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The Relationship between Foot Arch Angle and Individual Stability

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ABSTRACT

Foot arch types are categorized into three forms: high, normal and flat. Each arch type can influence walking, standing and athletic performance. How- ever, limited research has explored the relationship between foot arch structure and individual stability. This study aimed to examine the correlation between foot arch type and dynamic balance. Thirty participants (15 males and 15 females) mean aged 23.40 ± 0.894 underwent two tests: the Clarke's Angle Test and the Y-Balance Test. Clarke's Angle Test determined foot arch type, while the Y- Balance Test assessed dynamic stability in three directions: anterior, posterolateral and posteromedial. Pearson's correlation was used for statistical analysis. A significant positive correlation was found between normal foot arch angles and Y-Balance scores in the posterolateral (r = 0.638, p = .004) and posteromedial (r = 0.640, p = .004) directions. In contrast, high arch angles showed strong but statistically non-significant negative correlations in all directions. Flat arch angles showed no significant relationship with balance. These findings suggest in Divi duals with normal arches may exhibit superior dynamic stability, while flat and high arch types require further investigation due to inconsistent trends.

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Introduction

Background of Study

Foot arches are classified as high, normal or flat and play a crucial role in influencing gait, standing posture and athletic performance. The development of foot structure be- gins in early childhood, with approximately 52 bones in human foot, with a significant concentration in the ankle [1]. Metatarsal bones support stability during standing, whle phalanges help coordinate foot posture during movement [2,3].

According to Harian Metro on January 26, 2018, flat feet are common in children (estimated in around 44% of children aged 3 to 6 years). Flat feet are typically painless but may cause discomfort during weight-bearing activities due to stress on the Achilles tendon. This tendon connects the calf muscles to the heel and is critical in foot motion.

Previous studies have shown that imbalances in intrinsic foot muscles, such as the abductor hallucis and flexor digitorum brevis, can cause foot problems [4]. Balance, closely tied to foot structure, impacts daily activities and overall quality of life [5,6].

Problem Statement

Foot arch type plays a significant role in selecting footwear, receiving medical intervention and maintaining balance. According to M Star on November 15, 2021, the arch helps maintain the balance during walking [7]. Balance refers to controlling the body's center of mass relative to its base of support. It is influenced by the musculoskeletal and nervous systems [8]. According to the World Health Organization (WHO), one of the factors that can cause disturbances in a person's balance is musculoskeletal disorders, including those affecting foot structure. In sports, dynamic and static balance is essential. Sports Science students require proficiency in psychomotor skills like athletics and gymnastics, which depend on balance. This study investigates the relationship between foot arch type and dynamic stability among Sports Science students at University Technology Malaysia (UTM).

Literature Review

Foot Arch

The foot arch serves as a foundational structure for biomechanical movement, providing support and distributing body weight across the foot. Hillstrom et al. (2012) [9] categorized foot arches into three types: flat, normal and high. Flat arches allow for greater flexibility and shock absorption but may compromise structural support, potentially resulting in overuse injuries. Conversely, high arches create a rigid structure that concentrates pressure, potentially enhancing force transfer but reducing shock absorption.

Individuals with high arches often exhibit stronger, stiffer foot mechanics, enabling greater muscle activation and energy transfer [10]. However, this rigidity may predispose them to conditions like stress fractures. Flat-footed individuals tend to compensate through increased muscle activity from both intrinsic and extrinsic muscles, leading to fatigue over prolonged activity [11].

While anatomical classification provides a basis for understanding foot function, foot arch alone may not be a determinant of performance [12,13]. Fengqin et al. (2016) emphasized that structural differences must be interpreted alongside neuromuscular control and motor learning patterns [11]. The interplay between foot shape and movement adaptation suggests that compensatory mechanisms may neutralize potential structural disadvantages.

Dynamic Stability

Individual stability is the ability to maintain control of the body's position, whether in motion or at rest. McKeon et al. (2014) proposed that foot arch type influences postural control through its impact on proprioception and load distribution [14]. Stability is not only a function of joint position but also a result of continuous neuromuscular feed- back, particularly from the feet.

