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Characterization of Foot Arch among Male Office Workers in Selangor

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Abstract
This study aims to identify the type of foot arch among male office workers in Selangor. A total of 100 participants aged 20 to 50 years participated. The arches were determined using the Harris-imprint index parameter. Analysis showed that normal arch 71% (n=71) 0.23 (±0.09), high arch (28%) 0.18 (±0.10), and flat arch (1%). Additionally, 55% (p<0.001; or 4.850) experienced discomfort with the shoe insoles, while 36% (n=36) had the same pair for the left and right foot, and 64% (n=64) had different pairs of foot arches. Findings revealed a different foot arch between their left and right feet.

Keywords: Foot arch; Harris-imprint; Male; Office workers.

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1.0 Introduction

The foot represents the distal part of the leg. It helps perform two fundamentally vital shock absorption and propulsion activities during bipedal locomotion, which require high stability. This shape has been adapted over millions of years of evolution to move in various directions and balance our vertical body against gravity (Verpillot, 2019). In addition, (Ficke et al., 2022) also stated that the foot comprises 26 bones tarsal, metatarsal, and phalanges (Figure 1), divided into three sections named the forefoot, midfoot, and hindfoot. While (Quinn, 2022) believed that each of our feet has 28 bones, 30 joints, and more than a hundred muscles, ligaments, and tendons. Furthermore, all these structures cooperate to perform two main functions: weight-bearing and propulsion-forward movement.

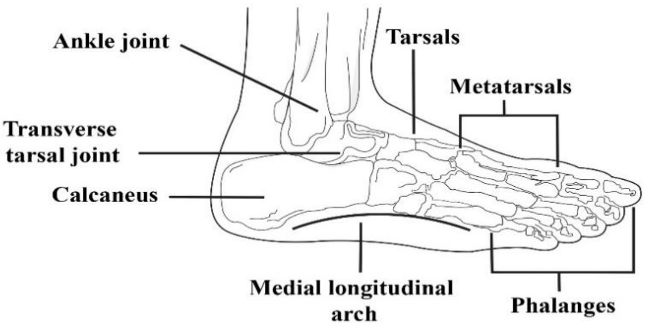

Fig. 1: The anatomical structure of the human foot. The figure illustrates the three major foot components: the tarsal, metatarsal, and phalanges, along with the medial longitudinal arch.
(Source:)

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The human foot is divided into three main parts: the tarsal, metatarsal, and phalanges (Figure 1). The tarsals constitute the tarsus, which forms the rear part of the foot. The talus, the second largest of the tarsal, has an articular surface on its superior aspect that resembles a convey pulley-shaped, known as the trochlear surface of the talus (Watkins, 2010). In addition, the beam action of the tarsal and metatarsal represents the supportive aspect of the long bone of the foot and acts as a primary stabilizer for the foot—the metatarsal works with the calcaneus to sustain the body's weight. There are five significant points of contact between the metatarsus and the ground. The first metatarsal carries most of the weight, and the second to fifth metatarsals help with balance and comfort (O'leary, 2022).

Furthermore, the structure of the foot is unique to every individual. It varies within a single individual from one side to the other, and can be classified into foot arches. Thus, the two prominent arches of the human foot are known as the transverses arches and the medial and longitudinal arches (Chadikovska et al., 2018). The functional anatomy of the arches enables the foot to maintain stability while absorbing the stresses and putting forth the energy required for locomotion. It allows the body to maintain flexibility, allowing the foot to grip various surfaces and improve forward propulsion. In addition, (Gosling et al., 2016) also added that the medial longitudinal arch, which extends up to the first three metatarsals, is the tallest of the arches and runs down the instep of the foot between the calcaneus, talus, navicular, and cuneiform bones. The cuboid, the fourth and fifth metatarsals, the calcaneus, and the lateral longitudinal arch make up the lateral longitudinal arch, which is lower and flatter than the media arch. Therefore, the arch plays a crucial role in walking and running safety, thus having a direct influence on the biomechanics of an individual in case of any change (Mootanah et al., 2013).

