

Review Article

## The prevalence of flatfoot among Saudi population: A systematic review

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### ABSTRACT

Flatfoot is a foot deformity characterized by a collapsed medial arch, plantar flexion and medial rotation of the talus, eversion of the calcaneus, and forefoot abduction. The flatfoot prevalence and causes are not well known despite its correlation with multiple factors. This study aimed to systematically review all studies that estimated the flatfoot prevalence among Saudi population and list the associated factors. Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines and Joanna Briggs Institute reviewer's manual were followed to perform this systematic review. Data collection was through several databases using terms including prevalence, Saudi, and flatfoot with their synonyms. The inclusion criteria were both adults and children's studies that were carried out in Saudi Arabia (Saudi and non-Saudi), with the exclusion of secondary flatfoot (due to traumatic or pathological causes) studies. A total of 361 published studies before July 2021 which involved 6190 participants were reviewed, and only six studies were included in the study. The participants' age ranged from  $4.2 \pm 3.6$  to  $37 \pm 11.26$  years. There was male predominance, with body mass index (BMI), age, and gender being common factors studied in the articles. Flatfoot prevalence in Saudi Arabia differed according to multiple factors as reported by different authors. This review revealed a wide range of flatfoot prevalence among the Saudi population. Most of the included studies reported that BMI, age, gender, residence, family history of flatfoot, footwear type during childhood, hypermobility, functional mobility, balance, and flexibility of the whole body had a significant impact on flatfoot prevalence.

**Keywords:** Flatfoot, Flattened arch, Medial arch, Pes planus, Prevalence, Saudi Arabia

### INTRODUCTION

Flatfoot, also known as pes planus, is a foot deformity characterized mainly by a collapsed medial arch, plantar flexion of the talus, medial rotation of the talus, eversion of the calcaneus, and abduction of the forefoot.<sup>[1]</sup> Hindfoot valgus and forefoot supination are two of the numerous deformities that cause the term flatfoot.<sup>[2]</sup> The exact cause of flatfoot deformity is not well known despite its correlation with multiple factors, including age, gender, weight, race, and type of footwear.<sup>[3]</sup>

In children, the clinical manifestations of flatfoot extend from being flexible and painless to rigid and painful.<sup>[2]</sup> Although flexible flatfoot is considered physiological in most children,

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it can induce pain, which can be exacerbated by loading activities and eventually lead to early fatigue and medial foot callus.<sup>[2]</sup> In contrast, children with rigid flatfoot experience more discomfort than the flexible type, as they encounter growing pain, muscle contractures, functional limitation, and fatigue associated with joint malalignment.<sup>[2]</sup>

Flatfoot can also be acquired in adulthood. Patients may vary from being relatively asymptomatic to showing apparent symptoms.<sup>[4]</sup> Symptoms might include ankle pain, bony bumps, and a gradual onset of vague pain in the medial foot, which may worsen with activity.<sup>[4]</sup> According to two systematic reviews done in 2017 and 2018, there are no universally accepted criteria for diagnosing flatfoot.<sup>[5,6]</sup> Only three methods were recommended for further research, including the Chippaux-Smirak index, Staheli arch index, and foot posture index.<sup>[5]</sup> Therapeutic interventions are usually not required in managing flexible flatfoot since it typically resolves during the child's first decade.<sup>[2,7]</sup> However, children with rigid flatfoot may benefit from conservative therapy or surgical interventions.<sup>[7,8]</sup> On the other hand, adults with flatfeet may use orthoses, braces, and shoe modifications as medical treatment. However, reports have shown minimal improvements in many adult cases compared to children.<sup>[9]</sup>

No systematic reviews were found studying the Saudi population based on comprehensive searching. Therefore, this study aimed to systematically review all related studies that estimated the prevalence of flatfoot among the Saudi population in both children and adults and list the associated factors.

## MATERIAL AND METHODS

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and Joanna Briggs Institute (JBI) reviewer's manual were followed to perform this systematic review of the literature on the prevalence of flatfoot among the population live Saudi Arabia (Saudi and non-Saudi).<sup>[10,11]</sup> The protocol was registered and approved by King Abdullah International Medical Research Center (KAIMRC).

