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Original Research Article

IMPACT OF BMI AND FOOT ARCH HEIGHT ON PHYSICAL PERFORMANCES

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Abstract

Aims: The study aimed to determine the association between BMI, foot arch height and physical performances and also to ascertain the impact of BMI and foot arch height on physical performances.

Methodology: This was a cross-sectional study conducted on 118 university students (59 males and 59 females) between the age group of 18 to 25 years by using convenience sampling method. Measurements of BMI and Normalized navicular height truncated (NNHt) for foot arch height (FAH) was taken for all subjects. Physical performance tests of 50-m sprint and vertical jump height (VJH) were performed with their comfortable sports shoes. Relations between all variables were analyzed by Pearson correlation coefficient test and multiple regression analysis. A 2-tailed test of significance of < 0.05 was considered statistically significant.

Results: A two-tailed test of significance indicated that BMI was unrelated to 50-m sprint, r_s (118) = -0.08, $p > 0.05$ and VJH, r_s (118) = 0.072, $p > 0.05$. A two-tailed test of significance indicated that FAH was unrelated to 50-m sprint, r_s (118) = -0.07, $p > 0.05$. But there was a weak or negligible negative relationship between FAH and VJH, r_s (118) = -0.21, $p < 0.05$. The results of multiple linear regression analysis showed that BMI was not a significant predictor for both 50-m sprint and VJH physical performances. FAH was a significant predictor for VJH but not for the 50-m sprint.

Conclusion: BMI is not related to 50-m sprint and VJH. FAH is not related to the 50-m sprint but there is a weak relationship between FAH and VJH. FAH was a significant predictor for VJH.

Keywords: Body mass index; Foot arch height; Normalized navicular height truncated; 50-meter sprint; Vertical jump height.

Introduction

Medial longitudinal arch (MLA) plays a significant role in supporting the body weight during static and dynamic posture.[1] Distribution of weight on different regions of the foot is based on the foot types and activities. The weight acts primarily at the hind foot and metatarsal regions in pes cavus and the weight is primarily distributed over mid-foot in pes planus rather than other regions of the foot in the normal fashion as in the normal walking foot.[2,3] From a previous study, it was estimated that the prevalence of bilateral pes planus in an age group of 18 to 25 years old physiotherapy students was 11.25%.[4] In another study, the prevalence of bilateral flexible flat foot among 18 to 21 years old adults was 13.6%.[5] Prevalence of overweight and obesity in adult Kuwaiti population were 80.4% and 47.5% respectively. The percentage of overweight (81.9%) and obesity (53%) were higher in women compared to the percentage of overweight (78%) and obesity (53%) in men.[6] According to the National Health Morbidity Survey data, 20.7% were overweight and 5.8% were obese in the adult population of Malaysia.[7]

There are altered functional alignments, muscle activation patterns and different injury patterns in lower extremity associated with pes planus and pes cavus.[8-12] Flat foot is always associated with excessive pronation which leads to an increase in stress to the surrounding soft tissues and reduces physical performances.[13] There was a relationship between body mass index (BMI), arch type and peak plantar pressure. The elevated plantar pressure was found in high BMI and low arched foot.[14] Ground reaction forces of healthy weight subjects can be as high as 3 to 6 times of their body weight. This magnitude could be more for overweight and obese subjects because of increased biomechanical loading which causes changes in their foot alignment.[15-18] In children aged 11 to 15 years, athletic performance was not influenced by flat feet.[19] There is a connection between BMI and physical fitness.[20] The decrease in physical performances of running and jumping were found among overweight basketball players in the age range of 9-12 years.[21] Through a systematic review, Butterworth et al found an inconclusive evidence regarding the relationship between BMI and flat foot.[22]

Various studies have denoted that BMI is correlated with foot arch height (FAH) and physical performance.[3,11,19,21] While there are few kinds of literature which claim that BMI has no impact on FAH and physical performance.[4,20,23,24] Similarly, regarding the association between FAH and physical performance, there are few articles which revealed that there was no relationship between them while some literature concluded the result conversely.[25-27] Numerous studies have been conducted to investigate the effect of BMI and FAH on physical performance in school going children. Hence, this study was conducted to find out the impact of BMI and FAH on physical performance among university students.

