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Original Article

Factors affecting foot posture in young adults: a cross sectional study

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Abstract

Objective: Age, Body Mass Index (BMI) and flexibility are factors affecting foot posture, which is poorly understood in young adults. The objective of this study is to discover the relationships among these factors. **Methods**: 252 healthy participants (106 males, 146 females) between the ages of 18 and 25 were selected. BMI and the Foot Posture Index - 6 item version (FPI-6) were assessed, a Beighton score was obtained for each participant, and a lunge test was conducted. **Results**: Pronated feet (indicated by an FPI-6 score of 6+ (had a weak positive correlation with Beighton score (r=0.25, p= 0.05, 95% CI [0.01 to 0.47]) and a weak negative correlation with BMI (r=0.31, p = 0.01, 95% CI [-0.52 to -0.07]). Females had a higher prevalence of pronated feet (81.75%) than males (18.75%). **Conclusion**: There is a mild relationship between ligament laxity and foot pronation, and females are more prone to have pronated feet than males. No correlation was found between body weight and pronated feet.

Keywords: Beighton Score, BMI, Foot Posture, Foot Pronation, Pes Planus

Introduction

Exercising and sports are important to health and well-being; the consequences of inactivity can be devastating. However, physical activities can also cause many injuries that affect an individual's quality of life. Foot posture (high or low arch) influences the lower limb and can contribute to injuries[1]. Pronated feet could contribute to low back pain[2,3], degenerative joint disease[4], hallux abducto-valgus[5], general lower limb pain[6,7] patellar tendinitis[2], and foot pain[8,9].

A supinated foot type has a positive correlation with ankle sprains and iliotibial band syndrome[10]. Therefore, understanding the factors that affect foot posture may aid in the clinical assessment and detection of risk factors for injury. Body mass index (BMI), joint flexibility[11,12], ligament laxity[13], and age[14] are factors that may impact foot posture, but further study in this area is needed[15].

The Foot Posture Index-6 item version (FPI-6)[16] is a reliable assessment tool that classifies static foot posture as normal, supinated, or pronated[17]. Most articles that address the relationship between the FPI-6 and the factors affecting foot posture examine children, whose growth and morphological characteristics differ from those of adults[15,18]. Therefore, the aim of this study is to discover the relationships among foot posture index, BMI, age, and flexibility (of the ankle and the whole body) in young adult subjects.

Materials and methods

Participants and setting

This cross-sectional study was conducted from January to April 2018 in Jeddah, Kingdom of Saudi Arabia. This study has been reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies[19].

Ethical approval was obtained from the Faculty of Applied Medical Sciences at King Abdulaziz University (KAU). Each participant consented before enrolling in the study. Two hundred fifty-two (146 female and 106 male) healthy, asymptomatic participants aged 18 to 25 years from KAU

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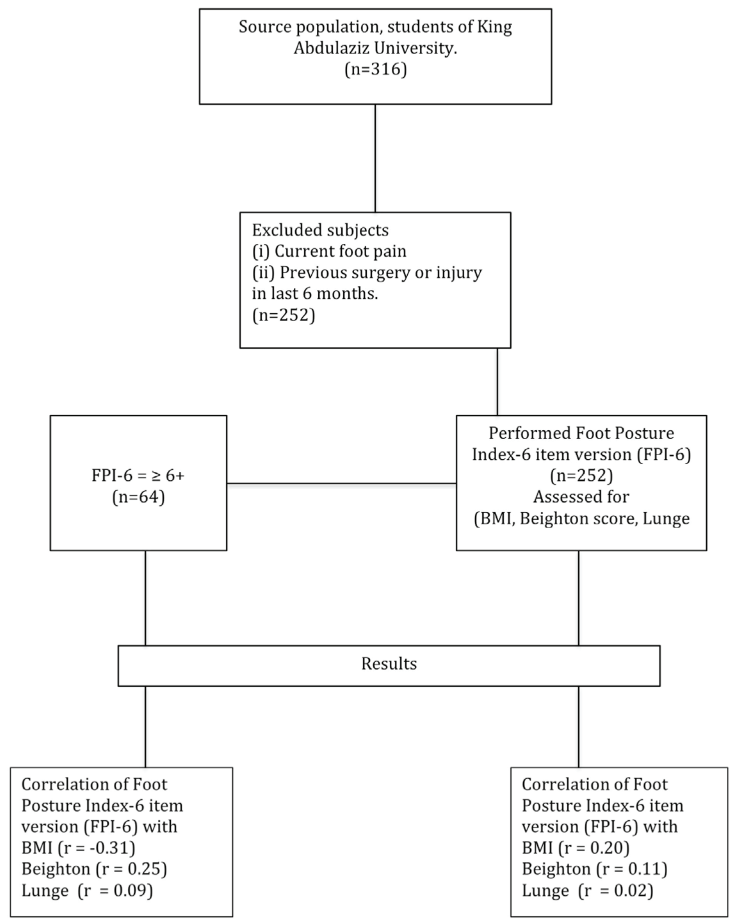

