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Association of Foot Arches with Plantar Pressure Distribution among Normal, Overweight and Obese Females: A Cross Sectional Study

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ABSTRACT

Background: Foot arches are the significant part of the human body, and they perform ceaseless work of bearing the entire weight of body. However, the foot is commonly ignored body part evident by lack of proper foot examination and awareness about deformities related to foot. As the formation of foot arch depends upon the age, gender, type of footwear, weight of the body and lifestyle, the aim of this study is to find out the distribution of plantar pressure in different types of foot arches among university normal, overweight, and obese females.

Methodology: The observational cross- sectional study was conducted at the department of Physiotherapy, Biomechanics Laboratory, Lovely Professional University, Phagwara, Punjab. A total of 150 females' participants between the age group 18- 25 years were included in this study, under three groups viz normal, overweight, and obese (50 each group). The baseline values for BMI and hip waist ratio were taken to classify the participants into normal, overweight, and obese. Foot arches were classified based on clinical evaluation included navicular drop height and foot posture index. Win track Dynamic foot scan software (Medicapteurs, France) was used to determine the plantar pressure distribution.

Results: A statistically significant correlation was established between the plantar pressure distribution and BMI (p value less than 0.05). For overweight and obese group, p value was significant for both dynamic and static maximum plantar pressure compared to normal participants.

Conclusion: Foot deformities and altered foot arches are common in younger female population, but pronated foot arches were seen in obese group more than others. There was significant difference shown for overweight and obese group for maximum plantar pressure in association with foot arches.

Keywords: Flat Foot; Pescavus; Pesplanus; Plantar Pressure; Peak/Maximum Pressure; Foot Arch

Introduction

The foot is the well-organized body part which provides mobility and stability to the body while sustaining extensive pressure on the plantar surface for static and dynamic movement. Arches of the foot are commonly ignored body part evident by lack of proper foot examination and awareness about deformities related to foot [1]. Foot arches are the significant part of the human body, and they perform ceaseless work of bearing the entire weight of body. People often use footwear that does not correspond to their arch type [2]. Tight shoes, high heels disturb the foot arches which could eventually alter biomechanics of the body. Increased body weight can also influence the foot arches and foot biomechanics [3]. The changes in the foot arches among growing adolescents including young college students have been often seen [4]. The structure of the foot plays an important role to maintain gait, posture, and balance. The most common variation of foot structure is relatively alteration of arches that could lead to musculoskeletal disorders which could be the source of biomechanical changes in the lower limb. The arches of the foot

have been strongly associated with altered plantar pressure and poor foot biomechanics [5]. Altered foot arch could be a potential source of abnormal plantar pressure distribution and symptomatically painful as the changes in the foot arch could affect the bony articulation, ligaments, and muscles of the foot [6].

Among many factors that can influence the foot structure, body weight could be the most significant [7]. Overweight and obese have been shown to negatively affect foot structure causing discomfort for individual particularly among the adolescent [8]. Previous studies have reported a higher incidence of foot arch changes in growing females [9]. Among the university female students, the trend for fashionable footwear has increased causing further damage to their natural foot arches. A study has concluded that female putting higher heels have higher foot arch [10]. In addition, obesity and overweight could be an important factor to damage the natural foot arch and alter the plantar pressure distribution [11]. As university students are an important part of the society, an early detection of abnormal foot arches could be useful to prevent future foot complications. Thus, the aim of the study was to find an association between the foot arch and plantar pressure distribution among normal, overweight, and obese university female students.

The objective of this study was:

1. To find the changes in the foot arch among university normal, overweight, and obese females' student.
2. To determine and compare the average and peak plantar pressure among university normal, overweight, and obese females' student and
3. To find the association of foot arch type and plantar pressure among university normal, overweight, and obese females' student
4. Methods

Study Design and Settings

The observational cross- sectional study was conducted at the department of Physiotherapy, Biomechanics Laboratory, Lovely Professional University, Phagwara, Punjab.