The objectives of this study were, 1) To determine the prevalence of different BMI groups and foot types, 2) To determine the association between BMI, foot arch height and physical performances, 3) To ascertain the impact of BMI and foot arch height on physical performances. Thus, the null hypothesis were, i) There is no significant association between BMI, foot arch height and physical performances, ii) There is no significant impact of BMI and foot arch height on physical performances.

Material and Methods

This was a cross-sectional study conducted on 118 university students (59

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males and 59 females) between the age group of 18 to 25 years by using convenience sampling method. Subjects with recent ankle & knee sprain, fracture, inflammatory disease, unstable cardiovascular and metabolic disease were excluded from the study. The required samples for the study were collected from Asia metropolitan university (AMU) and Universiti Tunku Abdul Rahman (UTAR), Malaysia. The study was approved by the AMU research ethical committee. The study procedures and its objectives were clearly explained to all the subjects before informed consent was obtained from them. Subjects were informed that they can withdraw at any time without revealing any reason.

Measurements of weight and height of all the subjects were taken for calculation of BMI. The BMI was calculated based on the formula of body weight in kilograms divided by height in meters squared. Based on BMI, the subjects were grouped into underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2) and overweight (25-29.9 kg/m^2). Arch Index (AI), Navicular Drop Test (NDT) and Foot Posture Index (FPI) are commonly used clinical methods for assessing foot arch height in clinical research. However, there is another clinical measurement technique known as Normalized Navicular Height truncated (NNHt) which is one of the most reliable and valid methods to measure the foot arch height.[28-30]

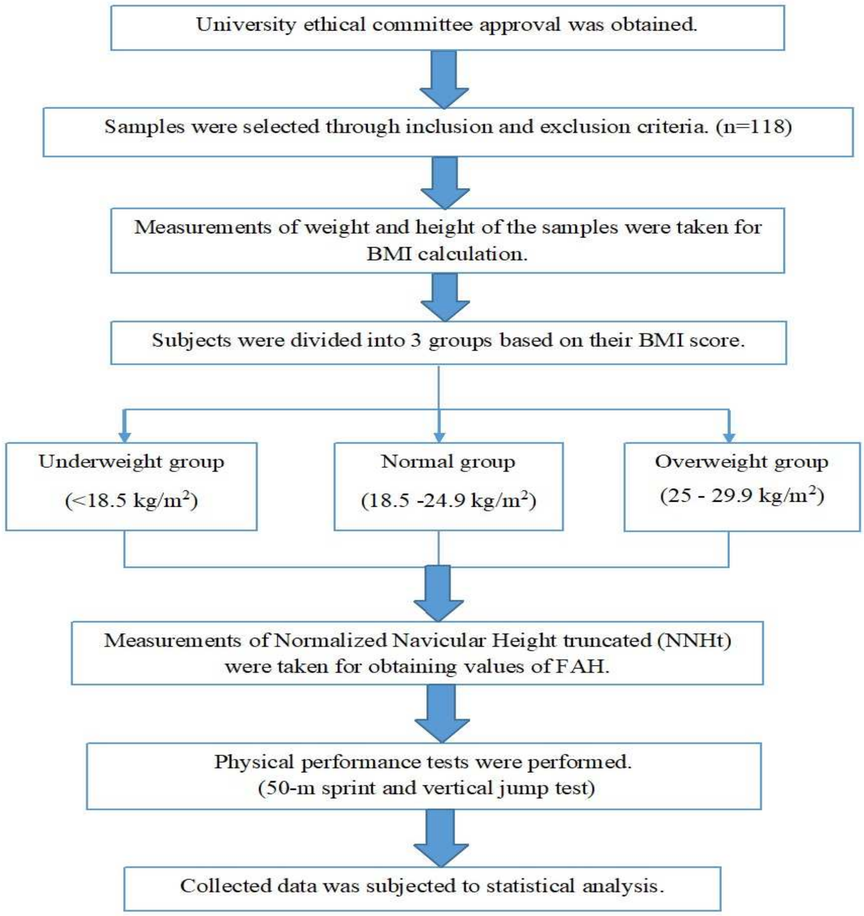

Figure 1: Flow Diagram Shows The Procedure Used In The Study.

