The association between flat feet and body mass index in the adult population: A systematic review

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Abstract:

Background: Flat foot is one of the foot disorders that is usually neglected which may seriously affect the quality of life in a longer term. Among the etiological factors, one of those is the higher body mass index (BMI). While flat foot incidence is common, its relationship with body mass index remains equivocal. **Aim**: This systematic review investigated the association between flat feet and body mass index in the adult population. **Methods:** A systematic search of three electronic databases was conducted. Studies on human adults (>18 years) with flat feet and gold standard outcome measures were included. This review was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The Appraisal tool for Cros-Sectional Studies (AXIS) was utilised to assess the methodological quality. All articles had good score of methodological quality. **Results:** Out of the 720 articles that were screened, only eight studies met the inclusion criteria and were included in this systematic review. From these eight articles, seven studies reported a significant relationship between flat feet and body mass index in the adult population. **Conclusion:** There is a significant association between flat feet and body mass index among the adult population. Therefore, as the BMI increases, the chances of developing flat foot increases.

Keywords: Flat feet; Pes Planus; Body mass index; Association; Relationship

Introduction:

Adult population is susceptible to various musculoskeletal disorders as they age, one of the disorders being flat foot. Flat foot is a commonly observed foot disorder in clinical practice yet neglected. American College of Foot and Ankle Surgeons (ACFAS, n.d.) described flat foot as foot deformity with varying degrees of physical impact and characterized by no arch when weight-bearing. Flat feet have also been described (Pourghasem et al. 2016) as fallen arches where the inner side of the foot is flattened, allowing the entire foot to touch the ground. Flat foot can be classified as rigid or flexible. In case of flexible flat feet medial longitudinal arch (MLA) persists during non-weight bearing and disappears with weight-bearing and this contrasts with rigid flat feet whereby the MLA is absent in both the conditions, i.e... weight-bearing and off-load (Pourghasem et al., 2016).

The causative factors can be obesity, poor footwear in early childhood, injury, overdue stress on the foot, laxity of muscles and ligaments, and faulty biomechanics. The prevalence of flat foot is higher in females, individuals with excessive BMI, and those with bigger feet (Arachchige et al. 2019). Hence obesity has been indicated as a factor that can lead to

flat foot. Flat foot may increase the incidence of lower extremity injuries due to alteration of foot kinetics or poor balance due to abnormal foot structures such as excessive pronation of foot (Arachchige et al., 2019). Flat foot is common in children due to physiological concern of incomplete process of developing medial arch and excessive fat deposition under foot. However, most flat foot cases among children will disappear with age (Suciatiet al., 2019).

According to World Health Organisation body mass index is a widely used indicator for classifying the people according to their body weight and height (WHO, 2023). World health organisation classifies the BMI into categories from underweight, normal weight, overweight and obesity (WHO, 2023).

The World Health Organization reported that in 2016, 1.9 billion people aged above 17 were overweight adults and among them, over 650 million were reportedly obese (WHO, 2020). According to them, the prevalence of obesity globally tripled from 1975 to 2016 which illustrated that there was a significant increase in the obese population. In Malaysia during National Health and Morbidity Survey 2019, it was found that 1 out of 2 Malaysian adults were either overweight or obese as reported by National Institutes of Health (NIH, 2020).

Keeping all the mentioned factors in mind, obesity seems to be one of the important causative factors for flat foot. Due to higher prevalence of obesity in the world it is present among most obese individuals. Therefore, the general population needs awareness regarding the effect of obesity on posture. Therefore, this review was intended to know the association between BMI and flat foot in the available published literature.

Methodology:

Identification

This study used the preferred Reporting items for Systematic reviews and Meta-analyses (PRISMA) guidelines to aid in reporting the findings. Three different databases were used to retrieve the articles which included the PubMed, Science Direct, and SCOPUS databases. The Boolean operators 'AND' and 'OR' was used during the searching process. Following combination of words were used: "flat feet" AND "body mass index OR excessive body weight", "association between body mass index" AND "pes planus OR flat feet".

