RESEARCH ARTICLE

Impact of different foot arches on standing balance and physical performance among nursing students

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Abstract:

Foot arches were classified into normal, high and low arches. Abnormal foot arches has been reportedly high prevalent among young adult population. Balance and physical performance are considered important elements among nursing students especially during clinical which primarily involved prolonged weight-bearing activities. This study aimed to identify different foot arches and to assess the impact of those foot arches on standing balance and physical performance among nursing students. This study was conducted among 80 nursing students, age between 18 to 25-year-old. Types of foot arch were identified using navicular drop test (NDT). Static balance was measured using the One-Legged Stance test (OLS) in eyes open (EO) and eyes closed (EC). Dynamic balance was measured using Star Excursion Balance Test (SEBT) in anterior (ANT), posterolateral (PL) and posteromedial (PM) direction while physical performance components were tested using Vertical Jump Test (VJT) and Edgren Side to Side Test (ESST). No significant differences in OLS in EO (p=0.608), EC (p=0.363) and SEBT ANT (p=0.704), PL (p=0.997), PM (p=0.088),VJT (p=0.626) and ESST (p=0.469) score among participants. Nursing students with normal, low and high arches were no impact in both standing balance and physical performance.

Keywords: Dynamic balance, foot arch, nursing student, physical performance, static balance

1. INTRODUCTION

Foot arches were classified into three different types, based on the height of the medial longitudinal arch which is the normal arch, flat foot and high arch. Abnormal foot arches were reportedly has a high prevalence in educational institutions of up to 61.3 to 79 %[1]. There were 31.8% of flat foot and 47.7 % of high arch experienced by population aged between 20 and 29 years has been reported [2]. Abnormal foot arch may cause foot pain due to stress that continuously exerts and inflammation on the plantar fascia [3] and the damage will worsen with prolonged activities of weight bearing [4].

Among health care workers, the nursing profession has been mentioned primarily having foot pain (43.8%) [5-6] compared to other healthcare professionals including physiotherapists (30%), physicians (12%), and dentists (28.5%) [7]. The nature of works that usually involved prolonged standing, prolonged working hour, and repetition lifting is known to be the contributing factor [8]. The long duration of working up to 12-hour specifically for those nurses who worked in the Intensive Care Unit (ICU) was reportedly equivalent up to 9.6 km of walk per day [5].

Physical performance is an integrated consequence of multiple body systems, and it is susceptible to biomechanical changes in lower extremities including an altered foot arch, generally involves force, agility, and proprioception [9]. Flat foot was found to reduce physical performance by exerting excessive stress to the surrounding tissues of the foot [10]. Previous studies reported that there were changes in the biomechanics of lower extremities caused by altered foot arch, and physical performance is susceptible to any biomechanical changes of lower extremities [10-11]. A normal foot arch has been mentioned crucial to provide appropriate weight distribution during movement and help to maintain good postural balance. Balance and physical performance are considered essential among nursing professions including nursing students as their nature of works during clinical experience primarily involved prolonged weight-bearing activities [8].

Regardless, some studies reported abnormal foot arch does not affect the balance ability in young adult populations due to muscular and postural adaptation [12-13]. Nevertheless, the majority of the study include asymptomatic individual or young healthy adult population in the previous study. It is also critical in assessing the symptomatic individual as it may be a challenging task especially for subjects with musculoskeletal conditions including abnormal foot arch and foot pain [13]. Hence, the purpose of this study was to identify the different types of the foot arch and to assess the impact of different foot arches on static balance, dynamic balance, and physical performance among nursing students in UiTM Puncak Alam.

2. MATERIALS AND METHODS

2.1 Study design

This is a cross-sectional study with recruited nursing students in Universiti Teknologi Mara, (UiTM) Puncak Alam who has experienced clinical placement in the hospital. The study protocol was approved by the Research Ethics Committee (REC) of UiTM (600-TNCPI (5/1/6) on 29 October 2019.

2.2 Participants and setting

A convenience sampling method was used to recruit participants. The sample size was calculated using GPower 3 with an effect size of 0.3, the alpha error probability of 0.05 and power (0.9). The total sample size was approximately 130 subjects with consideration of corrupted data. The inclusion criteria for the participants to be included were (i) nursing students age from 18-25 and (ii) must have experienced clinical placement for at least two consecutive semesters. The participants were excluded if presented with (i) recent ankle and knee sprain, (ii) recent lower limb fracture, (iii) unstable cardiovascular disease, (iv) previous foot surgery, (v) vestibular problem, (vi) limb length discrepancy, (vii) amputation and (viii) reduce foot sensibility. The study was conducted in a high-performance gym, level 4, FSK 2, 3, 4, UiTM Puncak Alam, Selangor. Subjects required to sign written informed consent prior to measurement.