Other than that, foot arch type can be classified by the Medial Longitudinal Arch (MLA) as high arch (cavus foot), normal arch (retus foot,) or low arch (planus or flat foot) (Nilsson et al., 2012). Evaluation of the type of foot that relies on the arches can be done statically or dynamically. The high arch foot has a curve point where the mid-foot is generally rigid, lacking a good pile, and is not a good shock absorber when running or landing from a jump (D'Aout et al., 2009). This condition, where the toe remains partly flexed and causes bruising in the area of the ball of the foot, can lead to foot pain. Meanwhile, the low arch foot is the condition that causes the Medial Longitudinal Arch (MLA) to have a more flattened curve than is typical and allows the entire foot sole to make partial or complete contact with the ground.

2.0 Literature Review

Several techniques for classifying the foot types, which measure the morphology and foot posture either in a static position or during locomotion, are described in the literature. Wet tests, ink or digital footprint (Staheli et al., 1987), and photography techniques (Saltzman et al., 1995) are indirect measurement methods. In contrast, direct methods include clinical assessment (Rose et al., 1985), and radiographic evaluation (Cobey, 1981). Within the morphological classification methods of the foot while standing are visual inspection non-quantitative, anthropometric values, footprint parameters, and radiographic evaluation (Razeghi et al., 2022). Nonetheless, the footprint approach is one of the most widely used methods for studying the Medial Longitudinal Arch (MLA). Several measurement techniques and footprint characteristics have been proposed to categorize the foot into lower, normal, and higher arch types (Stavlas et al., 2005). On the other hand, Shariff et al. (2017) compared five indexes (CA index, CSI, ST index, Arch index, and the Harris-imprint index). They concluded that the Harris-imprint index was appropriate to identify the left and right foot arches in adult women.

Several studies reported that abnormal foot arch may cause foot pain due to stress that continuously exerts inflammation on the plantar fascia. The damage will worsen with prolonged weight-bearing activities (NF Md Yunus et al.,2020). This is supported by Cen X (2020), who mentioned an example of the abnormality of the foot arch as the excessive collapse of the medial longitudinal arch will lead to the loss of static and dynamic support function, which is the contact area in the medial midfoot. Peak pressure and force significantly decreased in the lateral forefoot in the flat foot type Cen X (2020). The knowledge of foot arch problems is essential in helping to design proper footwear that prevents or relieves pain and disorders in the feet and lower limbs (Jonely et al., 2011). Such concern is particularly valid for workers who spend more than four hours daily on their feet standing or walking. As supported by Saadah et al. (2015), the effect of medial arch support on sixteen hospital security guards while standing and walking during work hours suggested that using insole support to reduce foot pressure and muscle work can strengthen the medial arch. Moreover, most literature on foot arches and shoe insoles is based on Western societies or developed countries. To the best of our knowledge, despite apparent differences in social, cultural, and shoe-wearing habits, there is a lack of available information on footwear, insoles, and foot health in Malaysia. Therefore, due to the importance of understanding the appearance of certain foot arch types among workers, which would aid in the development of techniques to prevent foot pain and even help in the design of good insoles and footwear, the general objective of this study was to address this lack of information as well as identify the type of foot arch among male office workers in Selangor.

