ASSOCIATION OF FOOT POSTURE AND STATIC BALANCE AMONG SENIOR HIGH SCHOOL STUDENTS IN BALI, INDONESIA AS PREDICTOR OF INJURY: A CROSS-SECTIONAL STUDY

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Abstract. Foot posture abnormalities cause body structure abnormalities; the center of gravity (COG) follows and directly results in the balance disorders. Variations in weight-bearing foot posture are associated with an increased risk of tibial stress syndrome and excessive foot injuries such as pes cavus (high arch) and pes planus (low arch). In Indonesia, studies focusing on foot posture and static balance are still exceptionally few. By performing research on foot posture, particularly when children are involved, we will become aware of balance abnormalities and be able to engage in initiatives promoting health, education, and prevention. This cross-sectional study included students from Senior High School 7 Denpasar in Bali, Indonesia, and about 70 students aged 15 to 17, currently involved in an athletic club and had no history of foot deformity or surgery were recruited. The Foot Posture Index-6 was used to assess foot posture. We used the single leg stance (SLS) test to evaluate static posture and balance control. Shapiro-Wilk test was used to test the normality, and the association was accessed by spearmen-rank test. A significant relationship exists between foot posture and static balance within p-value<0.001 and the correlation between foot posture and static balance has a strong correlation level in a negative direction (r) value of -0.559. Male students are more likely to have higher score of pes cavus compared to female students. These results give more insight especially on the clinical assessment and should be a new information for the further specific exercise for the young students or athletes.

Keywords: foot posture, static balance, students

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INTRODUCTION

The position or posture of the feet indicates whether the body is aligned normally or abnormally, and this is known as foot posture. Pes planus, which has a low arch and is pronated, and pes cavus, which has a high arch and is supinated, are examples of different foot postures. Normal posture is the position of the feet in line with the body, pronation posture is a motion that causes the foot to rotate the front of the foot laterally, causing the medial side of the pedis to be flatter, and supination posture is the motion of turning the front leg to the medial, causing the medial side of the pedis to be higher (Cote *et al*, 2005). Foot posture can predict the risk factors for musculoskeletal injury, especially in the lower extremities (Golightly *et al*, 2014). Compared to individuals with pes cavus, persons with pes planus have a greater range of motion in their legs (Barnes *et al*, 2008). Due to inappropriate joint rotation during running and walking, those with pes planus foot posture are more prone to tissue stress injuries (Nigg *et al*, 1993). However, those with pes cavus foot posture reported having less leg mobility and were more vulnerable to injuries brought on by diminished stress absorbance or elevated plantar peak pressure (Burns *et al*, 2005).

Previous research conducted in Indonesia found that out of 58 children aged 8-12 years in the early school age, there were 28-35% of

children experiencing pes planus deformity (Lendra and Santoso, 2009). In general, the arch develops in children between the ages of 2 and 6, because in neonates and toddlers there is a fat pad at the bottom of the middle leg (midfoot), this fat pad will disappear with age (Lendra and Santoso, 2009). Another study states that about 20-30% of all children in the world experience flat feet (pes-planus) (Evans and Rome, 2011). Musculoskeletal abnormalities of the legs are also common among adults. It is estimated that more than 60% of foot abnormalities occur in the ankle joint, that will affect daily activities (Frank, 2017).

An asymmetrical foot posture leads to irregular body structure, and when the center of gravity (COG) shifts, balance issue was occurred (Syafi'i *et al*, 2016). Balance is the ability of the neurological, motor, or musculoskeletal systems to control the body's center of mass in opposition to the fulcrum plane and resist gravity (Boccolini *et al*, 2013). The term 'balance' refers to the ability to keep one's center of gravity within one's base of support. It is widely used to examine the responsiveness of lower limb segments (Cote *et al*, 2005). The central and peripheral nerve systems interact to regulate the body's alignment and center of gravity within the base of support in order to retain balance in an upright position (Cote *et al*, 2005).