Figure 1. Flow chart of study design according to STROBE guidelines.

were selected. The size of the sample was decided through a power analysis based on previous studies; the power was set at alpha=85%. Subjects with current foot pain, a previous surgery, or an injury in the previous six months that restricted the range of motion of the foot and ankle and subjects with systemic or inflammatory conditions affecting the foot joints were excluded from the study. The following data were collected from each participant: age, gender, BMI, FPI-6[16], Beighton score[20], and an ankle lunge test[21]. Two assessors took all measurements except the FPI-6. One of the senior authors (M.C., who has twenty years of experience in the musculoskeletal field) assessed the FPI-6; these assessments were cross-checked by F.K., a senior author with fifteen years of experience. The sequence of measurements was consistent with all participants (Figure 1).

Procedure

After age, gender, and BMI were documented, the FPI-6 measurements were taken; which identifies the foot posture. The FPI-6 consists of six elements: (1) talar head palpation, (2) the curves above and below the lateral malleolus, (3) inversion/eversion of the calcaneus, (4) the bulge in the region of the talonavicular joint, (5) the congruence of the medial longitudinal arch, and (6) the abduction/adduction of the forefoot on the rear foot. Each element was graded between +2 (indicating foot pronation), and -2 (indicating foot supination). Foot posture was then classified as normal (0 to +5), pronated (+6 to +12), or supinated (-1 to -12). Maximum pronation and supination of each foot were indicated by grades of +12 and -12, respectively. The participants took three to five steps before the FPI-6 measurements were taken. They were then positioned in an erect, static, standing position with the upper limb beside the body and the head aligned in a neutral position[16,22]. The inter- and intra-rater reliability for the FPI-6 were found to be 0.62 to 0.91 and 0.81 to 0.91, respectively[17]. For simplicity, in this study, an FPI-6 score of ≥6+ is used to describe subjects with foot pronation of +6 to +12 in the FPI-6.

The Beighton score was used to test whole-body joint hypermobility. It has nine components: passive extension of the elbow and knee (from a non-weight bearing position), pulling the little finger into an extension beyond 90°, pulling the thumb to touch the forearm, and trunk flexion from

Table 1. Demographic characteristics and test scores.

	All subjects (n=252)			FPI-6 = ≥6+ (n=64)		
Variables	**Mean ± SD**	**Median (range)**	**95% CI**	**Mean ± SD**	**Median (range)**	**95% CI**
Age (years)	21.28 ± 1.29	21.5 (18-25)	21.12- 21.44	20.70 ± 1.37	21 (18-24)	20.36 - 21.04
BMI (kg/m²)	23.94 ± 5.25	23.06 (16.20-42.80)	23.29-24.60	24.67 ± 4.26	24.83 (16.2-36)	23.61 - 25.74
FPI-6	4.07 ± 2.87	4 (0-12)	3.71- 4.42	8.02 ± 1.90	8 (5-12)	7.54 - 18.49
Beighton score	2.33 ± 2.42	2 (0-9)	2.03-2.63	3.48 ± 2.81	3 (0-9)	2.78 - 4.19
Lunge test (cm)	12.32 ± 3.29	12.5 (2-20)	11.91-12.72	12.37 ± 3.47	12.25 (4-19.5)	11.5 - 13.23

SD: standard deviation, 95% CI: Confidential Interval, FPI: Foot Posture Index, BMI: Body Mass Index.
Abbreviations: FPI: Foot Posture Index, BMI: Body Mass Index

Table 2. Correlation matrix showing the relation between different variables in FPI-6 = ≥6+ subjects.