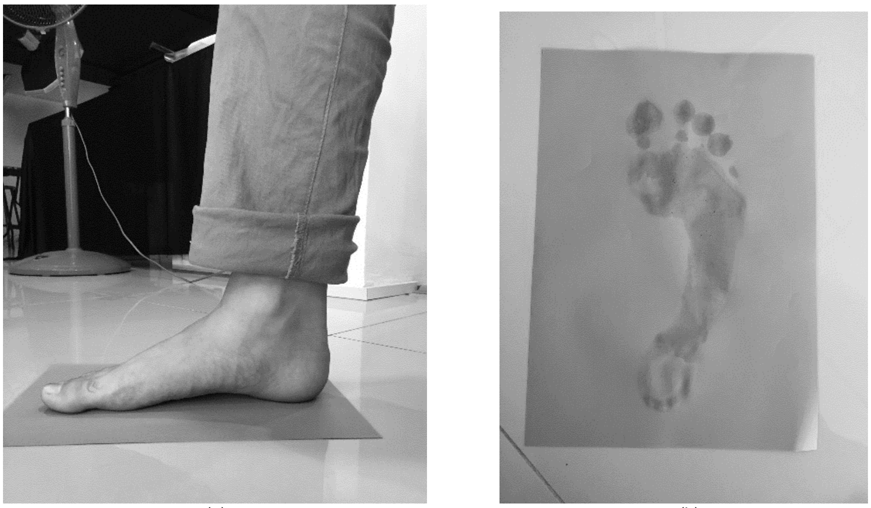
3.0 Methodology

3.1 Participants

This population survey study targeted men aged 25 and 50 working in the Selangor area office in Shah Alam and Petaling Jaya. Office workers wear shoes for more than eight hours daily, which can cause foot discomfort related to shoe insoles. Office workers wear shoes for more than eight hours daily, which can cause foot discomfort related to shoe insoles. In addition, as Hassan (2020) stated, Selangor is the most populated state with multi-ethnic citizens (6.57 million) among all the 13 states in Malaysia and has the most industrial sector workers. To select the study sample, adult male office workers in Selangor who volunteered to participate were selected through a self-structured questionnaire and footprint method. A total of 100 male office workers were chosen by convenient sampling to participate in this three-month study, which lasted from March 2021 to June 2021. A sample size calculation for population proportion required a minimum sample of 100 respondents to achieve a 95% confidence level for 10% precision (Israel, 1992). Considering the limited time and resources, the sample size was based on the available number of office workers at the recruitment sites, with 100 male office workers from different companies. Information was collected regarding the participants' demographics, name, age, body weight (in kg), height (in cm), and questions related to work, which was the duration of work in days. Participants were also asked about shoe insoles' use and comfort level in a day. As the use of insoles is likely to have a more significant impact and is related to foot arch, insoles to work (typically worn for longer durations) were used to establish a possible association between the use of shoe insoles and the prevalence of foot arch.

3.2 Experimental Design

The wet test technique determines the foot and arch form (Patil, 2017). The wet test involves getting the foot wet and then stepping on paper. Related to that, the arch height is determined based on the outline and footprint. The materials used in this test were colored A4 size paper, a spray bottle, a pen, tissue, a hand glove, and a drawing ruler for the measuring process. The participants were instructed to stamp their feet in a weight-bearing stance on colored A4 paper on both feet. The selection of colored paper is because colored paper is more accessible to see the effect stamped by the wet feet earlier. The footprints were immediately marked on paper with a ball pen. Later on, the impregnated footprints were scanned to provide a visual representation of the footprints. From a digital image of the footprint, the arch morphology was used to determine based on the Harris imprint index. Shariff et al. (2017) used the wet test technique in their research to determine the foot arch morphology based on the foot arch index parameters.



(a) (b)

Fig. 2. (a) Stamping wet foot onto paper; (b)The footprint on paper.

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3.2 Data Processing and Statistics

