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Original Article

# The Prevalence of Flatfoot in Taoyuan Teenagers

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**Background:** The prevalence of flatfoot is various among each age group, and whether children with flatfoot should receive treatment or not is still controversial. Most studies of flatfoot in Taiwan place emphases on children but not on teenagers. This research aimed to establish a database of a prevalence of flatfoot among Taiwanese local teenagers.

**Methods:** Five hundred forty-four 12- to 14-year-old teenagers in Taoyuan were enrolled in this study. Footprint analysis methods were used to diagnose a flatfoot (plantar arch index more than 1.15 or Denis grade equal or more than grade 1 or footprint index less than 1 cm). The height, body weight, and body mass index were recorded and compared using independent *t* tests to identify the statistical significances between teenagers with and without a flatfoot.

**Results:** The prevalence of flatfoot in teenagers in Taoyuan, Taiwan, ranged from 11.6% to 37.6%. This variation was attributed to the different footprint analysis methods used. The prevalence of flatfoot was highly correlated with body weight and body mass index.

**Conclusions:** The prevalence of flatfoot in teenagers in Taoyuan, Taiwan, was relatively higher than that reported in other studies. The causes may be the initial differences between races and the increased body weight of teenagers in Taiwan. These hypotheses need further studies to confirm. ( Tw J Phys Med Rehabil 2010; 38(4): 223 - 228 )

**Key Words:** flatfoot, teenager, prevalence, BMI

## INTRODUCTION

Flatfoot is one of the most discussed pathological changes in the foot. The prevalence of flatfoot shows significant diversity among age groups.[1-3] It decreases significantly with age: in the group of 3-year-old children, 54% showed a flatfoot, whereas in the group of 6-year-old children only 24% had a flatfoot.[4] As children grow and their foot arches develop, flatfoot becomes less common especially with those older than 10 years of age.[4,5] Therefore, the timing for definitive flatfoot treatment is still controversial.[6,7]

In Taiwan, there are no reports about flatfoot in teenagers. However, complications of flatfoot often happen after adolescence, which might have a negative physical and psychosocial influence on the patient's life.[8] Thus, even though the population of teenagers' flatfoot is not as large as children's, relevant studies and therapies for flatfoot in teenagers should not be neglected.

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Footprint analysis is often used for a flatfoot screening. It is a type of noninvasive examination with no radiation exposure. Types of footprint analyses include plantar arch index,[9] Denis grade,[6] and footprint index.[10,11] Our aim with this study was to establish the prevalence of teenagers with a flatfoot in Taoyuan by the footprint analysis.

## METHODS

We recruited 544 teenagers aged between 12 and 14 years old from 7th-grade junior high school in Taoyuan, Taiwan. Teenagers were excluded if they had an inability to perform the examination. Forty-eight teenagers were excluded because of refusals. Another 22 teenagers did not cooperate with the footprint sampling and were excluded. Therefore, 474 teenagers (233 boys and 241 girls) were enrolled. Body weight, height, and static standing footprints were also recorded. The static footprint for each foot was recorded on a Harris-Beath mat during half body weight-bearing position.[12] Clinical diagnoses of a flatfoot were based on three different footprint analysis methods, including plantar arch index more than 1.15 (Figure 1A),[9] Denis grade equal to or more than grade 1 (Figure 1B),[6] and footprint index less than 1 cm (Figure 1C).[11] All footprint samples were analyzed by the same physical medicine and rehabilitation doctor.

## STATISTICAL ANALYSIS

The prevalence of flatfoot diagnosed from three different footprint analysis methods was calculated. The height, body weight, and body mass index (BMI) were compared using independent *t* tests to identify the statistical significance between teenagers with and without a flatfoot.

The data were analyzed using SPSS 15.0 (SPSS 15.0 for Windows; Chicago, IL). The statistical significance was defined as a probability value less than 0.05.