Pronation and supination, linked with flat and high arches respectively, affect balance control differently. Flat feet often exhibit excessive pronation, potentially reducing alignment efficiency. High arches, meanwhile, create a more supinated foot posture, which may compromise shock absorption but increase stiffness and responsiveness [15]. Studies by Carson et al. (2012) and Zifchock et al. (2006) indicate that high-arched individuals may experience improved performance in balance-based tasks but are also at risk of reduced adaptability [16,17].

Furthermore, external factors such as surface type, footwear and task complexity play a role in modulating stability outcomes [18]. Andreeva et al. (2021) highlights that stability performance varies based on sport specialization and gender, with athletes from balance-intensive sports showing superior control [19]. This suggests that foot arch analysis should be contextualized within a broader biomechanical and functional frame- work.

Methodology

Research Design and Participants

This study adopted a quantitative cross-sectional design to investigate the relationship between foot arch type and individual dynamic stability. The design allowed for the collection and analysis of data at a single point in time, providing a snapshot of corre- lations between physical structure (foot arch) and functional outcome (balance). This approach is suitable for identifying statistical relationships in healthy populations with- out introducing time-dependent variables. A total of 30 undergraduate students (15 males and 15 females) from the Sports Science program at University Technology Malaysia (UTM) voluntarily participated in the study. Participants were selected using purposive sampling based on the inclusion criteria: aged between 22 and 24 years, actively involved in sports activities and without any history of lower limb musculoskeletal injury, neurological disorders or balance impairments. The sample size was deter- mined based on feasibility and prior literature indicating sufficient power for correlation analysis in small-to-moderate samples. All participants signed informed consent forms prior to data collection. Confidentiality and anonymity were maintained throughout the study. The gender balance allowed preliminary comparisons across sexes, although the primary analysis did not stratify by gender due to sample size limitations [20,21].

Instruments and Procedures

Two main instruments were used: the Clarke's angle method to determine foot arch type and the Y-Balance Test (YBT) to assess dynamic postural stability. Clarke's Angle was measured using a footprint method (Figure 1 and Figure 2). Participants applied washable paint to the sole of their dominant foot and stamped it onto A4-sized paper three times using different colors to differentiate the trials. The angle was measured using a protractor at the medial border of the footprint to classify foot arch as flat (10°- 30°), normal (31° - 45°) or high (46° - 66°), following standard diagnostic thresholds.

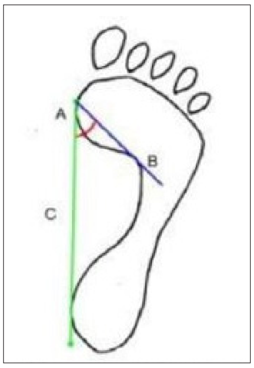

Figure 1: The measurement of Clarke Angle (Adapted from Ozer & Barut, 2012)

Figure 2: The example measurement of Clarke Angle

Anthropometric data, including height and weight were collected prior to testing. Each participant performed a 5-minute dynamic warm-up to reduce the risk of injury and enhance test performance. The YBT was administered using a Y-shaped tape layout on a flat surface (Figure 3 and Figure 4). Participants stood on their dominant leg and extended the non-dominant leg in the anterior, posterolateral and posteromedial direc- tions as far as possible without losing balance or foot contact. The maximum reach in each direction was measured in centimeters.

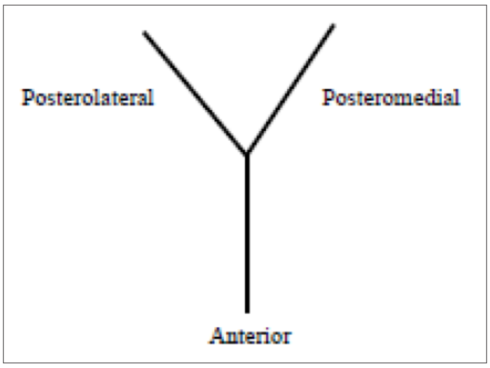

Figure 3: The Y-shaped used during the Y-Balance Test (Adapted from Shaffer et al., 2013)

Figure 4: The example of Y-Balance Test

Each reach direction was tested three times, and the highest valid measurement was recorded. Standardized verbal instructions and demonstrations were provided to minimize variation. A rest interval was provided between trials to prevent fatigue and cool- down exercises were encouraged after testing. All tests were conducted on a non-slip surface to ensure safety and standardization.