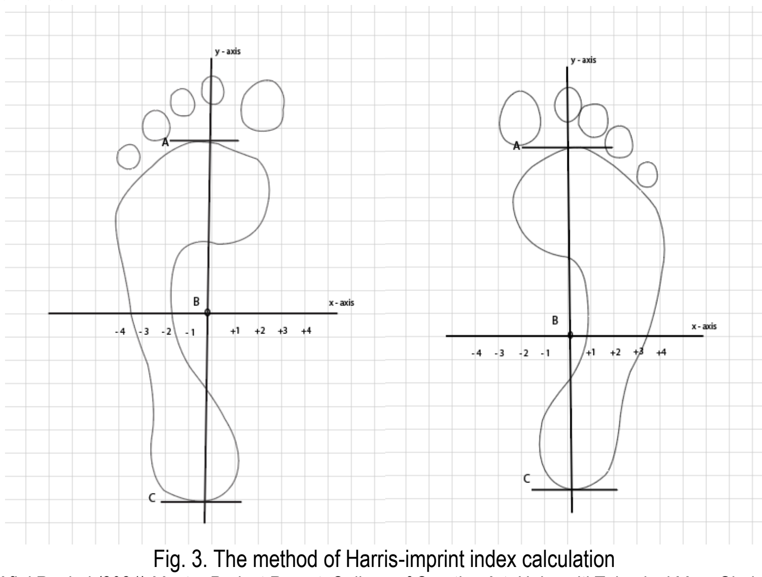

Fig. 3. The method of Harris-imprint index calculation

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The footprints were scanned to provide a digital image of the impregnated footprints. The arch morphology was calculated from a digital image of footprints by using the Adobe Illustrator CC vector graphics editor software (Figure 3). A grid of 0.5 cm width and 0.5 cm length was defined on the digital footprint photos. The y-axis is represented by the line ABC (midline foot axis), which runs from the tip of the second toe to the midway of the hindfoot. Meanwhile, the x-axis is represented by a perpendicular line drawn medial and lateral to line ABC. The x-axis scores are used to identify arch types: high arch (-4,-3,-2), normal arch (-1, 0, +1), and flat arch (+2,+3,+4) (Shariff et al., 2017). The foot y-axis, which runs from the middle of the second toe to the center of the heel, was used to measure the footprint. The foot axis was divided vertically into three equal parts, namely the forefoot (A), the midfoot (B), and the hindfoot (C). The AI was calculated by the midfoot area (B) x–axis. If the arch index (AI) was -2 and above, it was regarded as a high arch; if the AI was between -1, 0, and +1, it was regarded as a normal foot; if the AI was greater than +2, it was regarded as flatfoot. Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows version 16.0 (SPSS Inc, Chicago, IL, USA). Descriptive data analysis involved comparing prevalence using the chi-square test with calculated 95% confidence intervals. All information collected was stored on a Microsoft Excel spreadsheet and an SPSS database for analysis. Results were considered statistically significant when the p-value was less than 0.05.

The IBM SPSS, Statistics for Windows version 23 was used for data analysis in this study. Besides the usual descriptive statistics, a paired t-test with a 95% confidence interval was conducted to compare the mean differences between types of foot arches.

4.0 Findings

Tables 1, 2, and Figure 4 demonstrate the detailed distribution of footprint types according to the demographic characteristics of the participants. For all 100 male office workers who participated in this study, the mean age was 18.88 (0.83) (Table 2). Most aged 25-30 were 48.5% (n=49) and weighed 71-80kg 47% (n=47). The race or ethnicity of the participants is shown in Table 1. The data analysis of respondents' footprints based on the Harris-–imprint index was analyzed. The analysis was based on a digital image of the respondent's footprint. We successfully utilized the data and observed that male office workers in Selangor do not necessarily have the same foot arch pair. Several participants have different arches on their left and right feet, and some have the same foot arches. The grid lines utilized and Shariff et al. (2017) calculation assure consistency in the scaling of foot arches, which may explain the Harris-imprint index's efficiency. Notably, in each footprint that has been analyzed, approximately 70% of participants have normal arch either on the left foot, right foot, or both feet (Figure 4). Only a minority of participants had a combination of flat and normal arches.

