effect on work		
Yes	47	31.5
No	101	67.8
Not reported / missing	1	0.7

All percentages are based on the 149 participants who reported foot pain during the preceding three months, *The anatomical sites were not mutually exclusive, as pain could be reported at more than one site, so the percentages do not sum to 100%

DISCUSSION

Principal Findings

Of the 301 adult participants in this convenient online sample from Saudi Arabia, foot pain in the prior three months was reported by 149 (49.5%). Foot pain is a common musculoskeletal complaint in population-based surveys, though its prevalence depends heavily on case definition [1,2]. There was no statistically significant difference in the prevalence or severity of foot pain between any two groups based on habitual footwear category ($X^2 = 1.75$, p = 0.417, Cramér's V = 0.08; Kruskal-Wallis $X^2 = 0.917$, p = 0.632). The adjusted logistic regression models showed imprecise estimates: being in the rigid/formal footwear category compared to the flexible/athletic footwear category was associated with lower odds of foot pain (OR 0.90, 95% CI 0.41-2.00). Sandals compared to the reference footwear were also associated with lower odds of pain (OR 0.59, 95% CI 0.25-1.39). Participants differed significantly by footwear comfort by footwear category based on a significant F-test from Welch's ANOVA (F (2, 61.1) = 17.4, p<0.001). Tukey post hoc contrasts indicated that those in the flexible/athletic category found their footwear significantly more comfortable compared to the rigid/formal group (mean difference 1.74, p<0.001) and the sandals group (mean difference 1.45, p<0.001). There was no significant difference between rigid/formal footwear and sandals (mean difference -0.29, p = 0.820). Age ≥56 years, female sex and manual labour each had significant negative associations with being pain-free, whereas the 61-70 kg weight category had higher odds of being pain-free compared to the reference group. The oldest age group (N = 17) and the manual labor group (N = 8) contained relatively few participants and therefore the adjusted estimates require cautious interpretation.

Comparison with Existing Literature

Overall, these findings are largely compatible with previous population-based studies, where the impact of footwear was shown to be only part of a larger multidimensional process underlying foot pain. The Framingham Foot Study did not find consistent associations of current shoewear with generalized foot pain, though historical shoewear showed associations with hindfoot pain in women [9]. Population-based studies generally agree that certain individual characteristics, including age, female sex and body weight are important predictors of foot pain [24-26]. Therefore, the lack of independent associations of footwear category with foot pain in the current analysis does not mean that footwear is not related to foot health problems.

There are two key points that need to be made regarding the category-specific results and specific shoe characteristics. There is a body of biomechanical evidence indicating that the hardness of the sole affects plantar pressure. For example, in the study by Lane *et al.* [5], progressive increase in plantar pressure with the increased hardness of the sole was demonstrated in forefoot-painful older adults, while there were no significant differences in comfort perception. That makes it a good contrasting finding against which to interpret the results of the current study, since this paper analyzed self-reported rather than experimental footwear categories.

In a systematic review, the footwear comfort was found to depend on multiple features of the footwear, body, task and environment [27]. This means that the current category-level results cannot be seen as an evidence against the hypothesis that individual shoe features like cushioning, hardness, flexibility or fit are biomechanically relevant.

Comfort Versus Pain

Two comfort-related pieces of information provided by the results are key to clarifying what conclusions can and cannot be drawn about the relationship between comfort and foot pain. First, as was previously mentioned, the rating of comfort differed across footwear categories. The flexible/athletic footwear category received the most positive rating. Second, people reporting foot pain found their footwear significantly less comfortable (MWU = 8177, $p<0.001$, RBRC = 0.28), which is a moderate effect size.

Combining these two pieces of information leads to a conclusion that comfort and foot pain are related but distinct phenomena. Comfort perception is likely dependent on multiple factors including both immediate characteristics of the footwear like cushioning and fit and the features of the individual's body, physiology and psychology [27,28]. Therefore, the category-level differences in comfort perception do not necessarily imply the same differences in the prevalence of pain.

Since comfort and pain perceptions are measured only once at a single point in time, the direction of causality in individual-level data remains unknown. It might be possible that people with foot pain report more uncomfortable footwear but it might also be true that discomfort causes foot pain and both mechanisms exist.

The present findings are compatible but not directly testable against the concept of comfort filter developed by Nigg and his colleagues and specifically applied to running biomechanics. According to this theory, people select footwear on the basis of comfort perception and their chosen footwear may interact with their movement pattern and biomechanical response [24]. This is why the comfort filter offers one possible explanation for the lack of direct relationship between footwear comfort and foot pain in individual cases.

However, evidence collected since that time indicates both support and challenges to the comfort filter concept. Lindorfer et al. found no improvements in running economy or biomechanical variables after choosing more comfortable running shoes [29,30]. More recently, in a secondary analysis of a randomized trial, the relationship between cushioning and comfort was found to be a potential way of reducing running injuries but it should be kept in mind that the validity of the comfort filter concept has not been proved yet [31]. Therefore, the current findings can be seen as conceptually compatible with the comfort filter theory.