Participants Characteristics

A total of 150 females' participants between the age group 18-25 years were included in this study, under three groups viz normal, overweight and obese (50 each group) using convenient sampling method based on the following inclusion and exclusion criteria:

Inclusion Criteria:

1. Healthy University females
2. Age 18-25 years old.
3. Normal weight, overweight and obese female based on BMI and hip waist ratio findings.

Exclusion Criteria:

1. Abnormal neurologic gait pattern
2. Acute foot injury, open wound
3. Recent fracture of lower limb
4. Pregnant participants
5. Musculoskeletal condition of lower limb affecting gait pattern
6. Underweight females.

Outcome Measures

The baseline values for BMI and hip waist ratio were taken to classify the participants into normal, overweight, and obese. Foot arches were classified based on clinical evaluation included navicular drop height (NDH) and foot posture index (FPI-6). Win track Dynamic foot scan software (Medicapteurs, France) was used to determine the plantar pressure distribution.

Study Procedure

The study was approved by the Institutional Review Board and Institutional Ethics committee. Written informed consent was obtained from all participants prior to the data collection. The data collection was anonymized to assure the protection of confidentiality. All participants were screened based on inclusion and exclusion criteria. Demographic and baseline data was collected for age, height, weight, body mass index (BMI), hip waist ratio. The type of foot arch type was assessed through clinical examination consisting of navicular drop height test, and foot posture index [12]. Any foot deformity was also noted. Participant's physical activity like running, jogging, and walking was recorded for intensity and duration. The type of footwear and duration of application at work and home was noted. The barefoot static and dynamic plantar pressure distribution pattern, peak pressure and average pressure was finally recorded using Win track software. To check static plantar pressure, subjects were instructed to stand straight, looking towards the wall, put equal weight of body on both feet and stay still for a while. The dimensions of the platform were 1610-millimetre x 30 millimetre. The thickness of platform was 9 millimetre and it comprised of 12288 resistive sensors. The sensors were having dimensions of 7.8 x 7.8 mm2 and recording acquisition frequency of the instrument was 200 images /sec. To check the dynamic plantar pressure, participants were instructed to walk at their normal speed on the platform as shown in Figure 1. We acquainted subjects with entire procedure prior to the readings. Classification of normal, overweight, and obese participants was done based on BMI and waist hip ratio given by WHO [13].