Table 1. Race / Ethnicity of participants

Total participants	n=100
Malay	n=94
Chinese	n=5
Indian	n=1

note n= number of participants

Table 2. Characteristics of participants

No.	Characteristic	Mean	Std. Dev.	Range
1.	Age (years)	18.88	0.83	25 - 50
2.	Height (cm)	162.83	8.88	140 - 190
3.	Weight (kg)	70.59	11.56	50 - 90

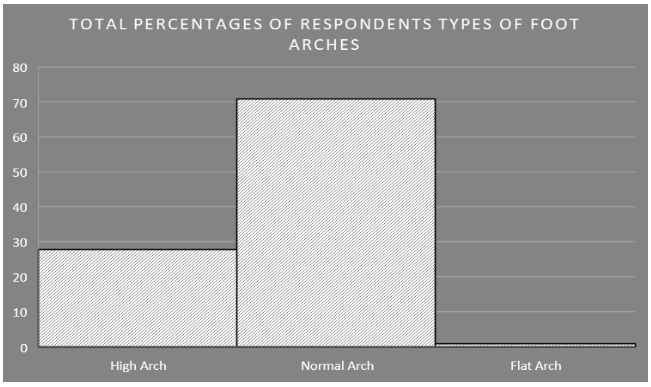

Fig 4. Total percentages of participants' types of foot arches

Based on the results, 64% of the participants possess different arches between left and right feet, either with a pair of normal and flat arches, normal and high arches, or flat and high arches. Concerning that, the majority of respondents' right feet are normal arches (n=43), where the high arch is (n=20), and the least is a flat arch (n=1). On the other hand, the respondents' left foot indicates the highest number is the normal arch (n=39), the second highest is the high arch (n=24), and the least is the flat arch (n=1). The researcher found that some respondents do not necessarily have a pair of the same foot arch. A few participants have different foot arches between their left and right feet. Additionally, in each footprint that has been calculated, approximately 71% (n=71) of participants have normal arches either on their left or right foot, about 28% (n=28) of respondents have high arches, only a minority of respondents, 1% (n=1) have flat arches (Figure 4). In relation to that, in comparing their type of foot arch, participants who have normal arch foot 0.23 (±0.09) and high arch foot 0.18 (±0.10) showed a statistically significant difference (p=0.003) (Table 3).

Table 3. Arch index means and standard deviations for high and normal arch and comparison between each group