Data Analysis

Data were analyzed using Statistical Package for the Socials Sciences (SPSS) software. Descriptive statistics, including mean and standard deviation, were computed for demographic variables (age, weight, height), Clarke Angle values and Y-Balance Test scores. Foot arch categories were also analyzed based on frequency and percentage to assess distribution across the sample.

Pearson's correlation coefficient was used to examine the strength and direction of the relationship between foot arch angle and dynamic stability scores in the three reach directions. The correlation values (r) were interpreted based on standard guidelines: weak (0.1-0.3), moderate (0.3-0.5), strong (0.5-0.7) and very strong (>0.7). A significance level of $p < .05$ was adopted to determine statistical relevance.

Given the small number of participants in the high arch group (n = 3), the correlation results were interpreted with caution. No additional statistical tests (e.g., regression or ANOVA) were conducted due to sample size constraints. However, results from this study serve as a baseline for future larger-scale investigations exploring biomechanical implications of foot structure on postural performance.

Results

Descriptive Analysis

A total of 30 participants were assessed, comprising 15 males and 15 females, aged between 22 and 24 years (mean age = 23.40 ± 0.89 years). The mean body weight was 64.67 ± 16.53 kg and mean height was 164.47 ± 9.45 cm. The average Clarke Angle was 33.80 ± 11.36°, indicating that most participants had a normal foot arch.

In terms of balance performance, the mean reach distances during the Y-Balance Test were as follows: anterior direction = 75.56 ± 13.04 cm, posterolateral direction = 82.15 ± 12.36 cm, and posteromedial direction = 95.73 ± 15.09 cm. These results indicate good overall dynamic stability across the group.

Foot arch classification based on Clarke Angle revealed that 18 participants (60%) had normal arches, 9 (30%) had flat arches and 3 (10%) had high arches. This distribu- tion supports the general population trends and provides a sufficient baseline for com- parative analysis across groups.

Table 1 presents the mean and standard deviation for subject demographics and bal- ance scores.

Table 1: Mean and Standard Deviation of Subjects

Item	Mean ± SD / Frequency (%)
Age (years)	23.40 ± 0.894
Weight (kg)	64.67 ± 16.527
Height (cm)	164.47 ± 9.449
Clarke Angle (°)	33.80 ± 11.363
Anterior (cm)	75.56 ± 13.042
Posterolateral (cm)	82.15 ± 12.357
Posteromedial (cm)	95.73 ± 15.086
Foot arch type: High	3 (10%)
Foot arch type: Normal	18 (60%)
Foot arch type: Flat	9 (30%)
Total subjects	30 (100%)

Inferential Analysis

Pearson's correlation analysis was performed to determine the relationship between foot arch angle and dynamic balance in each directional reach. For the high arch group (n = 3), strong negative correlations were observed in all directions: anterior (r = -0.820, p = .388), posterolateral (r = -0.553, p = .627) and posteromedial (r = -0.603, p = .588). However, none of these correlations were statistically significant, likely due to the limited sample size.

In the normal arch group (n = 18), a weak and non-significant negative correlation was found in the anterior direction (r = -0.089, p = .726). However, statistically signif- icant moderate to strong positive correlations were observed in the posterolateral (r = 0.638, p = .004) and posteromedial (r = 0.640, p = .004) directions. These results suggest that individuals with normal arches may demonstrate superior lateral and medial balance stability.