2.3 Instrumentation and procedure

The demographic data which consists of name, age, gender, education level, semester and the total duration of clinical placement (weeks) were all fulfilled by the participants in a structured questionnaire. Meanwhile, the anthropometric data including weight was measured using weighing scale, whereas height was measured using standard tape measure prior to the calculation of body mass index (BMI) using the Quetelet Index = body weight (kilograms) divided by height squared (meters) formula [14]. Physical activity readiness questionnaire (PAR-Q) was fulfilled by participants prior to data measurement and collection.

The Navicular drop test (NDT) was used to differentiate the types of foot arches. A 15 cm ruler was used to measure the height between the navicular bone and the floor in standing for weight-bearing measurement as shown in Figure 1. The test was repeated in a non-weight bearing position where the subject sat on a chair. The differences of less than 4mm between both measurements were considered a high arch, 5-9mm as normal arch and more than 10mm was considered as low arch (flat foot) [15]. NDT is a common test used to measure the types of foot arch and has been proved to be valid and reliable [16].

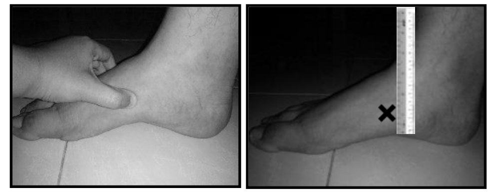

Figure 1: Navicular drop test

The One-Legged stance test (OLS) test was used to assess static balance of the subjects. This was proven with excellent validity and reliability during eyes open (ICC=0.99) or eyes closed (ICC=0.99) [17]. The subject was asked to stand barefoot on dominant limb and cross their arm around the chest. The other leg was instructed to be lifted from the floor and must not in contact with the other ankle. The time was set at 45 seconds using a stopwatch. The test was terminated if the subjects uncross the arms, move the lifted leg toward or away from the standing limb, the lifted leg touch the floor, the standing foot moved to maintain balance, a maximum of 45s had elapsed, or if subject open the eyes on eyes closed trials. Three mean of three trials of eyes open and eyes closed will be recorded. Normative results for open eyes and closed eyes were reported to be 43.3s and 9.4s, respectively [17].

The dynamic balance test was measured using the Star Excursion Balance Test (SEBT). The validity and inter-rater reliability (0.83-0.93) has been proven to estimate the lower extremity injury and dynamic balance performance for those with lower extremity problems [18-19]. A star-shaped line was drawn on the floor, with a 45° angle in eight directions. Anterior (ANT), posterolateral (PL), and posteromedial (PM) directions were used as shown in Figure 2. With the heels of the dominant leg located at the centre point, the subject was asked to stretch the other leg anteriorly as far as possible and lightly touched the big toe on the floor while maintaining the balance with 5-second rest interval between each reach [19]. The farthest point touched by the big toe was marked and measured using a standard measuring tape. The test was terminated if the subject's feet touched heavily on the ended point or abruptly rest the feet on the point. The same procedure was repeated in PL and PM directions. The mean values of the 3 trials in each direction were calculated [18]. Composite score (CS) was calculated using the formula [(ANT+PM+PL)/(3 x LL) x 100] to reduce the error between the subjects according to limb length [20]. The composite cut-off score below 89.6% was classified as reduced postural stability and has 3.5 times risk for injury [21].

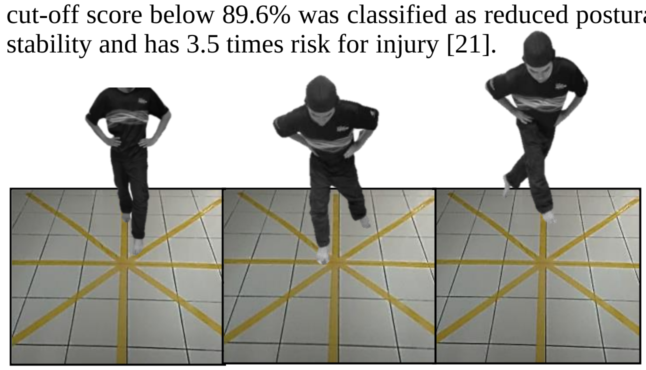

Figure 2: SEBT ANT, PL and PM direction

Vertical Jump Test has been identified as a valuable measurement in identifying lower-limb functionality as well as knee extension power [22]. Prior to the test, the subject was required to stand upright beside the wall and raised their hand above their head. The point of the third finger was marked as standing reach height and was used as the baseline. The subject was taught to jump vertically with their arm pointing upward to reach as high as possible and the leg starting with approximately 90° of knee flexion. The highest point where the finger reached was marked [23]. The subject performed the test for three trials, with approximately 15 to 30 s recovery between jumps and the average score was taken. The difference in distance between the vertical jump height and the baseline was calculated in centimetres.