### Literature searching

Electronic searching for eligible peer-reviewed articles was conducted through several databases (EBESCO, EMBASE, OVID, PubMed, ISI, SCOPUS, ProQuest, and Google Scholar). In addition, reference lists of the included studies and related published systematic reviews were screened manually. Database searching terms are shown in [Table 1]. All related studies that estimated the prevalence of flatfoot

**Table 1:** Database searching terms.

| Term       | Synonymous   |
|------------|--|
| Prevalence | Prevalence   |
| Saudi      | All population in Saudi Arabia   |
| Flatfoot   | Pes planus, fallen arch, flat footed, pes valgus, planovalgus, low arch, flat footedness |

in the Saudi population and fit the inclusion criteria were included in the study.

### Selection criteria

Inclusion criteria were determined using the CoCoPop mnemonics (conditions, context, and population) used in this review.<sup>[10,12]</sup> When it came to flatfoot as a condition, the context was Saudi Arabia, and the population included both Saudis and non-Saudis living in Saudi Arabia. Therefore, this systematic review included all full-text studies diagnosed in both adults and children in Saudi Arabia and published before July 2021. There were no language restrictions. Studies examining patients with flatfoot due to secondary causes (either due to traumatic or pathological causes) were excluded from the study.

### Literature quality assessment

Various important quality assessment tools have been found to evaluate prevalence surveys. In 2012, the JBI Working Group was able to develop an important rating format for assessing studies for systematic reviews of prevalence, which was well received by many authors.<sup>[12,13]</sup> Therefore, the JBI critical appraisal tools for systematic reviews checklist for prevalence studies were used for this systematic review. It included nine questions to analyze the quality of the studies. The answers to the questions were either yes, unclear, no, or not applicable. The authors had agreed to score the quality out of 18 points in total, where yes, unclear, or not equal to 2, 1, and 0, respectively. If the question was answered as not applicable, the item would be eliminated from the total.

### Data extraction

The data extraction format was prearranged and validated by the authors. Data items included publication year, geographic location, the number of participants (sample size), response rate, mean age, the number of males/females, outcome (flatfoot type), data collection instrument, the cutoff score used, prevalence estimates, and associated factors. Two authors did studies' eligibility review, quality assessment, and data extraction. They worked independently to identify, assess, and collect data from all studies. Any disagreement was resolved by a discussion with the third author.

## Data analysis

Descriptive data tables were developed to explore the articles' several extracted data. Microsoft Excel worksheet was used to calculate literature quality assessment scores and develop related graphs.