Screening and Eligibility

All the articles were screened for any duplication of articles by using *Mendeley* and removed all the redundancy within the papers. The articles were also screened based on the inclusion and exclusion criteria as presented in Table 1 The selected articles were further reviewed for their eligibility based on PICOS (Population, Intervention, Control, Outcome, Study type) Table 2.

Table 1: The Criteria for Inclusion and Exclusion

Inclusion criteria	Exclusion criteria
• English publications • Articles must be published • Articles published within 10 years • Full-text articles available • BMI parameter following WHO guideline	• Articles that need access to it • Magazines, e-books, and trade journals

Table 2: Detailed PICOS criteria

Criteria	Descriptions
Population	Individuals age ≥18 years old checked for flat feet disorder
Intervention	-
Comparison	Different groups of body mass index
Outcomes	Footprint Analysis, Footprint Indices, Static foot measure
Study type	Cross-sectional

Results:

Study selection

The selection process is simplified in the PRISMA flow diagram in Figure1. A total of 715 articles were sought from databases namely, Science Direct, Scopus, and PubMed. In this process of identification 591 references were identified from Science Direct, 85 references from Scopus, and 39 references from PubMed. In addition to these databases, five additional references from google scholars were also sought making a total of 720 references.564 duplicates were detected and removed leaving 156 articles were screened for the titles and abstract. Out of 156 articles, 104 were excluded based on the exclusion criteria and 44 of the articles were removed as they were not fulfilling the PICOS model set by the present study, leaving 8 studies to be reviewed.

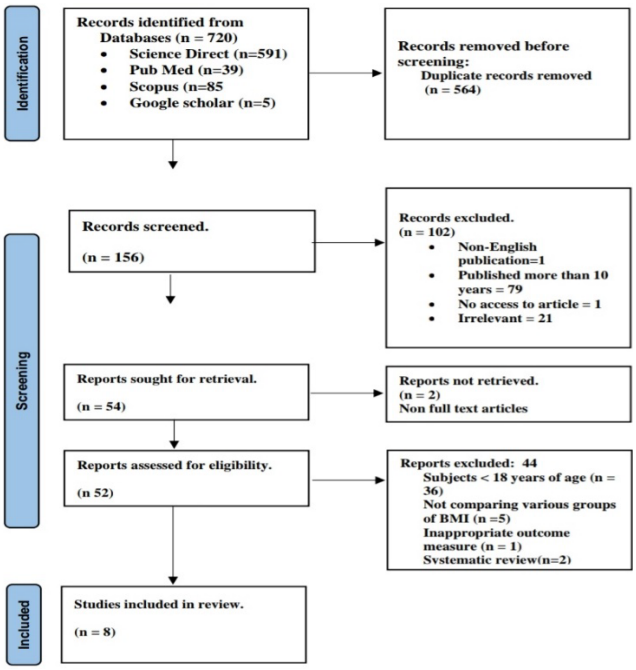

Figure 1: The Processes of Identification, Screening, Eligibility and Included by using PRISMA Guideline.

Description of Included studies

From the eight included studies, the number of subjects involved in the studies was ranged from 71 to 533 and the ages were ranged from 18 to 84 years old. The studies were conducted in various countries, Poland, India, Pakistan, Brazil, and Saudi Arabia. The study conducted by Jankowicz-Szymańska, (2018) included only female participants from various age groups meanwhile other studies recruited participants from both genders. All the subjects recruited in the studies were healthy individuals. The statistical analysis reported on the association between flat feet and body mass index in all the studies.

The results obtained were described in a table form in Table 4, adopted from Systematic Review Guidelines by The American Occupation Therapy Association, updated in March 2020 (American occupational therapy association, 2020).