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NNHt was used to measure the FAH. Measurements were taken bilaterally without shoes in relaxed bipedal standing position. Truncated foot length and navicular height were measured using a ruler and measuring tape. The most medial prominence of the navicular tuberosity was marked and navicular height was taken by measuring the distance between the most medial prominence of the navicular tuberosity to the supporting surface. The truncated foot length was calculated by measuring the perpendicular distance from the first metatarsophalangeal joint to the most posterior aspect of the heel. The results were analyzed by dividing the navicular height by truncated foot length in millimeters. NNHt value less than 0.21 indicates flat-arched foot posture while greater than 0.30 is indicative of a cavus foot whereas NNHt value between 0.24 and 0.30 corroborates normal-arched foot posture.[28]

Figure 2: Marking of the navicular tuberosity

Figure 3: Measurement of the navicular height

Figure 4: Measurement of truncated foot length

After baseline measurements, subjects were taught about the warm-up exercise for 5 minutes prior to the tests and cool down exercise for 5 minutes after completion of the tests including some practice on physical performances. Subjects were requested to put on their comfortable sports shoes before the tests. Physical performance tests of 50-m sprint and vertical jump test were performed by the subjects.

50-m sprint test: Subjects were prepared to run from the starting position, with one foot in front of the other and their front foot must be behind the starting line. Subject started to sprint on 50-m marked track after a signal. Time was measured in

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seconds twice using a stopwatch. Subjects were asked to wait until they felt completely recovered before performing the second sprint trial, which typically took 2 to 3 minutes. The best sprinting time was used for further analysis.[31,32]

Figure 5: Starting position of a 50-m sprint

Vertical jump test: It was used for measuring the vertical jump height. Before each jump, subjects were required to stand upright and raise their hand above their head. The point of the fingers were marked as standing reach height. Subjects were instructed to jump vertically with swinging their arm to reach as high as possible during the jump and counter movement with approximately 90° of knee flexion for three trials. The best score was taken for analysis and was measured in cm. The difference in distance between the vertical jump height and the standing reach height was found for further analysis.[33,34]

Figure 6: Marking of the standing reach height

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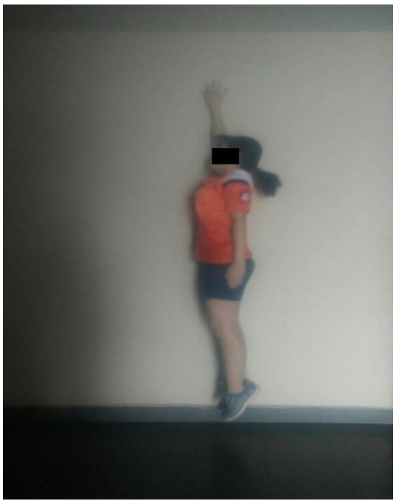

Figure: 7 (a) **Figure: 7 (b)** **Figure: 7 (c)**

a. Standing position with outstretched hand
b. Jumping with approximately 90° of knee flexion
c. Vertical jump

Statistical Analysis:

Data were analyzed by the descriptive statistical method by using mean, SD, frequency (n) and percentage (%). Relations between all variables were analyzed by Pearson correlation coefficient test and multiple regression analysis. A 2-tailed test of significance of < 0.05 was considered statistically significant. Data were analyzed using the Microsoft Excel 2010 and SPSS 20 version.

Results:

Table - 1: Morphological characteristics and physical performance of subjects

VARIABLES	Mean	SD	Minimum to Maximum
Gender: Male/Female	59/59		
Age (Yrs)	21.64	2.01	18 – 25
Height (m)	1.63	0.09	1.41 – 1.88
Weight (kg)	58.11	13.16	36.50 – 94.00
Body Mass Index (BMI)	21.51	3.88	14.82 – 29.90
FAH (Rt)	0.22	0.04	0.10 – 0.32
FAH (Lt)	0.22	0.04	0.11 – 0.36
50 meter sprint	11.52	2.55	6.54 – 20.27
Vertical Jump Height (cm)	32.75	11.40	11.00 – 86.33

Table - 2: Morphological characteristics and physical performance of subjects based on BMI.