	FPI-6	Lunge Score	Beighton score	BMI
Pearson Correlation				
FPI-6	1.000			
Lunge test	-0.096	1.000		
Beighton Score	0.251*	0.241*	1.000	
BMI	-0.313*	-0.128	-0.256*	1.000

**= significant value. FPI: Foot Posture Index, BMI: Body Mass Index.*
Abbreviations: FPI: Foot Posture Index, BMI: Body Mass Index.

a standing position. All components except the last were tested bilaterally. Each of the components was scored one or zero; a higher total score indicates more hypermobility (9=maximum, 0=minimum). The intra- and inter-rater reliability for the Beighton score were 0.86 and 0.87, respectively, and the cut-off score was set to 5. Subjects were considered hypermobile if they scored 5 or higher[20,23].

An ankle lunge test measures ankle flexibility when standing. Subjects stand against a wall and place their hands on the wall to maintain stability. The foot to be examined was placed at a right angle to the wall, and the other leg was positioned comfortably. The subjects were asked to touch the wall with the knee of the limb to be tested without raising the heel. The distance from the big toe to the wall was measured using a measuring tape placed on the floor. The ankle lunge test has good intra- and inter-rater reliability (0.97 to 0.98 and 0.99, respectively)[21].

Data analysis

The data were analyzed using SPSS version 21 (SPSS, Inc., Chicago, IL, USA). Graph Pad Prism version 7.0 (Graph Pad Software, La Jolla, CA, USA) was used to plot the graphs. Descriptive statistics were used to calculate the samples' mean ± SD and median (range); the confidence interval was 95%. The data were tested for normality using the D'Agostino and Pearson omnibus and Kolmogorov-Smirnov tests. Pearson's correlation coefficient for normal distribution and the Spearman's rho test were utilized to detect the relationships among the variables. An independent t-test was used to compare group means. Sensitivity and specificity were calculated for BMI, the lunge test, and the Beighton score; FPI-6 was used as the reference value of 1. The positive predictive value, negative predictive value, and the area under the curve were also analyzed.

Results

Two hundred and fifty-two subjects (146 female and 106 male) aged 18 to 25 years were recruited for our study. The descriptive statistics of the subjects' demographic characteristics and the tests are provided in Table 1.

The results of the correlation are presented in two categories: one including all subjects and one including only subjects with an FPI-6 score of ≥6+. In all subjects, there was no correlation between FPI-6 and BMI (r=0.20, p=0.02, 95% CI [0.07 to 0.32]), between FPI-6 and Beighton score (r=0.11, p=0.08, 95% CI [-0.02 to 0.24]), between FPI-6 and the lunge test (r=0.02, p=0.70, 95% CI [-0.10 to 0.15]), or between FPI-6 and age (r=-0.19, p=0.02, 95% CI [-0.31 to -0.07]).

For participants with an FPI-6 score of ≥6+, there was a significant weak positive correlation between FPI-6 and Beighton score (r=0.25, p=0.05, 95% CI [0.01 to 0.47]), a