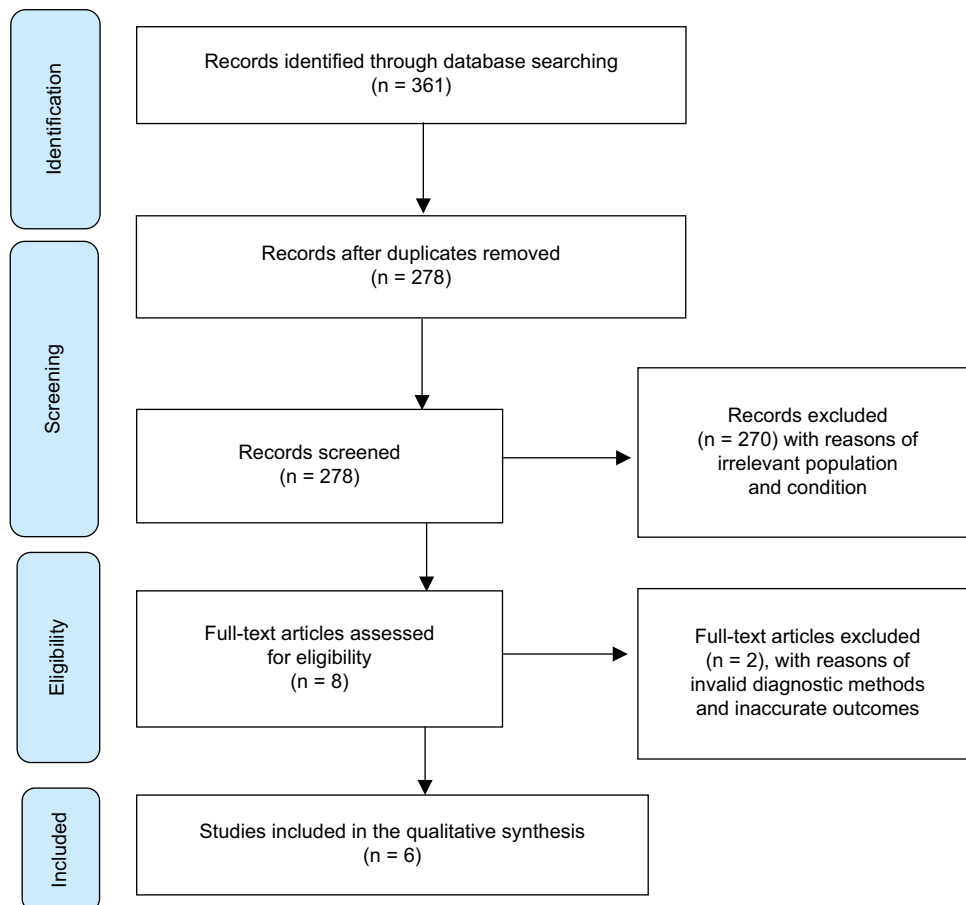
## RESULTS

The searched and screened articles were arranged according to the PRISMA flowchart [Figure 1]. The review yielded 361 published studies, of which 83 duplicates were excluded, and 278 were screened based on title and abstract. Two hundred and seventy were excluded due to irrelevant population and medical conditions resulting in eight eligible studies. However, after a full-text review, no further studies were excluded from the study. After the qualitative assessment, two out of the eight studies were excluded due to invalid diagnostic instruments and inaccurate outcomes reporting. Therefore, a total of six studies were included based on the authors' selection criteria. Manual searching did not reveal additional eligible articles.

## Studies main characteristics

A total of six studies, of which 6190 participants were included, published between January 2006 and March 2021, met the inclusion criteria. In addition, their quality was checked and had valuable quality scores [Figure 2].

All studies were conducted in Saudi Arabia from various geographical regions. The majority of the participants (5076; 82%) were from the Western region of Saudi Arabia, with only 533 (8.6%) from the central and 581 (9.4%) from the southern. Out of all the participants, only 208 (3.4%) were non-Saudis living in Saudi Arabia. The participants' age ranged from 4 years to 40 years. Bourgleh *et al.* and Alsuhaymi *et al.* included the pediatric population with a mean age of 4.2 and 10.5, respectively. Abdel Fattah *et al.*, Almaawi *et al.*, Khan *et al.*, and Alahmari *et al.* reported adult participants with a mean age of 19.1, 37, 21.3, and 21.7, respectively. All studies included both genders except for Abdel Fattah *et al.* participants, as only males were included. Females were 2328 (37.6%) and males were 3862 (62.4%) of the total number. Body mass index (BMI), age, and gender were the common factors studied. The studies main characteristics are summarized in [Table 2]. The included studies used several



**Figure 1:** The of flatfoot among Saudi population Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram.



**Figure 2:** Quality assessment scores of each included study using Joanna Briggs Institute critical appraisal tool.

assessment instruments with various cutoff values to detect the presence of flatfoot [Table 3].

### Prevalence

The literature on flatfoot prevalence in Saudi Arabia included participants in central, western, and southern regions with various age categories starting from toddlers to adults. Almaawi *et al.* conducted a flatfoot campaign in one of the biggest malls in Riyadh. People who were 18 years or older were asked to undergo feet examination by a podiatrist using three different footprint parameters (Clark's Angle, Chippaux-Smirak index, and Staheli index) to define foot arch. A total of 533 male and female participants were included in this study, with a mean age of  $37 \pm 11.26$  years, of which 417 (78.2%) were Saudis and 116 (21.8%) non-Saudis. Based on Clark's angle index, 221 (41.5%) right feet and 216 (40.5%) left feet had flattened arches. Similarly, 72 (13.5%) right feet and 67 (12.6%) left feet had flat arches based on the Chippaux-Smirak index, and 51 (9.6%) right feet and 45 (8.4%) left feet based on the Staheli index. According to Abdel Fattah *et al.*, among 2100 Saudi army recruits with an age group of 18–21 years in Taif, 104 (5%) participants were diagnosed with flatfeet. Khan *et al.* reported an estimated prevalence of 64 (25%) cases of flatfeet among 252 medical students using foot posture index-6 in King Abdulaziz University, Jeddah. They concluded that females had a higher flatfoot prevalence (81.75%) than males (18.75%). Likewise, Alahmari *et al.* reported that females (21.0%) had a higher incidence of pronation than males (16.8%). Out of the 581 patients, 110 (18.9%) had pronated and 41 (7.1%) had hyperpronated flatfeet using the FBI score at the outpatient physiotherapy department in King Khalid University, Abha. Alsuhaymi *et al.* conducted a study in Almadinah Almunawwarah, which showed that out of 403 school-aged children at multiple summer schools with ages ranging 7–14 years, flatfoot was witnessed in 119 (29.5%) students. Flexible flatfoot was found in 96.6% and rigid flatfoot was found in 3.4%, with the 7–8 age group being the highest. In Bourgleh *et al.*, 2321 patients <12 years old who visited a private pediatric orthopedic clinic had normal