VARIABLES	UNDER WEIGHT (n=28)	NORMAL (n=68)	OVER WEIGHT (n=22)
	Mean (SD)	Mean (SD)	Mean (SD)
Gender: Male/Female	9/19	37/31	12/10
Age (Yrs)	21.46 (1.95)	21.37 (1.96)	22.68 (2.00)
Height (m)	1.63 (0.09)	1.64 (0.09)	1.63 (0.08)

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Weight (kg)	45.06 (5.92)	58.22 (9.76)	74.37 (10.58)
Body Mass Index (BMI)	16.9 (1.23)	21.39 (1.74)	27.76 (1.84)
50 meter sprint (sec)	11.63 (3.06)	11.47 (2.52)	11.54 (2.01)
Vertical Jump Height (cm)	30.87 (9.90)	34.00 (12.52)	31.29 (9.25)

Table - 3: Percentage of different foot arch on the basis of BMI

BMI category n (%)	FOOT ARCH HEIGHT (FAH)		
	Flat-arched n (%)	Normal-arched n (%)	High-arched n (%)
Underweight 28 (23.73%)	9 (7.63%)	18 (15.25%)	1 (0.85%)
Normal 68 (57.62%)	26 (22.03%)	39 (33.05%)	3 (2.54%)
Overweight 22 (18.65%)	6 (5.09%)	15 (12.71%)	1 (0.85%)
Total **118 (100%)**	**41 (34.75%)**	**72 (61.01%)**	**5 (4.24%)**

Table - 4: Correlation coefficients of BMI and FAH on physical performances

Pearson Correlation		N	r	P value
BMI	50 meter sprint	118	-0.080	0.387
	VJH	118	0.072	0.441
FAH	50 meter sprint	118	0.077	0.406
	VJH	118	-0.212*	0.021

*Correlation is significant at the 0.05 level (2-tailed).

Table - 5: Multiple regression analyses to identify the determinants of physical performance based on BMI and foot arch height

Dependent variables	Predictors (Constant)	Regression Coefficients					Model Summary		ANOVA Model	
		B	SEB	β	t	p	R^2	Sig F Change	F	Sig p< 0.05
Sprint	BMI	-0.05	0.06	-0.08	-0.92	0.35	0.01	0.46	0.77	0.463
	FAH	5.20	5.82	0.08	0.89	0.37				
VJH	BMI	0.25	0.26	0.08	0.94	0.34	0.05	0.046	3.16	0.046
	FAH	-60.81	25.43	-0.21	-2.39	0.01				

B, unstandardized regression coefficient;
SEB, standard error of the unstandardized regression coefficient;
β, standardized regression coefficient.