In particular for static balance, balance control results from the individual's interaction with a task and their environment (Ghorbani *et al*, 2023). The static balance ability refers to the human body in a certain position to maintain a stable state (Wang *et al*, 2022). One factor that can cause balance disorders is musculoskeletal disorders in the form of foot posture abnormalities (Yasmasitha and Sidarta, 2020). Different foot postures have been linked to the emergence of some lower extremity ailments. Increased risk of tibial stress syndrome is linked to variations in weight-bearing foot posture, and severe foot injuries like pes cavus

(high arch) and pes planus (low arch) might show atypical biomechanical characteristics that contribute individuals at risk for injuries (Cobb *et al*, 2009).

Research related to foot posture and static balance is still very rarely done in Indonesia. By conducting research related to foot posture, especially at a young age we become more aware and certainly aware of balance disorders that occur due to variations of foot posture and later, we can carry out health promotion programs, education and also prevention efforts so that injuries do not occur.

MATERIALS AND METHODS

The study used a cross-sectional design and recruited students from Senior High School 7 Denpasar in Bali, Indonesia. The study comprised a group of healthy young people, aged 15 to 17, who were actively involved in a student athletic club and had no prior record of foot abnormalities or surgical procedures. Out of the entire student population of 1,509, a total of 70 students took part in this research study. We precisely asked for the schedule of the athletic club, which is one of the 29 clubs in the school. We reached out to the club's academic advisor and enrolled the person who met the inclusion criteria. An authorized physiotherapist assessed the foot posture of everyone in the group. The collected characteristics also covered age, gender, height, and weight.

The Foot Posture Index-6 (FPI-6) (Redmond *et al*, 2006) was used to assess foot posture. This measurement performed well, and the index is rapid and easy to use, allowing for multiple segments, and various plane evaluation (Redmond *et al*, 2006). Out of several methods to identify standing foot posture, FPI is a reliable as well as simple test

that allows health practitioners to compare standard criteria across different populations (Alahmari *et al*, 2021). Participants were given instructions to take off their shoes and stand comfortably with their feet shoulder-width apart. While rating the feet using the six FPI criteria, the assessor switched throughout the region. The talar head was palpated for medial and lateral prominence; the curvature above and below the lateral malleolus was measured; the angle of the calcaneal bisection line was measured; the area around the talonavicular joint was checked for excessive bulging; the congruency of the inner longitudinal arch was assessed, and any forefoot abduction or adduction to the rearfoot was noted. All criteria were assessed on a 5-point Likert scale ranging from (-2) to (+2). A possible summative score of (-12) to (+12) was obtained. More negative ratings suggested a supinated foot, compared to more positive scores showed a pronated foot. The FPI classification divides feet into three categories: high arched (FPI score of (-12) to (-1), regular arched (FPI score of 0 to (+5), and flat feet (+6) to (+12) (Ho and Tan, 2022).

This study focused on static balance, which is the ability to maintain the body in a stable posture. The single leg test is a balance test that is widely utilized to evaluate static posture and balance control (Buldt *et al*, 2013). Participants were instructed to stand on one leg without assistance, with their eyes open and their hands on their hips. The timer started when the opposite foot left the ground and stopped immediately when the opposite foot touched the ground and/or when the hands left the hips. Times were recorded in seconds, and the normative value for teenagers under the age of 18 is 43 seconds and maximum duration in 30 seconds.

We defined the balance score as a categorical measure including good and poor balance. The participants are required to complete the

tests in approximately 30 seconds and demonstrate the capacity to maintain balance for at least 30 seconds. We classify their balance as bad if they are unable to sustain it for 30 seconds, and as good balance if they surpass the 30-second threshold (Oh *et al*, 2011).

Descriptive statistics, mean and standard deviation (SD) were calculated. Shapiro-wilk test was used for normality test, and the association was accessed by Spearmen rank test. All datasets were managed in Microsoft Excel (MS Excel 2023; Microsoft Corp, Redmond, WA) and was analyzed by the Statistical Program for Social Sciences (SPSS) version 25.0 for Macbook (IBM Corp, Armonk, NY). It was considered statistically significant when $p<0.05$.