Figure 3: Vertical Jump Test

Edgren Side to Side Test is found to be a reliable measure of agility performance for the population between the ages of 18 and 40 years old [24]. Four cones were placed with an interval of 1 meter from each other and the subject was asked to stand behind the most left cone. On the "go" command, the subject sidestepped to the right until his right foot reached the next cone and continued until the farthest right cone is reached. Once the subject reached the most right cone, the subject then sidestepped to the left until he reached the starting position again. The subject sidesteps back and forth as rapidly as possible for 10 seconds. One point was given per completion of each 1-meter increment and 0 if he failed to keep his trunk and feet pointed forward at all times, crossed his legs, or do not complete the test successfully. The subject was first demonstrated and was asked to perform a trial before the actual test began. The total point was recorded as the score and the average score was calculated.

Figure 4: Edgren Side To Side Test

2.4 Data analysis

Data analysis was performed using the Social Package of Social Sciences (SPSS) version 25.0. The descriptive statistical was conducted to report the means (M), standard deviation (SD), frequency (n) and percentage (%) of the related parameters. A one-way ANOVA test was used to analyze the impact of foot arches on standing balance and physical performance. The significant level was set as $p<0.05$.

3. RESULT AND DISCUSSION

The demographic and anthropometric characteristics of the participants are presented in Table 1. More than half of the participant was female 68 (85%). The participants was comprised with the majority of semester 5 students, 32 (40%) followed by semester 7, 26 (32.5%) and semester 3, 22 (27.5%) respectively.

Table 1: Demographic and anthropometric characteristics (N=80).

Variable	Frequency(%)	Mean ± SD
Gender		
Male	12(15%)	
Female	68(85%)	
Semester of study		
Semester 3	22(27.5%)	
Semester 5	32(40%)	
Semester 7	26(32.5%)	
Age (years)		21.84 ± 1.66
Height (cm)		157.16 ± 6.99
Weight (kg)		55.47 ± 14.05
BMI (kg/m^2)		22.60 ±5.55
Underweight		17.00 ± 21.30
Normal		41.00 ± 51.20
Overweight		16.00 ± 20.00
Obese		6.00 ± 7.50
Navicular height (cm)		0.63 ± 0.54

3.1. Different types of foot arch among nursing students

Figure 5 displays that more than half of the total participants were abnormal arches which comprised of a low arch (flat foot), 38(47.5%) and high arch, 27(33.8%) respectively. Meanwhile, there were only 15(18.8%) participants presented with normal foot arches.

Previous study found that high prevalence of flat foot (32.6%) and high arch (47.7%) as compared to normal arch (20.5%) among young adults [2]. Nonetheless, other study have reported a much higher percentage of a normal arch (70%) compared to high arch (16.6%) and flat foot (11%)[16]. However, the study has a larger sample size compared to the present study. Besides, there are different approaches to classify the types of the foot arch, NDT has been proved to be more accurate and effective foot arch measurement [25].

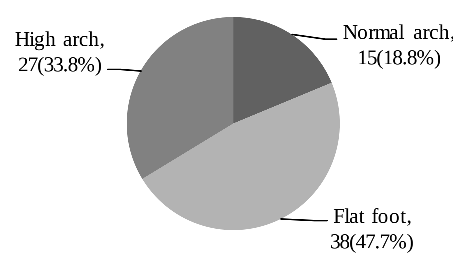

Figure 5: Different types of foot arch among nursing students (N=80)

3.2. Impact of different foot arches on static balance among nursing students

Table 2 presents the mean score of OLS test with eyes open and eyes closed among different foot arches. The mean score of OLS with eyes open for normal arches was 43.16s (SD=7.05), whereas the mean score for high arch and low arch (flat foot) were 41.04s (SD=6.41) and 41.31s (SD=7.25) respectively. The mean score of OLS test with eyes closed for normal arches was 19.52s (SD=11.21), whereas the mean score for high arches and low arch (flat foot) were 14.68s (SD=7.58) and 15.29s (SD=12.89) respectively.