Methodological quality

All included studies were assessed for methodological quality by Appraisal Tool for Cross-Sectional Studies (AXIS) (Downes et al., 2016). All studies were rated as per the instruction manual of AXIS, which has the highest score of 20. The score of all the articles included is summarised in the Table 3.

Studies done by (Jankowicz , et al 2018), (Chougala., et al 2015) , (Aurichio.,et al 2011), and (Arithi., et al 2018) scored 15 or more than 15 out of 20. Other studies reported less than 15 scoring based on the Appraisal Tool for Cros-Sectional studies.

Table 3: The Methodological Quality of the Included Studies using the Appraisal tool for Cross-sectional study (AXIS)

Item	Study							
	Jankowicz-Szymańska et al. (2018)	Ahmed, and Saleem (2019)	Chougala et al. (2015)	Aurichio et al. (2011)	Vijayakumar et al. (2016)	Arthi et al. (2018)	Przysada et al. (2013)	Almaawi et al. (2019)
1	Y	Y	Y	Y	Y	Y	Y	Y
2	Y	Y	Y	Y	Y	Y	Y	Y
3	Y	Y	Y	Y	Y	Y	Y	Y
4	Y	Y	Y	Y	Y	Y	Y	Y
5	Y	Y	Y	Y	Y	Y	Y	Y
6	Y	Y	Y	Y	Y	Y	Y	Y
7	NR							
8	Y	Y	Y	Y	Y	Y	Y	Y
9	Y	Y	Y	Y	Y	Y	Y	Y
10	Y	Y	Y	Y	N	Y	Y	Y
11	Y	N	Y	Y	Y	Y	N	Y
12	Y	Y	Y	Y	Y	Y	Y	Y
13	NR							
14								
15	Y	Y	Y	Y	Y	Y	Y	Y
16	Y	N	Y	Y	Y	Y	Y	Y
17	Y	Y	Y	Y	Y	Y	Y	Y
18	N	N	N	N	N	Y	N	N
19	NR	N	N	N	NR	N	NR	N
20	Y	NR	Y	Y	Y	Y	NR	NR
Total (/20)	**15**	**12**	**15**	**15**	**14**	**16**	**13**	**14**

Note. Y = Yes; N = No; NR = Not Reported

Discussion:

This systematic review was formulated or synthesized from eight studies of cross-sectional study design.

Jankowicz., et al (2018) reported a significant ($p<0.05$) difference of arch index of both feet between normal and overweight individuals in a cross-sectional study of 270 females, with Methodological quality score of 15 out of 20. Ahmed., et al (2019) reported a positive association($p<0.001$) between body mass index and level of arch using navicular drop test among 71 individuals including both males and females with

methodological quality score of 12. Chougala., et al (2015) reported a significant ($p<0.001$) relation between body mass index and flat foot using arch index as an outcome measure in 228 individuals including both males and females with methodological quality score of 15 out of 20. Aurichio., et al (2011) reported a significant ($p<0.001$) correlation between body mass index and arch index among 399 individuals including both males and females with methodological quality score of 15 out of 20. Vijayakumar., et al (2016) reported a strong relationship ($p\leq0.05$) between body mass index and flat foot among 412 individuals including both males and females with methodological quality score of 14 out of 20. Arithi., et al (2018) reported no significant difference ($p= 0.16$) between body mass index and types of foot arches, using staheli index as an outcome measure among 250 individuals including both males and females with methodological quality score of 16 out of 20. Przysada., et al (2013) reported a significant association between flat foot and body mass index($p<0.001$) among 108 individuals including both males and females with methodological quality score of 13 out of 20. Amaawi., et al (2019) reported a significant correlation between body mass index and flat foot($P<0.05$) among 533 individuals including both males and females with methodological quality score of 14 out of 20.

Association between flat feet and body mass index

According to the study by Jankowicz-Szymanska et al. (2018) the fallen longitudinal arch in one or both feet were found to be 45% from the group of overweight and obese and 10% from the normal BMI group based on the arch index (AI) value.