This study was approved for the Ethical Committee of Bali International University (01.041/UNBI/EC/V/2023).

RESULTS

About 55.7% of our sample were female and 64.3% of them are 16 years old (details are shown in Table 1). However, according to our findings, male respondents had a higher level of supination or flat feet (pes cavus) at 15.7% while that in female respondents was 12.9%. As many as 40% of female students had good balance, which was better than male students (27.2%). Characteristics of foot posture index (FPI) based on gender are shown in Table 2.

The result of Saphiro-Wilk test showed that data were normally distributed normal. In Table 3, there is a substantial association between foot position and static balance (p-value = 0.001). The correlation value (r) for the association is -0.559 indicating that there is a strong negative correlation between foot posture and static balance.

Table 1

Characteristic of students by age and gender (N=70)

Characteristics	Frequency *n* (%)
Age	
15 years	22 (31.4)
16 years	45 (64.3)
17 years	3 (4.3)
Gender	
Male	31 (44.3)
Female	39 (55.7)

Table 2

Comparison of foot posture index-6 (FPI-6) and balance category in male and female participants (N = 70)

Variable	Male participants *n* (%)	Female participants *n* (%)
Foot posture index		
High arched (pes cavus)	6 (8.6)	3 (4.2)
Regular arched (normal)	17 (24.2)	24 (34.3)
Flat feet (pes planus)	11 (15.7)	9 (12.9)
Balance		
Good	19 (27.2)	28 (40.0)
Poor	12 (17.1)	11 (15.7)

Note: Participants were considered having high arched when -12<(FPI-6)<-1, regular arched when 0<(FPI-6)<5 and flat feet when 6<(FPI-6)<12. Participants were considered having good balance when their balance time was ≥30 seconds and poor balance when their balance time was <30 seconds.

Table 3

Correlation of foot posture index and static balance (N = 70)

Variable	Frequency *n* (%)	*p*-value*	*r*
Foot posture index			
High arched (pes cavus)	41 (58.6)	0.001	-0.559
Regular arched (normal)	20 (28.6)		
Flat feet (pes planus)	9 (12.8)		
Balance			
Good	47 (67.1)		
Poor	23 (32.9)		

Note: Participants were considered having high arched when -12<(FPI-6)<-1, regular arched when 0<(FPI-6)<5 and flat feet when 6<(FPI-6)<12. Participants were considered having good balance when their balance time was ≥30 seconds and poor balance when their balance time was <30 seconds.

**p*-value was assessed by Spearman rank correlation test and significance was determined when $p<0.05$.

r: Spearman coefficient

DISCUSSION

This study determined the relationship between foot posture and static balance among high school students. Foot posture, also known as foot type in the literature, has been proven to have a substantial impact on injury (Alahmari *et al*, 2021). A previous study has shown a significant correlation about foot posture and lower limb injuries, and supported assessment in clinical setting when performing highly repetitive movement such as jogging or running would be developed overuse injury related foot posture (Buldt *et al*, 2013). Therefore, those with a poorly formed

foot structure were more likely to suffer from foot injuries. This medical condition necessitated evaluation in clinical and field settings for patients with foot and ankle running injuries, foot posture, and single-leg balance (Cobb *et al*, 2009).

According to Ho and Tan (2022), alterations in the orthopedic anatomy of the foot and/or its architectural and anthropometric characteristics can affect age-related variations in how foot posture is assessed. Therefore, it is suggested that those with reduced hallux mobility had greater center of pressure (COP) values, which were substantially correlated to poor balance. The Foot Posture Index (FPI) has been used in this study to assess participants' foot posture. It measures foot posture using six key criteria. Redmond *et al* (2006) developed a final version of FPI and executed it by participants standing on a "pedograph" ink and paper mat. In their study, they identified a number of techniques to assess standing foot posture, including radiographic techniques, the footprint method, the arch height index, the navicular drop test, and FPI which were applied in the present study.