Table 3 shows that for OLS eyes open and eyes closed, about 80% to 90% of normal arch participants able to reach the cut-off score. Nevertheless, approximately 60% to 70% of the high arch participants able to reach the cut-off score for OLS EO and EC. Meanwhile, only 68.4% of low arch (flat foot) participants able to reach the cut-off score for OLS EO and 57.9% for OLS EC. However, this study found that both normal and abnormal arches were not differed in the static balance performance with eyes open (p=0.608) and eyes closed (p=0.363).

The present study consistent with previous findings on the impact of various foot arches towards static balance among young adult population [26-27]. During static standing balance, the minimal movement of the centre of gravity (COG) creates only a small effort from the feet to maintain balance despite different types of foot arch [26]. Furthermore, balance was known not only depends on the proprioceptive input from the joint receptors, but also other sensorimotor systems like the visual and auditory system [27]. Hence, any changes in surface contact area seem to be insufficient to alter the base of support during static balance in standing regardless the types of the foot arch. There was found a significant difference in the static balance with open eyes and closed eyes between different foot arches [13]. In addition, the used of computerized systems which able to detect even minimal changes in postural sway and centre of pressure (CoP) speed between the subjects was seems to be more precise in evaluating the balance performance [28].

Table 2: Mean score of OLS among different foot arches (N=80)

Variable	Foot arch			P value[a]
	Normal arch N=15 Mean ± SD	High arch N=27 Mean ± SD	Low arch N=38 Mean ± SD	
OLS (s)				
OLS EO	43.16±7.05	41.04±6.41	41.31±7.25	0.608
OLS EC	19.52±11.21	14.68±7.58	15.30±12.89	0.363

[a] One-way ANOVA test

Table 3: Comparison of OLS cut-off score between different arches (N=80)

Foot arch	N	OLS EO		OLS EC	
		Normal N (%)	Below average N (%)	Normal N (%)	Below average N (%)
NA	15	14 (93.3%)	1 (6.7%)	12 (80.0%)	3 (20.0%)
HA	27	19 (70.4%)	8(29.6%)	18 (66.7%)	9 (33.3%)
LA	38	26 (68.4%)	12 (31.6%)	22 (57.9%)	16 (42.1%)

3.3 Impact of different foot arches on dynamic balance among nursing students

Table 4 presents the mean score of SEBT ANT for normal arch was 82.26cm (SD=11.97), whereas the mean score for high arch and low arch (flat foot) were 79.38cm (SD=7.14) and 79.79cm (SD=10.67) respectively. The mean score of SEBT PM for normal arch was 70.70cm (SD=8.88) greater than high arch 65.39cm (SD=5.00) and low arch(flat foot) 68.12cm (SD=12.50). The mean of composite score was larger in normal arch 94.86% (SD=13.49) compared to high arch, 89.46% (SD=7.31) and low arch(flat foot), 90.14% (SD=13.30). Surprisingly, the study also found in SEBT PL, the mean score among high arch subject was 72.63cm (SD=8.26) higher than low arch(flat foot), 72.45cm (SD=12.20) and normal arch, 72.61cm (SD=11.23).

Table 5 demonstrates that about 80% of normal arch participants were able to reach the cut-off score for SEBT, higher than high arch (51.9%) and low arch(flat foot) (55.3%). However, current study found that there is no significant different in SEBT score for ANT (p=0.704), PL (p=0.997), PM (p=0.088) and composite score (p=0.780) among different foot arches.

The finding of this study is similar to previous studies that used SEBT [12] and Y balance test [13] to measure dynamic balance in different foot arches among university students. This is due to compensatory postural adjustment by the muscular adaptation in response towards external factors such as visual, auditory and somatosensory system [12-13]. Besides, flat foot individual has a stable base of support through widen foot contact area on the ground [29] and has a better ability to absorb ground reaction forces that produce during activities [9].

However, other studies indicated a significant difference of dynamic balance between normal arch and flat foot among college students [26]. In the flat foot and high arch feet, the muscles such as tibialis posterior are incapable to exert force to produce eversion of the midfoot on the rearfoot to maintain postural stability which was supported by electromyography (EMG) [30]. In addition, the mean age difference between this study and a previous study that recruited older participants above 40 years old may also explain the different finding [30]. Increasing age was found to be a greater predictor of postural imbalance regardless of the different types of foot arches [29].