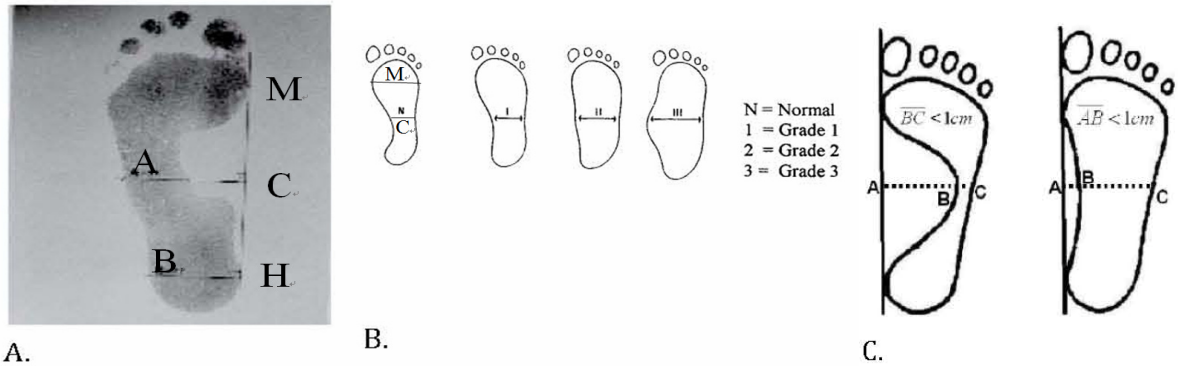


Figure 1. Footprint analysis methods

A: Plantar arch index is calculated as follows: a line drawn tangential to the medial forefoot edge (M) and at heel region (H). The mid point of this line (C) is calculated. From this point, a perpendicular line is drawn crossing the footprint. The same procedure is repeated for the heel tangency point (H). We thereby obtain the measurement of the support width of the central region to the foot (A) and at the heel region (B) in millimeters. The plantar arch index (PI) is a ratio of A to B (PI = A/B). A/B≦0.3 means high arch foot and A/B > 1.15 means flatfoot.[9]

B: Denis grade of flatfoot: grade 1: the support of the lateral edge of the foot (C) is half of that of the metatarsal support (M) (0.5≦C/M < grade 2); grade 2: the support of the central zone and forefoot are equal (equal is defined as 0≦M-C≦1cm); grade 3: the support in the central zone of the foot is greater than the width of the metatarsal support (C/M>1).[6]

C: Footprint index: Left: BC line segment is the narrowest distance of the footprint. BC<1 cm is defined as a high arch foot. Right: AB line segment is the widest distance of the indentation of footprint. AB<1 cm is defined as flatfoot.[11]

## RESULTS

A total of 474 teenagers were recruited in this study. There was no significant differences between BMI of boys and girls ($p$ = 0.167), although there was a significant difference of body weights between the gender ($p$ = 0.049; Table1).

The prevalence of flatfoot diagnosed by plantar arch index was 19.8% (n = 94);37.6% (n = 178) by Denis grade; and 11.6% (n = 55) by footprint index. The prevalence of flatfoot diagnosed by fulfilling all three criteria was 11.6% (n = 55; Figure 2).

When diagnosed by all methods including plantar arch index, Denis grade, and footprint index, patients with flatfoot showed significantly higher body weight and BMI ($p$ < 0.05, Table 2).

## DISCUSSION

There are many methods for a flatfoot diagnosis.[13-16] Compared with radiographic measurement and measurement of foot pressure distribution, the footprint analysis methods have the advantages of low cost, no radiation exposure, and no limitation of distant areas far from hospitals. The footprint analysis methods used in this research (e.g. plantar arch index, Denis grade, footprint index) only needed rulers as measurement tools, but no requirements to calculate the area or the curve length.

Table 1. Characteristics of the participants according to sex

| Characteristic | Male (N=233) | Female (N=241) | $p$ value |
|---|---|---|---|
| Height (m) | 1.53 ± 0.08 | 1.52 ± 0.06 | 0.096 |
| Body weight (kg) | 48.6 ± 13.4 | 46.3 ± 11.2 | 0.049 |
| Body mass index* | 20.49 ± 4.51 | 19.94 ± 4.09 | 0.167 |

Values are mean ± standard deviation.

*Body mass index is the weight in kilograms divided by the square of the height in meters.

Table 2. The height, body weight, and body mass index in flatfoot and non-flatfoot groups

| | Plantar arch index | Denis grade | Footprint index |
|---|---|---|---|
| | Flatfoot (N=94)/ Non-flatfoot (N=380) | Flatfoot (N=178)/ Non-flatfoot (N=296) | Flatfoot (N=55)/ Non-flatfoot (N=419) |
| Height (m) | 1.51±0.07/1.52±0.07 | 1.51±0.08/1.52±0.06 | 1.51±0.08/1.52±0.07 |
| Body weight (kg) | 51.39±15.14/46.49±11.44* | 50.51±14.83/45.63±10.27* | 51.87±17.22/46.89±11.52* |
| BMI | 22.07±5.58/19.75±3.79* | 21.63±5.14/19.35±3.44* | 22.23±6.17/19.94±3.93* |

*P < 0.05

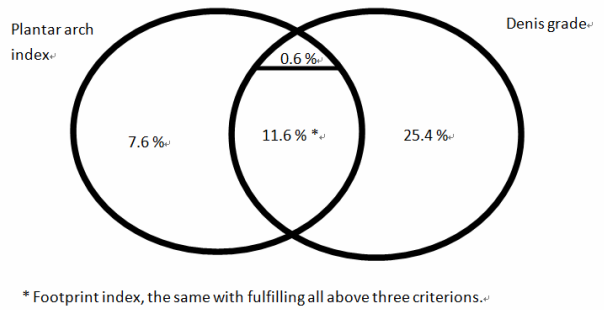


Figure 2. The prevalence of flatfoot diagnosed by different footprint methods.