musculoskeletal variation detected in 764 patients (32.9%), out of which 672 (88%) were Saudis, and 92 (12%) were non-Saudis. Flexible flatfoot was observed in 309 (41.9%) of these 764 patients.

### Factors associated with flatfoot

All articles studied the relationship between BMI and flatfoot except for Bourgleh's *et al.* study. Flatfoot was significantly higher among all participants with high BMI ( $P < 0.05$ ), excluding Alsuhaymi *et al.*, where no significant correlation was found ( $P = 0.636$ ). Out of six articles, five studied the relationship between age and flatfoot. Age was found to be a significant factor ( $P < 0.05$ ) in the development of flatfoot in four studies; while Khan *et al.* reported no significance ( $P = 0.08$ ). Bourgleh *et al.* ( $P = 0.73$ ) and Alsuhaymi *et al.* ( $P = 0.66$ ) found no significant association between gender and the occurrence of flatfoot. On the other hand, gender was significantly associated with flatfoot in Almaawi *et al.*, using Clark's angle ( $P = 0.001$ ) and in Khan *et al.*, using FPI-6 ( $P = 0.03$ ). Other predictors of flatfoot, such as residence, family history of flatfoot, and type of footwear during childhood, were reported to be significant in Abdel Fattah *et al.* study. Hypermobility, functional mobility, and balance were all significant variables mentioned in Alahmari's *et al.* article. Likewise, Khan *et al.* found that ligament laxity of the whole body was associated with flatfoot. Other factors are listed in [Table 4].

### DISCUSSION

This is the first systematic review that revealed a wide range of flatfoot prevalence among the Saudi population. The prevalence of flatfoot reported by different authors worldwide had great variations. The fact that the authors used different methods could explain these differences. Among adults, globally, a cross-sectional study conducted in Spain estimated the prevalence of flatfoot as 26.62% in 835 patients over the age of 40, with a higher incidence in older patients.<sup>[1]</sup> Japan which showed nearly identical results to Spain's exhibited a prevalence of 26.5%, with 340 (242 women and 98 men)