Other Footwear Characteristics

The survey also obtained the information on the frequency of wearing tight/narrow shoes, the use of high heels and orthopedic insoles. There were no statistically significant associations with foot pain for wearing tight-shoes ($X^2 = 8.55$, df = 4, $p = 0.074$), for high heels ($X^2 = 3.86$, df = 2, $p = 0.145$) and for insole use ($X^2 = 1.00$, df = 1, $p = 0.317$); those variables were not included into the logistic regression model, so their contribution independent of the possible confounding cannot be obtained from the current analysis.

Nevertheless, the absence of statistically significant associations should not be considered as proof that shoe fit and heely features are not related to foot problems. As previously reported in the literature, incorrectly fitted footwear was found to be a risk factor for foot pain and foot disorders but there is heterogeneous and population-specific evidence about that problem [30]. In addition, there is heterogeneous epidemiological evidence of high-heeled footwear causing musculoskeletal pain and other musculoskeletal outcomes but this research concerns specific exposure rather than broad footwear categories used in this study [29].

It is worth pointing out that the number of hours per day of wearing footwear was also statistically associated with foot pain ($X^2 = 8.35$, df = 3, $p = 0.039$), with people wearing footwear longer having more pain complaints; again, this variable was not included into the logistic regression model. Occupational loading might play an important role here since long-term standing has been found in various studies to be an important risk factor of musculoskeletal symptoms of lower extremities [32]. More generally, this study categorized footwear by the type chosen by the participants. There were no objective measures of sole hardness, fit and heel height.

Strengths and Limitations

The study's strength includes sample size, larger than the pre-specified sample size goal, the adjustment for several potential confounders and evaluation of not only the presence but severity of foot pain. Limitations, including a cross-sectional study design, which precludes causal inference and the presence of possible reverse causality (since those people experiencing foot pain might have already chosen certain type of footwear), are worth considering. Also all data on both exposure and outcome were self-reported data and there is potential for recall bias. It is also important to note that the presented value of Cronbach's α, equal to 0.624, was obtained from a pilot study before revision.

Participants were recruited using an online sampling procedure and were mostly young (69.1% of participants are <36 years old), primarily student and mainly from Saudi Arabia (82.1% are Saudis); these features of the sample can be explained both by the sampling technique used and patterns of usage of social media in Saudi Arabia and it restricts the ability of making generalizations on older participants, on participants not belonging to student population and not living in Saudi Arabia [33]. Moreover, sandals accounted for the lowest proportion of exposure but not a negligible footwear type (35 out of 301 participants wore them).

It should be noted that reasons for choosing certain types of shoes were not assessed and it is impossible to make conclusions on the effect of climatic conditions and footwear preference in Gulf Region based on these results. The information on footwear was provided only in three broad categories without measurements for hardness of the sole and cushioning which were shown to be important determinants of shoe comfort [27]. In addition, comfort and loading of the foot depends on several characteristics of the footwear (including shoe fit and hardness), not only footwear category [27]. Moreover, some types of footwear had relatively few numbers of subjects (the rigid and formal category had 37 participants and sandals-35), which means that corresponding odds ratios had wide confidence intervals. Lack of evidence of dose-response relation and isolated finding for 61-70 kg category in relation to body weight suggests a possibility of reduced power due to small size cells and usage of weight categories instead of body mass index.

Finally, foot anatomy and existing foot problems, footwear age and condition and length of daily wearing were not fully characterized by the adjusted analysis. Pairwise differences in comfort rating were cautiously evaluated considering different variances of the groups compared.

Implications

This survey revealed differences in the subjective evaluation of comfort by the footwear category used and uncertainty about the relationship between the type of shoes and foot pain. Such interpretation of findings corresponds with evidence that foot pain is associated with many individual characteristics and that comfort of the footwear itself depends on many factors [25-27]. Individual characteristics, work-related exposure and objective evaluation of footwear characteristics should be considered in future research. Comfort ratings cannot be treated as a surrogate of pain outcomes in both clinical counseling and research design.

For the purpose of research, it will be helpful to use the objective measures of sole hardness, fit, heel height and other footwear characteristics and to conduct prospective studies measuring also daily wearing time of the footwear. In addition, the prospective design will help to determine the temporality relations and minimize uncertainty associated with potential reverse causality inherent to the current cross-sectional design. Future research might use direct foot measurements to characterize footwear fit. Measured foot length varied by sex and correlated with height of Majmaah medical students aged 18-25 years [34].

CONCLUSIONS

This cross-sectional sample of adult Saudi Arabia showed prevalence of foot pain of almost 50%. There was no significant correlation between the type of self-reported footwear and foot pain. Participants rated flexible/athletic footwear more comfortable. Large prospective studies with objective measures of the characteristics of footwear are needed.

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