	Mean	SD	N	p-value
High arch	0.23	0.09	71	0.003
Normal arch	0.18	0.10	28	

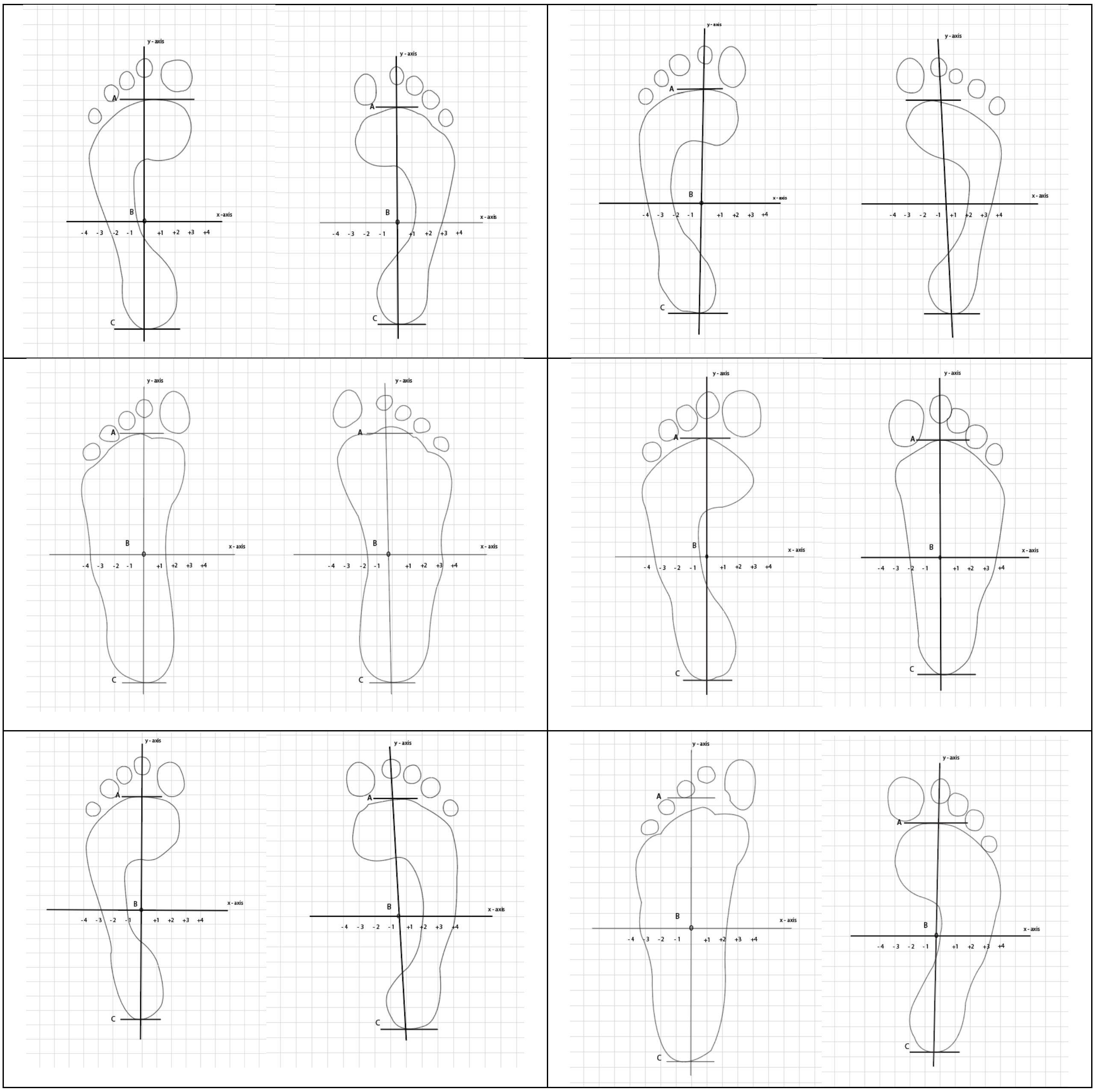

Fig 5. Participants who have the same pair and different pair types of arches between their left and right feet

Table 4. The Left and right foot arches of male office worker participants determine by using the Harris-imprint index.

		Harris imprint index right foot			
	Types of arches	Normal arch	Flat arch	High arch	Total
Harris imprint index left foot	Normal arch	41	3	15	59
	Flat arch	7	1	3	11
	High arch	23	0	7	30
Total		71	4	25	100

Data represented the number of participants in the wet test process.

Work shoes were worn for significantly longer, 7.36 hours per day, than for casual activities, which lasted 3.01 hours (Chua et al., 2013). Among all of the participants, 55 (55%) experienced discomfort with the shoe insoles they wore to work ($p < 0.001$; or 4.850) (Table 5). The remaining male office workers believed that they did not experience any discomfort with their shoe insoles. In our study group (n = 100), participants who wore shoe insoles during work hours (n = 69, 69%) were the majority, followed by participants who did not wear shoe insoles (n = 31, 31%). We found that 55% of the participants who wore shoe insoles complained of discomfort issues compared to 45% of male office workers who did not have issues with their shoe insoles. There was a statistically significant difference between participants experiencing discomfort with the shoe insoles who wore them during work hours and those who did not ($p = 0.027$; or 1.591).

Table 5. Comparison of the prevalence of participants who wear shoe insoles during work hours and participants who experience discomfort with their shoe insoles among male office workers in the study (n = 100) wearing shoe insoles, not wearing shoe insoles.