There was a significant association ($p=0.001$) found between the BMI and flat feet by (Chougala et al., 2015). This is in line with the result from Ahmad and Saleem (2019) who found that there was an association between BMI and the level of the arch.

Aurichio et al. (2011), stated that there was a positive association between BMI and AI value in women. Whereas in men, there was a low positive correlation between BMI and AI value. The result was upheld by the fact that women have moderate association is due to greater ligament laxity and lower muscle strength compared to men (Aurichio et al., 2011). Regardless of that, both genders still showed a positive correlation between BMI and AI value. As a result of prolonged stress onto the foot following a high body mass index, it might be responsible for the changes in the structure of the longitudinal arch.

Vijayakumar et al. (2016) investigated the relationship between flat feet and BMI by using four footprint parameters. The result of their study presented that there is a strong relationship between BMI and flat feet. The prevalence of flat foot increases as BMI increases. This can be proven from their results which showed that the prevalence of flat foot is the highest in the morbidly obese group. Similarly, with the previous study, Almaawi et al., (2019) also reported similar findings with use of different outcome tools. Another study (Przysada et al., 2013) also agreed that there was a significant association between foot defects, mainly flat foot and BMI. The prevalence of flat feet was 37% and of these, 34.5% came from the overweight group.

Based on the results of the studies done by Jankowicz., et al(2018), Ahmed., et al(2019), Chougala.,et al(2015), Aurichio., et al(2011), Vijaykumar., et al(1016), Przysada ., et al(2013), and Almaawi., et al(2019) it is reasonable to state that higher BMI does lead to flat feet incidence. Anatomically, the line of gravity of the human body passes downwards and falls between the heel and metatarsal heads through the cuboid-calcaneal junction (Schafer, 1987). Since the line of gravity passing through cubido-calcaneal junction, the medial longitudinal arch is always in continuous tension in weight bearing position (Akambase., et al. 2019). This continuous tension causes the surrounding structures such as ligaments to stretch and lose its elasticity forcing the arch to lower down as an adaptation to support the extra weight. Since anatomical literature already explains the elastic nature of the medial longitudinal arch, the association between obesity and the flat foot seems logical. Meanwhile the amount of drop in the medial longitudinal arch with increased body weight needs to be studied in future studies.

Moreover, people with excessive body weight have biomechanical deviations and adjustments happening in the lower extremities. People with flat feet tend to have a pronated foot which causes an internal rotation component in the entire lower extremity thus these people will develop a compensatory anterior pelvic tilt, which predisposes the person to many other musculoskeletal disorders like back pain, sacroiliitis, etc. (Son, 2016). Avery similar finding reported by Damien B Irving., et al. (2007), who concluded that obesity and pronated foot posture are associated with chronic plantar heel pain. Hence, it is inevitable to include the possibility of increased BMI contributes to the occurrence of flat feet.

However, a study done by Arthi et al. (2018) stated that the type of foot posture may not be significantly influenced by the body mass index of the individual. However, adults with increased weight has shown a tendency to develop lower foot arch. These insignificant results in this study could have been due to many reasons, one of the reasons could be the age group studied. Another reason also could have been that the outcome-measure used in their study did not have enough sensitivity to detect the initial grades of the flat foot which is most common in the younger population. According to the author's discussion the result of their study may also have been influenced by the uneven distribution of subjects into the groups of body mass index which might have affected the result.

Few limitations have been discovered throughout the process of collecting data until the discussion, one of them is that this review did not classify the grades of types of foot postures and the height was not taken into consideration. Further research should be carried out to study the effect of height on the flat foot. It is also recommended to include a larger sample size with an equal number of participants in each group of body mass index, so that the result can be inferred to the population. Also, the next study should include demographic data like age, gender, habitual posture, and nature of work in the study to achieve more definite findings.