**Table 2:** Studies main characteristics.

| Study name (author/year)          | Geographic location (region/city)        | Participants population   | Sample size  | Age in years (Mean $\pm$ SD)                            | Gender, n (%)                                 | Studied variables  |
|-----------------------------------|--|---|--|---|---|--|
| Abdel Fattah <i>et al.</i> , 2006 | • Western<br>• Taif                      | Male army, Recruitment Center at Al-Hada Armed Forces Hospital                    | 2100   | 19.13 $\pm$ 0.43  | Males only                                    | <ul style="list-style-type: none"> <li>• Body mass index</li> <li>• Residence</li> <li>• Foot site</li> <li>• Mobility</li> <li>• Heel condition</li> <li>• Associated deformities in the knee</li> <li>• Other congenital deformities</li> <li>• History of accident</li> <li>• Family history</li> <li>• History of rheumatoid</li> <li>• Usual wear during childhood</li> </ul> |
| Almaawi <i>et al.</i> , 2019      | • Central<br>• Riyadh                    | Outpatients, Department of Orthopedics, College of Medicine, King Saud University | 533<br>• Saudis: 417 (78.2%)<br>• Non-Saudis: 116 (21.8%)  | 37 $\pm$ 11.26  | • Females: 315 (59.1)<br>• Males: 218 (40.9)  | <ul style="list-style-type: none"> <li>• Height</li> <li>• Weight</li> <li>• Body mass index</li> <li>• Nationality</li> </ul>   |
| Alsuhaymi <i>et al.</i> , 2019    | • Western<br>• Almadinah<br>Almunawwarah | Students, various summer schools  | 403  | 10.5  | • Females: 210 (52.1)<br>• Males: 193 (47.9)  | <ul style="list-style-type: none"> <li>• Height</li> <li>• Weight</li> <li>• Body mass index</li> <li>• Participation in sports</li> <li>• History of pain in the foot and ankle after physical activity</li> <li>• Location of the pain</li> <li>• Duration of activity that causes pain</li> <li>• Flat foot type</li> <li>Not reported</li> </ul>                               |
| Bourgleh <i>et al.</i> , 2019     | • Western<br>• Jeddah                    | Outpatients, private pediatric orthopedic clinic                                  | 2321<br>Participants with normal musculoskeletal variation: 764 (32.9%)<br>• Saudis: 672 (88%)<br>• Non-Saudis: 92 (12%) | 4.2 $\pm$ 3.6   | • Females: 1367 (58.9)<br>• Males: 954 (41.1) | <ul style="list-style-type: none"> <li>• Body mass index</li> <li>• Flexibility of the whole body</li> <li>• Flexibility of the ankle</li> </ul>   |
| Khan <i>et al.</i> , 2020         | • Western<br>• Jeddah                    | Students, applied medical sciences at King Abdulaziz University                   | 252  | 21.28 $\pm$ 1.29  | • Females: 146 (57.9)<br>• Males: 106 (42.1)  | <ul style="list-style-type: none"> <li>• Body mass index</li> <li>• Flexibility of the whole body</li> <li>• Flexibility of the ankle</li> </ul>   |
| Alahmari <i>et al.</i> , 2021     | • Southern<br>• Abha                     | Outpatients, Physiotherapy Outpatient Department, King Khalid University          | 581  | • Males: 2182 $\pm$ 1:57<br>• Females: 21:68 $\pm$ 1:73 | • Females: 290 (49.9)<br>• Males: 291 (50.1)  | <ul style="list-style-type: none"> <li>• Height</li> <li>• Weight</li> <li>• Body mass index</li> <li>• Balance</li> <li>• Functional mobility</li> <li>• Joint hypermobility</li> </ul>   |

**Table 3:** Included studies' assessment instrument and cutoff values.

| Study name (author/year)          | Assessment instrument   | Cutoff values   |
|-----------------------------------|---|---|
| Abdel Fattah <i>et al.</i> , 2006 | Planter footprints were applied and classified according to denis   | Footprint was then classified as three grades: <ul style="list-style-type: none"> <li>• Grade 1: The support of the foot lateral edge is half the support of the metatarsal</li> <li>• Grade 2: The support of the foot central zone and forefoot are equal</li> <li>• Grade 3: The support in the foot central zone is greater than the metatarsal support width</li> </ul>  |
| Almaawi <i>et al.</i> , 2019      | Three types of footprints parameters: <ul style="list-style-type: none"> <li>• Clark's angle</li> <li>• Chippaux-Smirak index</li> <li>• Staheli index</li> </ul>   | <ul style="list-style-type: none"> <li>• Clark's angle: <ul style="list-style-type: none"> <li>• Normal: Between 42° and 54°</li> <li>• Flat arch &lt;41°</li> <li>• High arch &gt;55°</li> </ul> </li> <li>• Chippaux-Smirak index: <ul style="list-style-type: none"> <li>• Normal arch if the ratio is between 25% and 45%</li> <li>• Flat arch &gt;45%</li> <li>• High arch &lt;25%</li> </ul> </li> <li>• Staheli index: <ul style="list-style-type: none"> <li>• High arch (0.1–0.4)</li> <li>• Normal arch (0.5–0.7)</li> <li>• Flat arch (0.8–1.2)</li> </ul> </li> </ul> |
| Alsuhaymi <i>et al.</i> , 2019    | <ul style="list-style-type: none"> <li>• Footprint method was applied on both feet (Foot Imprinter Apex Harris Mat Set)</li> <li>• Staheli's Arch Index</li> </ul>  | Flatfoot: Staheli plantar arch index >1.15  |
| Bourgleh <i>et al.</i> , 2019     | <ul style="list-style-type: none"> <li>• As reported by a certified pediatric orthopedic surgeon's musculoskeletal evaluation</li> <li>• In accordance with the standard protocol through data record forms</li> <li>• X-ray test was requested in some cases based on the necessity</li> </ul> | Not reported  |
| Khan <i>et al.</i> , 2020         | <ul style="list-style-type: none"> <li>• Foot posture index-6 item version (FPI-6)</li> </ul>   | Foot posture was classified as: <ul style="list-style-type: none"> <li>• Normal (0–5)</li> <li>• Pronated (+6–+12)</li> <li>• Supinated (-1--12)</li> <li>• Maximum supination and pronation (indicated by grades of +12 and -12, respectively)</li> </ul>  |
| Alahmari <i>et al.</i> , 2021     | <ul style="list-style-type: none"> <li>• Foot posture index (FPI)</li> </ul>  | Each criterion scoring followed a scale of -2, -1, 0, +1, or +2<br>Scores were added for each criterion: <ul style="list-style-type: none"> <li>• Highly supinated foot: -5 to -12</li> <li>• Supinated foot: -1 to -4</li> <li>• Normal foot: 0 to +5</li> <li>• Pronated foot: +6 to +9</li> <li>• Highly pronated foot: +10 to +12</li> </ul>  |