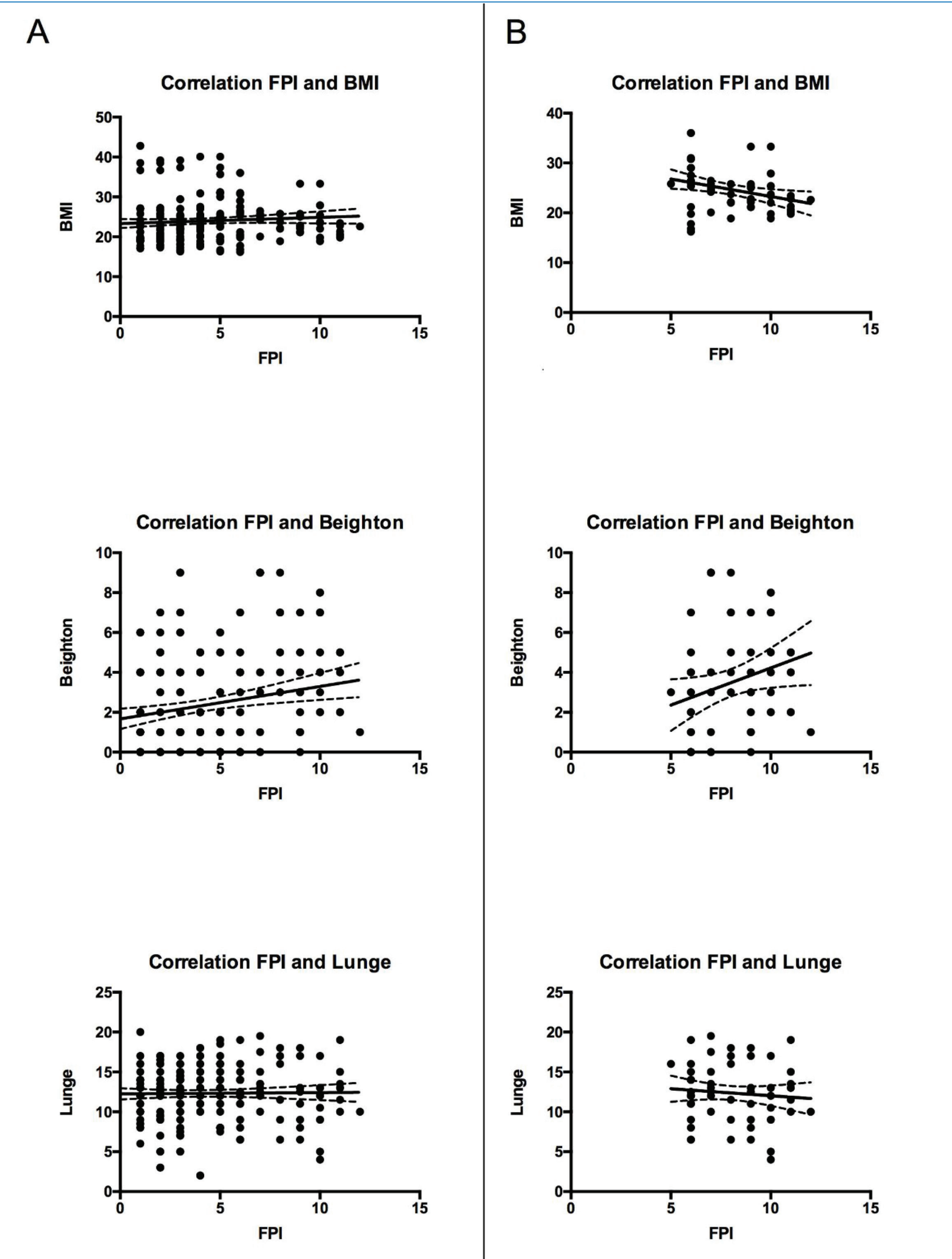

Figure 2. Correlation of FPI with BMI, Beighton and Lunge; A) for all subjects, B) FPI-6 = ≥6+ subjects. With the bold line representing the line of best fit and dotted lines for the 95% Confidence interval band. Abbreviations: FPI: Foot Posture Index, BMI: Body Mass Index.

Table 3. Sensitivity and Specificity of all the variables by considering FPI-6 as the standard.

	Sensitivity	Specificity	PPV	NPV	AUC
BMI	54.5	61.8	33.6	79.3	0.6
Beighton	47	76.3	41.3	80.2	0.64
Lunge	19.7	81.7	27.7	74.1	0.5

BMI: Body Mass Index, PPV: Positive predictive value, NPV: Negative predictive value, AUC: Area under the curve.

significant weak negative correlation between FPI-6 and BMI (r=-0.31, p=0.01, 95% CI [-0.52 to -0.07]), no correlation between FPI-6 and age (r=-0.22, p = 0.08, 95% CI [-0.44 to 0.03]), and no correlation between FPI-6 and the lunge test (r=-0.09, p = 0.45, 95% CI [-0.33 to 0.15]). The relationships among the different variables for FPI 6+ subjects are illustrated in a correlation matrix in Table 2 and Figure 2.

There was a significant difference between males' and females' FPI-6 scores in the total sample (p=0.03, 95% CI [0.08 to 1.52]). Of the 252 subjects, 64 (25.4%) had an FPI-6 score of ≥6+, and there was a significant difference between males and females among the subjects with an FPI-6 score of ≥6+ (p=0.01, 95% CI [1.20 to 3.36]); 52 (81.25%) of the female subjects had pronated feet. The sensitivity and specificity of all variables were also analyzed using FPI-6 as the reference value (Table 3).

Discussion

This study aimed to discover the relationship of foot posture with flexibility (of the ankle and the entire body), age, and BMI in young adults aged 18 to 25 years. The results showed no correlation between these variables. An FPI-6 score of ≥6+ had a direct relationship with Beighton score and a weak negative correlation with BMI. The majority of participants with an FPI-6 score of ≥6+ were females.