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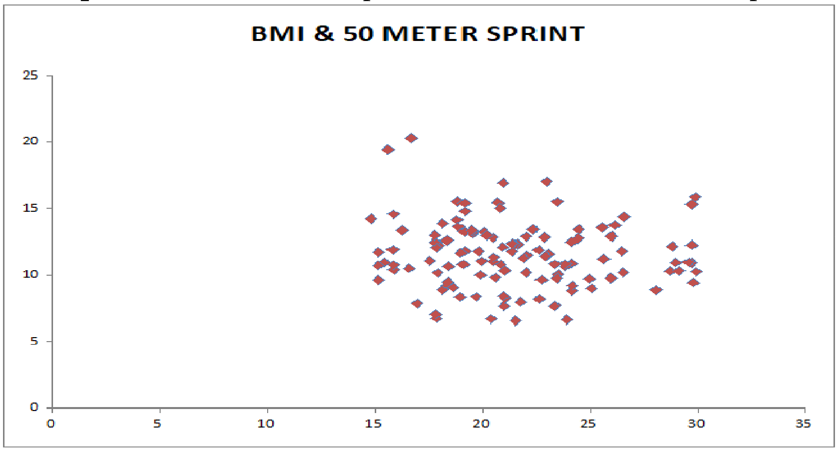
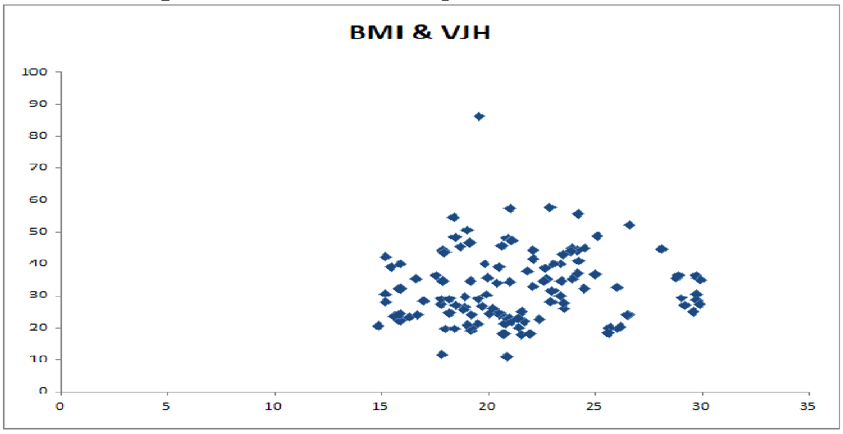
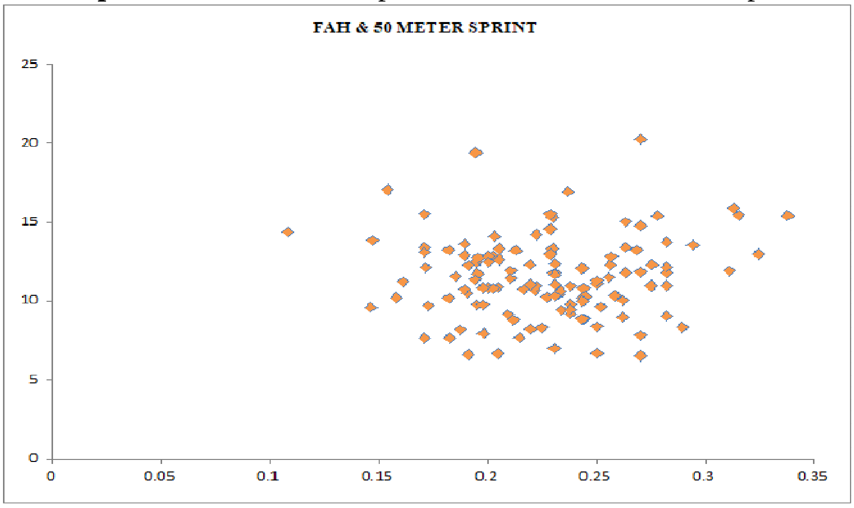
Graph - 1: The relationship between BMI and 50-meter sprint



Graph - 2: The relationship between BMI & VJH



Graph - 3: The relationship between FAH & 50-meter sprint



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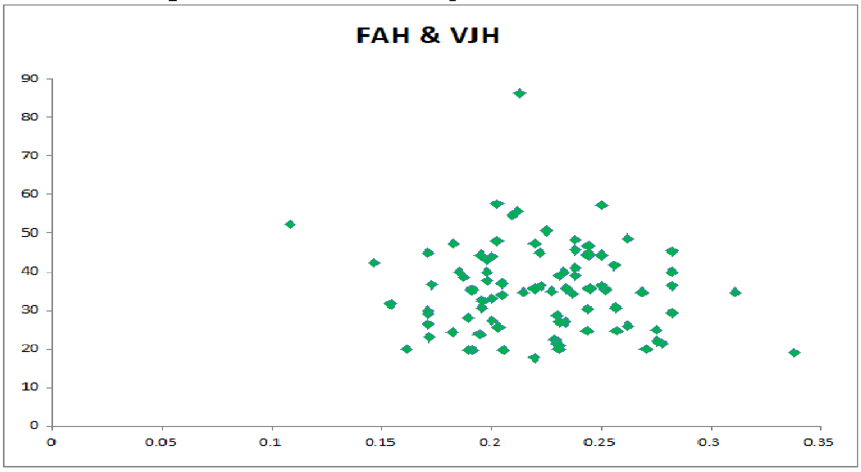
Graph - 4: The relationship between FAH & VJH