participants aged 60 and above who were neither hospitalized nor disabled in their regular activities.<sup>[14]</sup> In Saudi Arabia, Almaawi *et al.* used three different footprint parameters: Clark's angle, Chippaux-Smirak index, and Staheli index, to define foot arch.<sup>[15]</sup> As shown in [Table 4], there are wide variations between the results of each parameter in the study. However, the Chippaux-Smirak and Staheli indices exhibited a significant concordance in diagnosing flatfoot with kappa value >0.8 and  $P < 0.05$ .<sup>[15]</sup> In India, a cross-sectional study was

done in 2017 with 500 healthy Indian participants (250 males and 250 females) aged 18–21 years who reported a flatfoot prevalence of 13.6% (12.8% of males and 14.4% of females).<sup>[16]</sup> Abdel-Fattah *et al.* reported a flatfoot prevalence of 5% in 2100 male army recruits in Taif, Saudi Arabia, in a similar age group.<sup>[17]</sup> Worth noting, there may be an inherent bias as known patients with flatfoot would not apply to the military. In addition, Khan *et al.* concluded that among 252 participants aged 18–25 years, 64 (25%) of the cases had flatfoot using

**Table 4:** Included Studies' Overall Prevalence Estimates and Associated Factors

| Study Name (Author/ Year)    | Overall Prevalence Estimates n (%)   | Significant Associated Factors (P-Value < 0.05)   | Non-Significant Associated Factors   |
|------------------------------|--|---|--|
| 1. Abdel Fattah et al., 2006 | • 104 (5%)   | <ul style="list-style-type: none"> <li>• Residence</li> <li>• Body Mass Index</li> <li>• Family history of flat foot</li> <li>• The type of usual footwear during childhood</li> </ul>            | <ul style="list-style-type: none"> <li>• History of accidents with ruptured feet tendons and/or ligaments in feet</li> <li>• History of rheumatic arthritis.</li> </ul>          |
| 2. Almaawi et al., 2019      | <ul style="list-style-type: none"> <li>• Prevalence according to footprint parameters:</li> <li>• Clark's angle: <ul style="list-style-type: none"> <li>• Right = 221 (41.5 %)</li> <li>• Left = 216 (40.5 %)</li> </ul> </li> <li>• Chippaux-Smirak Index: <ul style="list-style-type: none"> <li>• Right = 72 (13.5 %)</li> <li>• Left = 67 (12.6 %)</li> </ul> </li> <li>• Staheli Index: <ul style="list-style-type: none"> <li>• Right = 51 (9.6 %)</li> <li>• Left = 45 (8.4 %)</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• Age</li> <li>• Body Mass Index</li> <li>• Gender</li> </ul>  | <ul style="list-style-type: none"> <li>• Nationality</li> </ul>  |
| 3. Alsuhaaymi et al., 2019   | <ul style="list-style-type: none"> <li>• 119 (29.5%)</li> <li>• Flexible flatfeet: 115 (96.6%)</li> <li>• Rigid flatfeet: 4 (3.4%)</li> </ul>  | <ul style="list-style-type: none"> <li>• Age</li> </ul>   | <ul style="list-style-type: none"> <li>• Gender</li> <li>• Body Mass Index</li> <li>• Participation in sports</li> <li>• History of foot pain after physical activity</li> </ul> |
| 4. Bourgleh et al., 2019     | • 309 (41.9%)  | <ul style="list-style-type: none"> <li>• Age</li> </ul>   | <ul style="list-style-type: none"> <li>• Gender</li> </ul>   |
| 5. Khan et al., 2020         | • 64 (25.4%)   | <ul style="list-style-type: none"> <li>• Flexibility of the whole body</li> <li>• Body Mass Index</li> <li>• Gender</li> </ul>  | <ul style="list-style-type: none"> <li>• Age</li> <li>• Flexibility of the ankle</li> </ul>  |
| 6. Alahmari et al., 2021     | <ul style="list-style-type: none"> <li>• Pronated foot: 110 (18.9%)</li> <li>• Hyper-pronated foot: 41 (7.1%)</li> </ul>   | <ul style="list-style-type: none"> <li>• Age</li> <li>• Height</li> <li>• Weight</li> <li>• Body Mass Index</li> <li>• Hypermobility</li> <li>• Functional mobility</li> <li>• Balance</li> </ul> | <ul style="list-style-type: none"> <li>• Nil</li> </ul>  |