Variable	**No. of participants (%)**		**p-value (χ2)**	**OR (95% CI)**
	Wearing shoe insoles (n= 69)	**Not wearing shoe insoles (n= 31)**		
Participants who wear shoe insoles during work hours (n= 100)	69/100 (69%)	31/100 (31%)	0.027 (4.861)	1.591 (1.071-2.362)
Participants who were experiencing discomfort with their shoe insoles	55/100 (55%)	45/100 (45%)	< 0.001 (23.522)	4.850 (2.556-9.201)

5.0 Discussion

Footprint evaluation is an old but proven method of determining foot morphology. The method continues to be an inexpensive, quick, simple, noninvasive, and credible technique for screening and follow-up studies (Forriol et al., 1990; Welton, 1992; Kanatli et al., 2001). In the previous literature, numerous parameters for evaluating the footprint have been proposed, including the footprint angle, the arch index, and the Chippaux-smirk index (Gilmour et al., 2001). The latest study by Tang (2022), also used foot-type classification methods, which are the footprint method and plantar pressure method, which need to collect, process, and store a large of data. Thus, according to the majority of authors, these parameters provide a reliable basis for predicting or categorizing foot arch (Cavanagh et al., 1997). Concerning that, a detailed analysis of Shariff et al. (2017) findings reveals that the midfoot is where a correct index parameter is extracted. They stated that the Harris-imprint index was the most appropriate method for determining left and right foot arches among the CA index, CSI, ST index, Arch index, and Harris-imprint index. The prominent feature is that midfoot derives Harris-imprint's two parameters.

This study aimed to identify the type of foot arch in male office workers in Selangor, comparing the type of foot arch related to experiencing discomfort with their shoe insoles during work hours. Whereas the foot type is related to foot function and comfort (Hillstrom et al., 2013), it is important to recognize differences in the foot arch between workers who spend most of their time on their feet to reduce the risk of injuries. The results of this study indicate that the male office workers in this group have normal arch feet compared to high and flat feet, showing a higher arch index mean. It corroborates with the previous study by Parash et al. (2013), which found that most adult Bangladeshi males had standard arched feet in both sitting and standing positions. Meanwhile, a study by Collins, 2023, reported that Ghanaian males' foot arch had a slightly higher mean right plantar arch index than the mean right plantar arch index recorded for females. It is also related to Janchai et al. 's (2010) study, which found that women tend to develop a flat arch, whereas men tend to maintain a normal or high arch. Most of the studies revealed that most subjects had a normal foot arch. Subjects with normal foot arches usually had no problems or complaints about their feet. Moreover, this is a preliminary study of foot arch that can be expanded to investigate the relationship between foot arch and gender, foot arch and foot problems, and foot arch and plantar pressure. Studying different variations can add to the foot arch database in Malaysia and worldwide, encouraging people to consider their body's health from the foot. Based on several studies on comparison and types of foot arch among men, race factors also play an essential role in determining the difference in the type of foot arch for men or women.

6.0 Conclusion and Recommendations

This study showed that most male office workers in Selangor have normal foot arches. We also found that the subjects do not necessarily have a pair of the same foot arch. Most of them owned different foot arches between their left and right foot. In addition, they also have an issue with their shoe insoles that cause discomfort during their work hours. Thus, the information obtained from this study will help create shoe insoles that offer functionality in one design that can fit any arch type, as well as the suitability for standing for a long time during work hours to prevent the development of foot discomfort. This is a step forward in reducing foot arch pain and aiding workers in increasing their work productivity while preventing medical problems and absenteeism. This is the first research in Malaysia to design a functional insole that helps the wearer accommodate their arch type and develop a new insole that accommodates the exact shape of human feet by using the harris-imprint index, which provides a guideline in the design process. A new design insole will promote better biomechanics while standing, walking, and working in the office.

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Paper Contribution to Related Field of Study

This study related to finding the right shoes requires knowing your foot arch type. The discoveries would improve foot arch support and comfort for Selangor workers. This study will help shoe designers comprehend the human foot arch's traits and issues to build shoes for people

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