Morphological characteristics and physical performances of the subjects are illustrated in tables 1 and 2. The percentage of flat-arch, normal-arch and high-arch were found higher in the normal BMI category which is shown in table 3.

Pearson correlation coefficient was done to determine the relationship of BMI and FAH on physical performances of 50-meter sprint and vertical jump height. These are explained in table 4 and graphs 1 to 4. A two-tailed test of significance indicated that BMI was unrelated to 50 meter sprint, r_s (118) = -0.08, $p > 0.05$ and vertical jump height, r_s (118) = 0.072, $p > 0.05$. There is inconclusive evidence about the significance of the association between BMI and physical performances of 50-meter sprint and VJH. A two-tailed test of significance indicated that FAH was unrelated to 50-meter sprint, r_s (118) = -0.07, $p > 0.05$. But there was a weak or negligible negative relationship between FAH and vertical jump height, r_s (118) = -0.21, $p < 0.05$.

The results of multiple linear regression analysis are shown in table 5. BMI was not a significant predictor for both 50-meter sprint and VJH. FAH was a significant predictor for VJH but not for the 50-meter sprint.

Discussion

The chief findings of this study were that physical performance of 50-m sprint was not associated with body mass status and FAH, whereas vertical jump was associated with FAH but not with body mass status. The results of regression analysis also proved that BMI was not a significant predictor for both 50-m sprint and VJH physical performances, whereas FAH was a significant predictor for VJH but not for the 50-m sprint. We clarified this finding to denote that 50-m sprint and vertical jump were not influenced by body mass. These study results match with those found in football and handball players. Increased BMI not necessarily depends on body fat percentage, but also on skeletal muscle mass. [35] Thus, BMI does not have any effect on vertical jump height. Predicting vertical jump height is not possible only on the basis of BMI. BMI classification has to be used carefully in college/university athletic and non-athletic population, particularly in overweight BMI groups.[36] Future studies have to be conducted based on body composition and not only relied on BMI. The application of fat percentage may be more effective than BMI in assessing obesity in young adults.

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The percentage of the flat, normal and high-arched foot was more in the normal BMI group compared to the other BMI groups. This study result supports the previous study findings that foot arch height is not much influenced on the basis of BMI alone.[23] The percentage of the normal-arched foot was higher compared to flat-arched and high-arched among underweight and overweight categories. This further insists that most of the underweight and overweight have more percentage of the normal-arched foot. This finding was very similar to the previous study findings.[17]

Subjects with flat foot have showed reduced vertical jumping ability. But in a practical scenario, there are many instances in which flat feet have no impact on jumping ability. Studies showed that foot posture and foot disorders may influence standing vertical jumping ability. There is a change in activation of abductor hallucis muscle in subjects with flat feet which is the primary dynamic stabilizer for medial longitudinal arch.[37,38] Greater hip and knee joint movements and also forefoot landing technique reduces the ground reaction forces. Previous experience of jumping and landing techniques determine the subject's ability to reach high in vertical jumping physical performance.[39] The foot posture is a complex system which cannot be viewed in isolation, despite the anthropometric and motor status. The other characteristics such as technical skills, muscle volume, the percentage of the type of muscle fiber distribution, fat percentage, relative age and personality of each subject may be the contributing factors for the performance ability.[40,41]

Conclusion

BMI is not related to 50-meter sprint and vertical jump height. FAH is not related to the 50-meter sprint but there is a weak relationship between FAH and VJH. BMI was not a significant predictor for both 50-meter sprint and VJH physical performances. FAH was a significant predictor for VJH but not for the 50-meter sprint.

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