Table 4: Mean score of SEBT among different foot arches (N=80)

Variable	Foot arch			P value[a]
	Normal arch N=15 Mean ± SD	High arch N=27 Mean ± SD	Low arch N=38 Mean ± SD	
SEBT(cm)				
ANT	82.26±11.97	79.38±7.14	79.79±10.67	0.704
PL	72.61±11.23	72.63±8.26	72.4 ±12.20	0.997
PM	70.70± 8.88	65.39±5.00	68.12±12.50	0.088
CS (%)	94.86±13.49	89.46±7.31	90.14±13.30	0.780

Table 5: Comparison of SEBT cut off score among different foot arches (N=80)

Foot arch	N	SEBT cut off score (%)	
		Normal N (%)	Below average N (%)
Normal arch	15	12 (80.0%)	3 (20.0%)
High arch	27	14 (51.9%)	13 (48.1%)
Low arch	38	21 (55.3%)	17 (44.7%)

3.4 Impact of foot arch on Vertical Jump Test (VJT)

The result of the mean VJT score for participants with normal arch was 29.29 cm (SD= 6.70), high arch, 28.51 cm (SD= 5.75) and low arch(flat foot0, 27.63 cm (SD= 5.62). There was no significant difference between VJT score among participants with normal, high arch and low arch(flat foot) (p = 0.626) (Table 6). This finding is similar with previous study that concluded no relationship between foot arch height and vertical jump ability [31].

In contrast, foot arch has a significant impact on VJT, and low arch (flat foot) showed reduced vertical jump ability compared to normal and high arch [32]. Lack of abductor hallucis muscle activation associated with low arch impaired the vertical jump ability as it provides dynamic stability to the arch [33]. Dynamic physical performance such as jumping is supported by muscle strength of the foot which requires high force production by the muscles [34]. Weak plantar intrinsic or extrinsic muscles associated with low foot arch were unable to provide sufficient dynamic support for the foot and impaired the ability to perform vertical jumping [35]. The previous study revealed that individual with low arch has poorer self-regulation ability while jumping compared to an individual with normal arch and it could increase the risk of getting injury [36]. In addition, foot arch significantly impacts vertical jump during dynamic movement of lower extremities because it stores and releases elastic strain energy [34]. It was proven that low arch reduced performance on VJT, and high arch has the most effective vertical jump compared to normal arch [23].

Table 6: Impact of foot arch on vertical jump test (N=80)

Variables	N	Mean±SD	P value
Foot arches			
High	27	28.51±5.75	0.626[a]
Normal	15	29.29±6.70	
Low	38	27.63 ±5.62	

[a] One Way ANOVA test

3.5 Impact of foot arch on Edgren Side to Side Test (ESST)

Table 7 shows mean of ESST score for participants with normal arch was 16.02 (SD= 1.6), high arch 15.89 (SD= 1.24), and low arch (flat foot), 15.45 (SD= 2.03). This study found no significant difference between ESST score among participants with normal, high arch and low arch(flat foot) (p = 0.469). Similarly, a previous study found that foot arch has no impact on agility performance [34]. Physical performance involving agility components such as sidestepping was claimed to be primarily determined by muscle functions of large muscles in the lower limb and it could be enhanced by strengthening the muscles, regardless of the foot arch type [34]. Low arch (flat foot) is shown to have reduced weight transfer, shock absorption, and pressure distribution which affects personal physical ability by increasing energy consumption, however, there was no correlation found between foot arch and agility [37]. In contrast, a significant impact of foot arch on agility was found and reported that flat foot was linked to reduced agility and speed [11].

Table 7: Impact of foot arch on Edgren Side to Side Test (N=80)

Variables	N	Mean ± SD	P value
Foot arches			
High	27	15.89 ±1.24	0.469[a]
Normal	15	16.02 ±1.60	
Low	38	15.45 ±2.03	

[a] one-way ANOVA test

4. CONCLUSION

In conclusion, the majority of nursing students having a low arch (flat foot). There was no significant difference in balance and physical performance among nursing students with different types of foot arch. Currently, little is known regarding the factors that influence changes in foot arch development. Foot-related problems are predisposing factors for activity limitations in later life. Foot problems lead to postural issues, gait disturbance, high risk of falls and uneven plantar distribution. However, the negative impact of abnormal foot arch can be effectively prevented through education and intervention, hence it should be exposed to nurses and future nurses thus preliminary actions can be taken. Future studies are recommended to be done on a larger sample size.

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