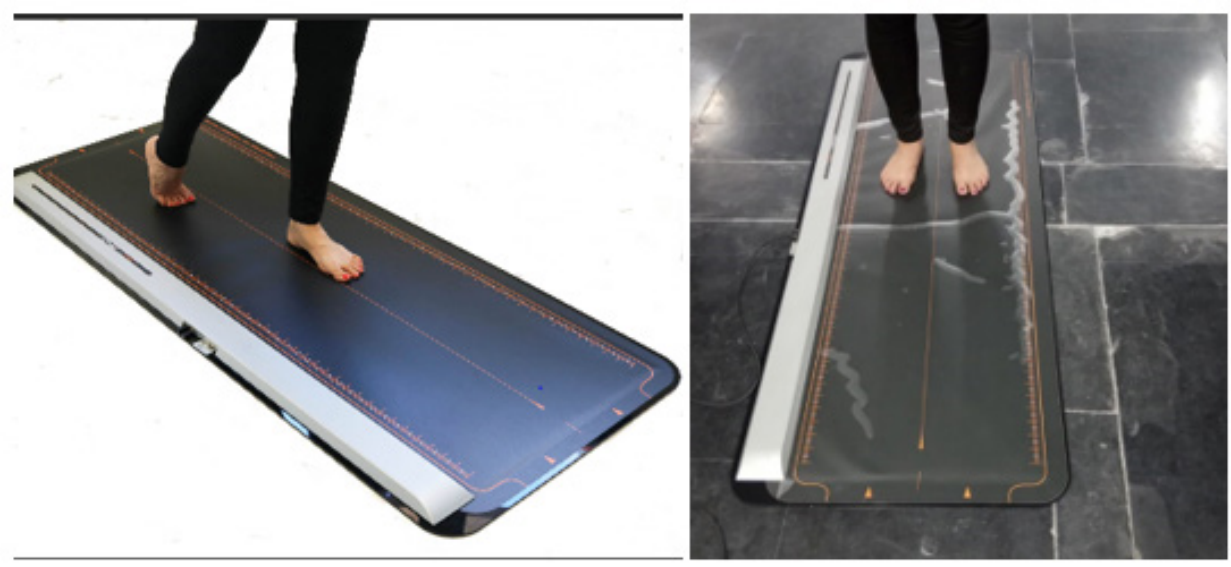

Figure 1: Plantar pressure analysis using Win track software.

Statistical Analysis

The data was analyzed using SPPS 21. The data was assessed for normality. The descriptive analysis was done to report demographic data. For comparison between the groups Paired T test was used and for the association of foot arches with plantar pressure distribution Pearson's Correlation test was conducted.

Results

Tables 1-5.

Table 1: Demographic Data.

Subjects	Age Mean±SD	Height Mean±SD	Weight Mean±SD	BMI Mean±SD	HWR Mean±SD
Normal	21.18±1.82	1.61±5.62	51.24±6.56	19.76±2.45	0.74±0.33
Overweight	21.04±1.39	1.61±6.20	62.08±9.04	23.80±3.09	0.91±0.12
Obese	21.74±1.49	1.63±5.15	74.02±7.73	27.87±2.65	1.07±0.17

Note: *BMI- body mass index, * HWR- hip to waist ratio

Table 2: Foot characteristics among Normal, Overweight and Obese Participants.

Subjects	Foot Size Mean±SD	Foot Arch N (%)	Foot Deformity N (%)
Normal (N=50)	5.34±1.22	Neutral: 44(88%)	Yes: 1(2%)
		Low Arch: 6(12%)	
		High Arch: 0	
Overweight(N=50)	5.66±0.87	Neutral: 34 (68%)	Yes: 3(6%)
		Low Arch: 15(30%)	
		High Arch: 1(2%)	
Obese(N=50)	5.80±0.83	Neutral: 29 (58%)	Yes: 4(8%)
		Low Arch: 21(42%)	
		High Arch: 0	

Table 3: Comparison of Plantar Pressure between normal, overweight, and obese participants.

Variables	Normal Mean±SD	Overweight Mean±SD	Obese Mean±SD	P Value
Static average pressure (kg/cm²)	1129.9±230.18	1211.6±208.29	1498.2±319.13	0.001
Static max. pressure (kg/cm²)	1621.1±531.52	2321.1±568.97	2557.5±721.19	0.001
Dynamic avg. pressure (kg/cm²)	2554.9±543.02	2393.8±610.71	2217.3±633.46	0.02
Dynamic max. pressure (kg/cm²)	4777.6±1105.44	4989.7±1409.14	5246.2±1411.79	0.03

Table 4: Post hoc analysis for Plantar pressure distribution between the groups.

Dependent Variable	(I) GROUP	(J) GROUP	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Static AVG Pressure	NORMAL	OVERWEIGHT	0	94.1408	307.3392
		OBESE	0.005	44.7599	315.4001
	OVERWEIGHT	NORMAL	0	-307.339	-94.1408
		OBESE	0.973	-151.855	110.5352
	OBESE	NORMAL	0.005	-315.4	-44.7599
		OVERWEIGHT	0.973	-110.535	151.8552
Static MAX Pressure	NORMAL	OVERWEIGHT	0.023	32.7146	567.4054
		OBESE	0.001	155.5984	771.6816
	OVERWEIGHT	NORMAL	0.023	-567.405	-32.7146
		OBESE	0.506	-152.094	479.2541
	OBESE	NORMAL	0.001	-771.682	-155.598
		OVERWEIGHT	0.506	-479.254	152.0941
Dynamic AVG Pressure	NORMAL	OVERWEIGHT	0.419	-119.561	441.721
		OBESE	0.015	50.9651	624.1149
	OVERWEIGHT	NORMAL	0.419	-441.721	119.561
		OBESE	0.404	-125.65	478.5696
	OBESE	NORMAL	0.015	-624.115	-50.9651
		OVERWEIGHT	0.404	-478.57	125.6496
Dynamic MAX Pressure	NORMAL	OVERWEIGHT	1	-627.527	603.4467
		OBESE	0.001	-84.8134	1147.613
	OVERWEIGHT	NORMAL	1	-603.447	627.5267
		OBESE	0.04	-141.403	1228.283
	OBESE	NORMAL	0.001	-1147.61	84.8134
		OVERWEIGHT	0.16	-1228.28	141.4025
Static Contact AREA	NORMAL	OVERWEIGHT	0.324	-76.7154	17.1954
		OBESE	0	-30.4841	-14.5159
	OVERWEIGHT	NORMAL	0.324	-17.1954	76.7154
		OBESE	0.974	-40.0917	54.6117
	OBESE	NORMAL	0	14.5159	30.4841
		OVERWEIGHT	0.974	-54.6117	40.0917