The flat arch group (n = 9) exhibited weak and statistically non-significant correlations across all directions: anterior (r = 0.096, p = .806), posterolateral (r = 0.028, p = .943) and posteromedial (r = 0.091, p = .817). These findings indicate minimal influ- ence of flat arch structure on dynamic balance performance within this sample.

Table 2 shows summarize the Pearson correlation coefficients between foot arch types and balance directions.

Table 2: Correlation Between Foot Arch Angle and Y-Balance Test

		Anterior	Posterolateral	Posteromedial
High Arch	r	-.820	-.553	-.603
	Sig.	.388	.627	.588
Normal Arch	r	-.089	.638	.640
	Sig.	.726	.004*	.004*
Flat Arch	r	.096	.028	.091
	Sig.	.806	.943	.817

Discussion and Conclusion

Discussion

The results of this study provide insight into how different foot arch types influence dynamic balance. Individuals with normal foot arches demonstrated significantly better stability in the posterolateral and posteromedial directions, indicating that their foot structure may support more effective lateral and diagonal movement. This finding aligns with earlier research that suggests a biomechanical advantage for individuals with normal arches when performing multidirectional tasks.

For participants with high arches, the data revealed strong negative correlations be- tween foot arch angle and balance performance. However, due to the small number of participants in this group (n = 3), these relationships were not statistically significant. It is possible that individuals with high arches experience compromised shock absorption and limited contact area, which could impact stability. Nevertheless, the observed trend warrants further investigation using a larger sample to determine if this effect is consistent.

Interestingly, the flat arch group showed no statistically significant correlations in any of the balance directions. This contradicts some earlier studies that associated flat feet with reduced stability. One possible explanation is that individuals with flat arches may develop compensatory neuromuscular adaptations such as increased proprioceptive reliance or greater activation of stabilizing muscles, allowing them to perform comparably to those with normal arches.

These findings are partially consistent with previous research. For example, Fengqin et al. suggested that flat feet can negatively affect ankle control and postural balance [11]. However, the present study did not observe significant performance deficits in individuals with flat arches, contradicting prior assertions. This discrepancy could be attributed to factors such as small sample size, testing conditions or compensatory adaptations in individuals with flat feet. It is also plausible that flat foot individuals develop neuromuscular adaptations such as increased activation of proximal muscle groups or improved proprioception that help maintain balance despite structural disadvantages. This potential mechanism may explain the absence of significant deficits in flat foot participants during the Y-Balance Test in the present study. Furthermore, the observed moderate associations in the normal arch group support previous findings suggesting a structural advantage in maintaining balance during dynamic tasks [13,14,18].

Overall, the data suggests that while extreme arch types (high or flat) may influence balance in specific directions, the most consistent and significant balance advantages were associated with the normal arch structure. These insights have implications for athlete screening, injury prevention and footwear recommendations, particularly in sports requiring multidirectional balance control.

Study Limitation

These are several limitations to this study. The sample size was relatively small, particularly in the high arch group, limiting the statistical power and generalizability of the results. Additionally, the study did not stratify results by gender, despite known differences on postural control between males and females. Only static measurements (i.e., Clarke Angle) and reach distances were assessed, without any kinetic or kinematic analysis to provide deeper biomechanical insights.

Other potential confounding variables such as lower limb strength, flexibility or habitual footwear usage were not controlled for and may have influenced the results. Furthermore, only the dominant leg was tested for balance, which might not fully rep- resent bilateral stability patterns.

Conclusion and Recommendations

This study concludes that individuals with normal foot arches tend to perform better in dynamic balance tasks, particularly in the posterolateral and posteromedial directions. Although no significant findings were observed for the flat or high arch groups, trends in the data suggest this foot types may still influence balance through biomechanical or neuromuscular pathways.

Future research should include larger and more evenly distributed samples across foot arch types. Gender-based comparisons and the use of motion analysis tools such as 3D motion capture, plantar pressure sensors and electromyography (EMG) could provide a more comprehensive understanding of how foot structure affects dynamic stability. Intervention-based studies such as targeted balance training programs tailored to foot arch type may also be valuable in enhancing postural control in both athletic and clinical populations.

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