Conclusion:

There seems to be a significant association between flat feet and body mass index among the adult population. As the BMI increases, the prevalence of flat foot increases too. This indicates that body mass index does contribute to the lowering of the medial longitudinal arch of foot resulting in occurrence of flat foot. For that reason, those who have excessive body weight or are under the categories of overweight and obese are at higher chances of getting flat foot.

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Table 4: Description of included studies, their score of methodological quality, participants, methods, outcome measures and results

No	Author (Year)	Level of Evidence Study Design Methodology quality, score	Participants Inclusion criteria	Methodology	Outcome measure	Result
1	Jankowicz-Szymańska et al. (2018)	Level of evidence: 4B Study Design: Cross-sectional Score of methodological quality: 15/20	*N*= 270 (all females) *Age:* 19-22 years old (19.91 ± 0.74) 60-84 years old (67.76 ± 6.30)	Calibrated anthropometer was used to measure the height and the Tanita scales were used to measure the body weight. BTS P-WALK baroresistive platform was used to assess the longitudinal foot arch.	Arch index (AI)	Significant differences of AI of both feet between normal and overweight/ normal and obese/ overweight and obese (P<0.05).
2	Ahmed, and Saleem (2019)	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:* 12/20	*N*= 71 (58 males, 3 females) *Age:* 19-24 years old	Height and body weight were measured following standard protocol and BMI was calculated. Brody's Navicular Drop test was used to measure the medial arch.	Brody's Navicular Drop Test (NDT)	The prevalence of flatfoot was 15.5% out of 71 subjects and from them 14.1% were obese. An analysis between BMI and the level of arch showed a positive association (p<0.001).
3	Chougala et al. (2015)	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:* 15/20	*N*= 228 (46 males, 182 females) *Age:* 18-25 years old	Standard method was used to measure BMI and Arch Index was used to assess flat feet.	ArchIndex (AI)	A significant relation (p<0.001) was found between BMI and flat foot.
4	Aurichio et al. (2011)	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:*	*N*= 399 (172 males, 227 females) *Age*: (69.6 ± 6.8) (69.4 ± 6.7)	A calibrated analog scale with stadiometer used to measure height and weight and Arch Index was used to assess flat feet.	Arch Index (AI)	In women, significant correlation between BMI and AI for both feet was reported. (p<0.001).

		15/20				In men, also a positive correlation between BMI and AI for left feet (p=0.008) and for right feet (p=0.032).
5	Vijayakumar et al. (2016)	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:* 14/20	*N*= 412 (229 males, 183 females) *Age*: 25-40 years old	The body weight and height were measured following standard protocol.	Clarke's Angle, Chippaux-Smirak Index, Staheli Index, and Arch Index	A strong relationship between BMI and the incidence of flat feet (p≤0.05) was reported.
6	Arthi et al. (2018)	*Level of evidence*: 4B *Study Design:* Cross-sectional *Score of methodological quality:* 16/20	*N*= 250 (109 males, 141 females) *Age:* 18-24 years old	BMI was measured according to standard protocols. Staheli Index was used to assess flat feet.	Staheli Index	There was no significant difference reported between BMI and types of foot arches (p=0.16).
7	Przysada et al. (2013)	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:* 13/20	*N*= 108 (28 males, 80 females) *Age:* 23 years old	The subjects' height and body weight were measured as per standard protocol. Clarke's angle was used to assess flat feet.	Clarke's Angle	A significant association was found between BMI and foot defects with P<0.001. 41.4% subjects under the overweight category were having fallen arch of the foot and 34.5% were tested and proved for flat feet.
8	Almaawi et al. (2019).	*Level of evidence:* 4B *Study Design:* Cross-sectional *Score of methodological quality:* 14/20	*N*= 533 (218 males, 315 females) *Age:* ≥18 years old (37.0 ± 11.26)	The body weight and height of the subjects were measured as per standard protocol. Foot examination was done by a podiatrist using a podoscope.	Chippaux-Smirak Index, Staheli Index, and Clarke's Angle	High BMI and flatfoot, were positively correlated (P<0.05).