FPI-6 in Jeddah, Saudi Arabia.<sup>[18]</sup> Noticeably, females showed a higher flatfoot prevalence (81.75%) than males (18.75%).<sup>[18]</sup> According to Alahmmari *et al.* article, out of 581 individuals, 110 (18.9%) pronated and 41 (7.1%) hyperpronated feet were found; similar to the previous literature, females (21.0%) had greater pronation rates than males (16.8%).<sup>[19]</sup> Likewise, in Boston, the United States, a study reported that the incidence of flatfoot in females is higher by 3% than in males.<sup>[20]</sup>

In children, flatfoot has been reported as one of the most common foot disorders internationally.<sup>[3]</sup> A study in Austria that included 835 children aged 3–6 years reported that 44% of them had flexible flatfoot, and males had a greater tendency.<sup>[21]</sup> In Taiwan, a study with 2083 children aged 7–12 years estimated that 59% had flatfoot.<sup>[22]</sup> Similarly to Austria, flatfoot is twice as common in males as in females.<sup>[21,22]</sup> A cross-sectional study was conducted in Islamabad on 714 students aged 6–10 years.<sup>[23]</sup> It showed that the prevalence of flatfoot was 14.8% and more common in males as in the Taiwanese and Austrian studies.<sup>[21–23]</sup> In Jeddah, Bourgleh's *et al.* study aimed

to determine the normal musculoskeletal variations in 2321 children (88% Saudis) who were <12 years of age, and reported that 309 (41.9%) had flatfoot.<sup>[24]</sup> In Alsuhaaymi *et al.* article, the 7–8-year-old group had the highest rate of flatfoot out of 403 school-aged children from various summer schools in Almadinah Almunawwarah, similar to the Taiwanese study.<sup>[25]</sup>

Multiple studies examined the association between gender and the presence of flatfoot.<sup>[15,18,26]</sup> In Nigeria, a study revealed a significant association between flatfoot and gender, in which flatfoot was 3 times more prevalent in females than males.<sup>[26]</sup> Similarly, two studies, Almaawi *et al.* and Khan *et al.* done in Saudi Arabia, have found that females are more prone to the development of flatfoot than males.<sup>[15,18]</sup> Khan's *et al.* article showed that wearing high heels among young adult females were a possible risk factor for the increased prevalence of flatfoot in females using the center of pressure excursion index.<sup>[18]</sup> When comparing genders in Almaawi *et al.* study, females had a higher prevalence of foot pronation using Clark's angle, while Chippaux-Smirak index and Staheli