We found in our study that male feet are longer and wider than female feet. According to a previous study, men had supinated and strongly supinated feet, whereas women had more neutral and pronated feet (Sánchez Rodríguez *et al*, 2013). This finding support for our finding for gender differences on foot posture describe as male students shown higher number of pes cavus compare to female students. Surprisingly, our participants shown that female students had normal foot posture or regular feet arch more than male students. Differences of foot morphology among both men and women based on pure anthropology to forensic medicine, and as effect of footwear industry. Female students were influenced by fashion or appearance on their foot ware design throughout

the ages and their activities on these ages has compromised the natural functioning of the foot (Tomassoni *et al*, 2014). Although our participants were dominantly by female students (55.7%), number of pes cavus posture was higher in male participants. Our finding is in line with Tomassoni *et al* (2014) and theory of differentiate morphology and anatomy foot by gender. However, this discrepancy is due to the different characteristics of sample size and variability by our measurement.

Our participants were high school adolescents between the ages of 15 to 17 who participated in sports and high-impact activities. According to our findings, there was a strong relationship between foot posture score and static balance which was in line with a study by Ghorbani *et al* (2023) which investigated static balance found that the flexible flatfoot had much inferior static balance. It acknowledges that flexible flatfoot soles can impair balance and sensation of joint position (Ghorbani *et al*, 2023). The right foot is more closely related to the forces produced by the body during locomotion than the left foot, which is more connected to weight bearing, because of the asymmetry of the human body. This hypothesis is supported by the finding that side foot abnormalities are connected to FPI, in accordance to a Saudi Arabian study (Alahmari *et al*, 2021).

This observation is supported by the clinical utility of foot posture evaluations, which is that foot structures influence balance (Carvalho *et al*, 2015). It was suggested that the presence of non-weight-bearing frontal plane foot postures like forefoot varus, rearfoot varus, plantar-flexed fifth, or ankle joint equines would cause compensatory foot pronation, which would exacerbate hypermobility of the midtarsal and subtalar joints and, as a result, possibly result in the development of an unstable base of support, which was part of postural balance. In contrast, Spink

Menz's study (Spink *et al*, 2011) indicated that foot posture was not an independent predictor of performance in balance and functional tests, however that study employed the FPI with 8 criteria whereas our study used 6-criteria. The foot support surface will probably have an impact on methods to maintain body standing equilibrium since foot biomechanics has a substantial impact on walking quality and walking. Similar to this study, another (Cote *et al*, 2005) revealed a strong relationship between balance and FPI, however, the focus of the previous research was primarily on standing dynamic balance (Cote *et al*, 2005). These elements may design for future rehabilitation efforts to pay more attention to preventive measures.

This study had several limitations. Firstly, our small sample size would not allow us to generalize the results to a bigger population even though we have covered one sport club in Bali. Second limitation is that our results only apply to the static foot assessment, not the other clinical measure by dynamic foot evaluation to have congruent data for balance. Further research should establish dynamic balance and reference values across various group for comparison purposes. This recognition from our result study in term of correlation foot posture and static balance during clinical examination might be given a new value for the clinicians as the information to build a specific exercise. Particularly, they were in young age and were active in sport activities, these findings will give new program as their foot posture. Hence, this study might provide suggestion and advice regarding their training program to teacher in charger based on their foot posture. In addition, they also could have advice about shoes sole that will correct their foot posture behalf to prevent injury and improve their performance.

In conclusion, our findings indicate a strong association between

foot posture and static balance. Additionally, we observed that male and female students exhibited different foot postures based on the classification of the Foot Posture Index (FPI). Our findings would enhance the understanding of clinicians and other professionals, particularly those in the sports field, regarding various foot postures that may influence static balance.

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CONFLICT OF INTEREST DISCLOSURE

This research has no conflict of interest.

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