Dynamic RT Contact Area	NORMAL	OVERWEIGHT	0	-12.0592	-2.9808
		OBESE	0	-18.7597	-9.5203
	OVERWEIGHT	NORMAL	0	2.9808	12.0592
		OBESE	0.012	-12.0799	-1.1601
	OBESE	NORMAL	0	9.5203	18.7597
		OVERWEIGHT	0.012	1.1601	12.0799
Dynamic LT Contact Areas	NORMAL	OVERWEIGHT	0.034	-11.6957	-0.3443
		OBESE	0.001	-15.1901	-3.3699
	OVERWEIGHT	NORMAL	0.034	0.3443	11.6957
		OBESE	0.478	-9.3437	2.8237
	OBESE	NORMAL	0.001	3.3699	15.1901
		OVERWEIGHT	0.478	-2.8237	9.3437

Note: *The mean difference is significant at the 0.05 level.

Table 5: Association of foot arches with plantar pressure distribution.

Participants Type	Foot Arch	Pearson's Correlation for Average Plantar Pressure (r value)	Pearson's Correlation for Maximum Plantar Pressure (r value)	Sig. 2 tailed (p value Average Plantar Pressure)	Sig. 2 tailed (p value Maximum Plantar Pressure)
Normal	Low	0.14	0.31	0.79	0.09
	High	NA	NA	NA	NA
Overweight	Low	0.72	0.87	0.006	0.001
	High	0.51	0.59	0.02	0.004
Obese	Low	0.77	0.93	0.001	0.001
	High	NA	NA	NA	NA

Note: *NA- not applicable.

Discussions

In the present study, a total of 150 female subjects participated and equally distributed into three different groups under the convenient sampling method. The demographic data for all participants have been presented in Table 1. The mean value of age was 21.8 years in normal, 21.04 years in overweight and 21.74 years in obese subjects. The mean weight in kg was 51.24 in normal, 62.08 in overweight and 74.02 in obese participants. In addition, the mean value for BMI was 19.76 in normal, 23.80 in overweight and 27.87 in obese group. We also calculated the mean value of hip waist ratio as 0.74 in normal group, 0.91 in overweight group and 1.07 in obese group. While checking the foot size in normal subjects, the mean value was 5.34, 5.66 in overweight and 5.80 for obese respectively. The findings of the study suggest that there was little difference in the mean values of foot size between the groups. Thus, groups with comparatively higher weight such as overweight and obese would have exerted higher plantar pressure (pressure= force/area).