Similar studies and foot posture prevalence

A similar study was conducted with children aged 7 to 15 years. That study found a significant positive correlation between pronated feet and whole-body flexibility but no correlation between foot pronation and ankle flexibility[15]. This may imply that ankle flexibility indirectly affects foot posture or that it does not affect foot posture unless whole-body hypermobility is also present and one-third of the participants had pronated feet. In Rodriguez et al., 21.1% of 400 participants had pronated feet according to the FPI-6; this is similar to our results[11]. In India, Sachithanandam et al. found that 2.9% of 1,846 participants had flat feet. This difference could be due to the method used for testing flat feet; that study used a footprint map to detect flat feet. Footwear may also contribute to the difference in Sachithanandam et al.'s findings; most participants in that study did not wear shoes during early childhood[13].

Foot posture and gender

Pronated feet were reported in 52 of 146 females (35.61%) and 12 of 106 males (11.32%) in the current study. Hagedorn et al. measured the center of pressure excursion index (CPEI) on adults and concluded that women had a lower CPEI (more foot pronation) than men. A possible explanation of the higher prevalence of flatfoot in females might be the wearing of high heels, especially among young adults[24]. Increased joint mobility has shown an association with foot pronation[25]; this is consistent with our finding that whole-body hypermobility is related to pronated feet. Ligament laxity has also been linked to foot pronation[26]. The results of a survey in the United States contradict our findings; that study concluded that males had a higher frequency of flatfoot than females[4]. In contrast, Redmond et al. found that gender did not correlate with FPI-6. However, this may be due to the subject selection in that study, for which data were collected from an online database containing measurements for subjects aged 3 to 96 years[27]. The findings of Rodríguez et al.[11] were similar to those of Redmond et al., and that study also included subjects with a wide age range (18-65 years).

Foot posture and age

The present study found no association between age and foot pronation. This contrasts with the findings of studies involving children, in which foot posture is related to age. This could be because the skeletal system is not yet fully developed in children[13]. Stavlas et al. found a significant difference between the ages of males and females with pronated feet; in that study, males had a higher frequency of flatfoot at the ages of 7, 9, 11, 14, and 15[28]. Eleven-year-old children had the highest FPI-6 score among children aged 10 to 14 years[18], and, in general, age is inversely related to foot pronation in children[29]. The results of studies with participants over the age of 16 years[13] or 18 years[30] are similar to those of our study. Females above the age of 65 and females and males above the age of 75 have a higher incidence of foot pronation[24].

Foot posture and BMI

Shibuya et al.[30], Hagedorn et al.[24,18], and Hawke et al.[15] agree that BMI is not related to foot posture. In the current study, increased BMI did not increase the chance of foot pronation; we found a negative correlation between these variables. However, in another study using self-reported data, BMI was directly related to flatfoot[21]. Contact plantar pressure increases with obesity, but the percentage of plantar distribution and the location of the center of pressure were similar to those with a normal BMI. Increased adipose tissue in the foot could create the illusion of flatfoot in obese individuals[31].

Study limitations

In the current study, the ratio of female to male participants was imbalanced; this could be avoided in future studies. Other factors affecting foot posture, such as type of footwear, playing barefoot during childhood, and muscle imbalance were not included in this study. Further studies should seek to contribute to a comprehensive understanding of the factors affecting foot posture.

Conclusion

This study found that FPI-6 had no significant correlation with BMI, age, ankle flexibility, or whole-body flexibility in participants aged 18 to 25 years. Whole-body flexibility had a weak positive correlation with an FPI-6 score of ≥6+, and more females than males had an FPI-6 score of ≥6+.

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Authors contribution

Fayaz R. Khan: Contributed in the conception, study design, data collection, data analysis, interpretation and revising drafts for submission, Mohamed F. Chevidikunnan: Contributed in the conception, study design, data collection and revising drafts for submission, Aseel F. Mazi: Contributed in writing the manuscript, Shahad F. Aljawi: Contributed in data collection, Fatmh H. Mizan: Contributed in data collection, Ejlal A. BinMulayh: Contributed in writing the manuscript, Kirti S. Sahu: Contributed in data analysis of the current study, Nada S. Al-lehidan: Contributed in data collection.

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