index showed higher prevalence in males.<sup>[15]</sup> Contradictory to our studies, a study in the United States, Texas, concluded that flatfoot deformity was strongly associated with the male gender.<sup>[27]</sup> This is thought to be due to the fact that the majority of participants were from the veteran population.<sup>[27]</sup> Globally, the prevalence of flatfoot varies with age.<sup>[27,28]</sup> Age was thought to be the primary predictive factor for flatfoot in a study done in Congo, Central Africa, where the youngest age group, 3–4 years, had a higher proportion of a descending medial arch.<sup>[28]</sup> Consistent with the previous article, Bourgleh *et al.* examined the prevalence of flatfoot among children aged 12 years or younger, and concluded that the highest incidence age at presentation was between 3 and 4 years.<sup>[24]</sup> Likewise, Alsuhaymi *et al.* studied children aged 7–14 years old and found that age was significantly associated with flatfoot.<sup>[25]</sup> Among other age groups, the 7–8 years group was rated the highest in prevalence.<sup>[25]</sup> Alahmari *et al.* investigated the significance of age in younger adults aged 18–25, while Almaawi *et al.* participants were older adults aged more than 45 years.<sup>[15,19]</sup> Both found a significant relationship using different foot posture measurements.<sup>[15,19]</sup> BMI is strongly related to the development of foot deformities.<sup>[29]</sup> In one Indian study, the distribution of flatfoot was found to be most prevalent in individuals categorized as morbidly obese with a BMI of 40 or more.<sup>[29]</sup> Thus, the study concluded a directly proportional relationship between BMI and flat-arched foot.<sup>[29]</sup> Similar results also illustrated a significant correlation between high BMI and flatfoot, which multiple authors have concluded in various countries.<sup>[15,17,18,26]</sup> This relationship is thought to be due to pressure over the foot arch caused by fat deposition, which leads to extreme mechanical loading while walking.<sup>[26]</sup> Equivalent to the previous studies, in Saudi Arabia, four articles showed a significant correlation between the flat-arched foot and an increased BMI.<sup>[15,17-19]</sup> Inconsistent with the aforementioned studies, Alsuhaymi *et al.* article showed no significant relationship.<sup>[25]</sup> Notably, a slight increase in weight could crucially affect the plantar fascia, while a slight weight reduction can drastically decrease plantar loading.<sup>[15]</sup> One study showed that losing more than 2 kg could ease foot pain and control functional limitations.<sup>[15]</sup>

The literature regarding the use of footwear during early childhood and its association with the occurrence of flatfoot is consistent both globally and locally.<sup>[17,30]</sup> In India, a survey that included 2300 children stated that children who wore shoes had a significantly higher prevalence of flatfoot than barefooted children.<sup>[30]</sup> Likewise, Abdel Fattah *et al.* reported that the type of footwear used during early childhood was a key factor in diagnosing flatfoot later in life.<sup>[17]</sup> This establishment was done by studying both children who wore shoes and those who were barefooted.<sup>[17]</sup> To the best of our knowledge, only Abdel Fattah *et al.* examined the relationship between flatfoot and family history, which was a highly

significant risk factor.<sup>[17]</sup> Other multiple significant factors associated with flatfoot, such as hypermobility, functional mobility, the flexibility of the whole body, and balance, have been reported in several articles.<sup>[18,19]</sup>

### Limitations

Significant results heterogeneity found in the included studies suggested associations with multiple reasons, including various studies' methods and diagnostic instruments.

### CONCLUSION

Most of the included studies reported that BMI, age, gender, residence, family history of flatfoot, type of footwear during childhood, hypermobility, functional mobility, balance, and ligaments laxity of the whole body had a significant impact on the prevalence of flatfeet.

### RECOMMENDATIONS

High-quality multicenter epidemiological studies are required. Adopting standardized diagnostic instruments are essential to enable and identify the existence of flatfoot accurately and allow valid and generalizable recommendations.

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### AUTHORS' CONTRIBUTIONS

ASA: Reviewer of the study selection, reviewer of the quality assessment, and manuscript writing. MIA: Reviewers of the study selection, reviewer of the data extraction, and manuscript writing. SHA: Reviewer of the study quality assessment and manuscript writing. RKA: Reviewer of data extraction, reviewer of the study selections, and manuscript writing. ASA: Reviewer of the study quality assessment, data extraction, and manuscript writing. AHJ: Principal investigator and supervisor. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

### ETHICAL APPROVAL

Research ethics board approval was gained before starting any study procedure. This review's ethical approval was obtained from the KAIMRC in Saudi Arabia (IRB Ethical approval no: RYD-21-419812-117792) (IRB Ethical approval date: August 25, 2021).



## DECLARATION OF PATIENT CONSENT

Patients' consent was not required as there are no patients in this review.

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## CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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