It can also be suggested that higher weight and pressure could have led to compensatory foot arch drop among overweight and obese participants. This can be supported by findings of our study where the number of collapsed foot arch (pronated foot type) among the obese group was highest (n= 21, 42% of the population), as compared to overweight (n=15, 30% of the population) and normal group (n= 6, 12% of the population). A study conducted in India reported a prevalence of 14.4% among female adults [14], and the findings of our study for normal group were similar. Therefore, it can also be suggested that higher BMI and Waist to Hip ratio could have clinical association with higher prevalence rate of low pronated foot (low arch) among the obese and overweight group. Table 2 represents the characteristics of foot arch. In the normal group, 44 participants were with neutral arch and none with high arch foot. For overweight group, neutral arch was seen in 42 participants, and 1 with supinated arch. In obese group, 41 neutral arches were seen along without any supinated feet. This clearly suggested that high arch is very uncommon in overweigh and obese university females in absence of the characteristic underlying pathology. Apart from the foot arch changes we also checked for other foot deformity which could be a potential factor for altered plantar pressure distribution. In the in overweight group, 3 participants were evident with foot

deformity whereas in obese group, 4 participants presented with foot deformity. The most evident foot deformity seen in both the groups was hallux valgus which could have resulted due to flat foot arch and altered plantar pressure distribution resulting in change of the load bearing axis. These finding clearly suggested that weight was one of the biggest factors for arch collapse and could have altered the plantar pressure distribution.

Therefore Table 3 represents the comparison of plantar pressure distribution for all participants. There was significant difference in static average pressure, static maximum pressure, dynamic average pressure, dynamic right contact area, dynamic left contact area. The p value was 0.001 of static average and maximum pressure between the three groups suggesting a strong statistically significant difference, whereas the p value for dynamic average and maximum plantar pressure p value was 0.02 and 0.03 suggestive of statistically significant difference once again. It should be noted that the reason for the increased mean plantar pressure values for obese and overweight females was mainly contributed by the weight or the force exerted on the foot. Since collapse of the foot arch could have increased the contact surface area to generate a lower average plantar pressure, therefore the peak or the maximum pressure values could be a better indicator for association of BMI with plantar pressure. To find the group wise difference, we conducted the post hoc analysis which is represented in Table 4.

There were statistical and clinically significant difference between normal and overweight, normal, and obese group in context to the static maximum plantar pressure. Similarly, a higher significant difference was seen for the dynamic average plantar pressure, between normal and obese (p=0.015) compared to normal and overweight group. In context to the dynamic maximum plantar pressure, there was a significant difference between all the three groups suggesting that plantar pressure was drastically altered in dynamic state compared to the static state where no significant difference between the overweight and obese group was seen. This also suggests that apart from the body weight as the major factor, other factors may be responsible for altering the plantar pressure in dynamic state and they should be further explored. The main objective of the study was to determine the association of foot arch type with plantar pressure distribution. These findings have been presented in Table 5. There was a weaker association of foot arch type with maximum plantar pressure in relation with BMI and hip waist ratio for normal participants whereas there were strong correlations in overweight females (r=0.72 for low arch and r=0.51 for high arch, Table 5). The p-value was significant of foot arch in relation to maximum pressure (0.001) and average pressure (0.006). Among the obese participants the association was stronger for low arch foot with average and maximum plantar pressure (r=0.77 and r=0.93 respectively, Table 5).

For both overweight and obese participants, the p-value was negatively correlated in relation BMI to both maximum and average plantar pressure suggesting that lower the foot arches lead could be clinically associated with higher BMI. For hip waist ratio, the test determined positive correlation for both static and dynamic maximum plantar pressure with low arch of the foot for overweight females. In the study we also found a strong association for plantar pressure with BMI and Hip waist ratio among overweight subjects, the p value of foot arch. Pearson's correlation value was negatively correlated for BMI in relation to dynamic maximum pressure and static maximum plantar pressure. Thus, results have shown significant correlation of plantar pressure distribution with low foot arch among different groups i.e., normal, overweight, and obese females suggesting that young university students could be at the risk of developing altered biomechanics and peak plantar pressure. The consequences of high peak plantar pressure are well studied, and they become clinically significant underlying pathologies like diabetes mellitus [15-19]. It should also be noted that low foot arch is also associated with BMI and Hip waist ratio suggesting that higher weight.

Limitations

In this study, the role of regular footwear was neglected. For instance females wear high heels footwear often which could have affected their foot arch and the resultant plantar pressure distribution.

Future Scope

Study was done on female gender only, to check the more changes based on gender, males can be included in the study. Other factor than body weight could also be explored. Some intervention can be used on the altered foot arches and comparison can be done pre and post intervention for clinical implication.

Conclusion

Foot deformities and altered foot arches are common in younger female population, whereas pronated foot arches were seen in obese group more than others. In case of plantar pressure distribution, there were significant differences shown for normal, overweight, and obese group in association with foot arches. This indicates that future foot complications could be seen among the overweight and obese females and underlying the pathology like diabetes mellitus it could be a serious complication.

References

1. Buldt AK, Forghany S, Landorf KB, Murley GS, Levinger P, et al. (2018) Centre of pressure characteristics in normal, planus and cavus feet. Journal of foot and ankle research 11(1): 3.

2. Jankowicz-Szymańska A, Wódka K, Kołpa M, Mikołajczyk E (2018) Foot longitudinal arches in obese, overweight, and normal weight females who differ in age. Homo 69(1-2): 37-42.

3. Lin WY, Lee SY, Yang CH, Lin HT, Guo LY (2007) Changes in Plantar Pressure Pattern During Different Step Width During Level Walking. Journal of Biomechanics 40(2): S497.
4. Troiano G, Nante N, Citarelli GL (2017) Pesplanus and pescavus in Southern. Annalidell'Istitutosuperiore di sanita 53(2): 142-145.
5. Kharbuja R, Dhungel S (2017) Prevalence of Pes Cavus and Pes Planus Among School Going Children of Bhaktapur District, Nepal. Nepal Med Coll J 19(1): 9-12.
6. Periya SN, Alagesan J (2017) Prevalence and incidence of flat foot among Middle East and Asian Population: An Overview.
7. Periyasamy R, Anand S (2013) The effect of foot arch on plantar pressure distribution during standing. Journal of medical engineering & technology 37(5): 342-347.
8. Fang Q (2018) Comparisons of foot pressure between teenager girls and young female adults. Physical Activity and Health 2(1).
9. Ramachandra P, Maiya AG, Kumar P (2012) Test-retest reliability of the Win-Track platform in analyzing the gait parameters and plantar pressures during barefoot walking in healthy adults. Foot & ankle specialist 5(5): 306-312.
10. Syed N, Karvannan H, Maiya AG, Binukumar B, Prem V, et al. (2012) Plantar pressure distribution among asymptomatic individuals: a cross-sectional study. Foot & ankle specialist 5(2): 102-106.
11. (2008) World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, p. 8-11.
12. (2007) S1 – Leitlinie Vorsorgeuntersuchungim Sport. Dt. Gesellschaft fur Sportmedizin und Praventione.V (DGSP).
13. Flynn T, Cleland J, Whitman J (2008) Users' guide to the musculoskeletal examination: fundamentals for the evidence-based clinician. Louisville, KY: Evidence in Motion 88(12): 1605-1606.
14. Aenumulapalli A, Kulkarni MM, Gandotra AR (2017) Prevalence of flexible flat foot in adults: a cross-sectional study. Journal of clinical and diagnostic research: JCDR 11(6): AC17.
15. Neumann Donald (2016) Kineiology of the Musculoskeltal system.
16. Shree S, Revathi S, Thiyagarajan A, Kumar D (2018) Does Obesity Cause Flat Foot? J ObesTher 2: 1. of 4: 2.
17. López-López D, Vilar-Fernández J, Barros-García G, Losa-Iglesias M, Palomo-López P, et al. (2018) Foot arch height and quality of life in adults: a strobe observational study. International journal of environmental research and public health 15(7): 1555.
18. Mohd Said A, Justine M, Manaf H (2016) Plantar pressure distribution among older persons with different types of foot and its correlation with functional reach distance. Scientifica.
19. Hazari A, Maiya AG, Shivashankara KN (2019) Foot Kinetic and Kinematic Profile in Type 2 Diabetes Mellitus with Peripheral Neuropathy: A Hospital-Based Study from South India. Journal of the American Podiatric Medical Association 109(1): 36-49.

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