In this study, we found great variations among prevalence of flatfoot diagnosed by different footprint analysis methods (prevalence was 11.6% by footprint index versus 37.6% by Denis grade). Nikolaidou et al analyzed the static standing footprints from 132 schoolchildren (average, 10.4 years old) and diagnosed the flatfoot by four different methods including arch index (AI), Martirosov's K index (KI), Chippaux-Smirak index (CSI), and footprint angle (FPA).[13] They found that there were variations among diagnoses of flatfoot by different

methods (CSI, 2%, versus FPA, 31%). These articles reporting of large variation are similar to our findings.

The results of past studies showed that the prevalence of flatfoot varies among different races and ages. In this study, we found that the prevalence of flatfoot was also affected by diagnostic analysis methods. Therefore, it might be better to use the same diagnostic method if we wanted to compare the prevalence of flatfoot between teenagers and children, predict the natural course of flatfoot and foot arch development, or analyze the impact of different regions or age groups.

García-Rodríguez et al examined 1,181 schoolchildren (age ranges from 4 to 13 years old) in Spain and used a Denis grade of more than 1 (means grade 2 or grade 3) as the diagnostic criterion for the flatfoot.[6] The prevalence of flatfoot was 2.7% in their study and was similar to our study (Denis grade 2 or 3 were 4.2% in right foot, 4.8% in left foot, and 2.3% in both feet). They also found that 75% of flatfoot was found in the first 2-year age group (4 and 5 years) and the remaining 25% was distributed between the second and third groups (12.5% in 8 and 9 years, and 12.5% in 12 and 13 years, respectively). This might suggest that the condition of flatfoot patients is more likely to improve before 8 years old.

Hernandez et al examined 100 children in Brazil (age range from 5 to 9 years old) and calculated the plantar arch index.[9] Their results showed that children in Brazil seemed to have higher plantar arch than teenagers in Taoyuan, Taiwan (plantar arch index, 0.67 in right, 0.61 in left foot of Brazilian children versus 0.83 in right, 0.82 in left foot of teenagers in Taiwan). This might suggest that the prevalence of flatfoot in Taoyuan was higher than the one reported in Brazil.

Wenger et al stated that flexible flatfoot is a manifestation of a constitutional laxity affecting all ligaments and joints.[17] Cheng et al measured 2,360 normal Chinese children aged from 3 to 13 years and found that Chinese children were far more lax throughout the age range, with 100% “laxity” at age 3, 67% laxity at age 6, and 28% laxity at age 12, while the laxity in the same Caucasian age group was 50%, 5%, and 1%, respectively.[18] These may be one of the reasons why Taiwanese have a higher prevalence of flatfoot.

Pfeiffer et al found the prevalence of flat foot is influenced by three factors: age, sex, and weight. [3] In overweight children and in boys, a highly significant prevalence of flatfoot was observed. In the present study, patients with flatfoot diagnosed by one of the three footprint analysis methods showed significantly larger body weight and BMI. Otsuka et al collected 242 women and 98 men aged 60 years or older and found a significant positive association between obesity and flatfoot.[19] However, the actual correlation between body weight and flatfoot was still under investigation, and needs further studies to be confirmed.

A limitation of our study was that the teenagers enrolled in it were confined to a junior high school, and the limited sample size might not represent the whole teenage group in Taiwan. It was difficult to analyze whether living in rural or urban areas had any impacts on the foot arch development.

## CONCLUSION

In this study, the prevalence of flatfoot in teenagers in Taoyuan, Taiwan, was 11.6% to 37.6%. This variation was attributed to the different footprint analysis methods used. The prevalence of flatfoot in teenagers in Taoyuan, Taiwan, was relatively higher than in other studies. The causes may be the initial differences between races and the increased body weight of teenagers in Taiwan. We should pay more attention to the relationship between foot problems and increasing body weight in Taiwan teenagers.

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# 桃園地區青少年扁平足盛行率

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前言：扁平足盛行率隨著年齡層的不同而相異，對於扁平足兒童是否應接受治療目前也尚無共識。在台灣，絕大部分對於扁平足的研究都局限於兒童而少見針對青少年的報告，因此，本研究之目的在於建立台灣局部地區青少年扁平足之盛行率之資料。

方法：本實驗收錄 544 位 12 至 14 歲台灣桃園的青少年，運用三種足印分析法(包含 plantar arch index 大於 1.15；Denis grade 大於等於 1；footprint index 小於 1 公分) 作爲診斷扁平足的依據，同時量測身高、體重並計算身體質量指數(BMI)。另使用獨立樣本 t 檢定分析扁平足與非扁平足青少年在身高、體重、身體質量指數與性別上是否有差異。

結果：桃園區青少年扁平足之盛行率介於 11.6%到 37.6%之間，其差異來自於分析方式之不同，另外，扁平足青少年相較於非扁平足青少年有較重的體重及較大的身體質量指數。

結論：台灣桃園地區青少年之扁平足盛行率相對高於其他研究，其原因可能是人種間既存的差異以及台灣青少年日漸增高的肥胖問題，此推論仍有待更多的實驗予以證實。（台灣復健醫誌 2010；38(4)：223 - 228）

**關鍵詞：**扁平足(flatfoot)，青少年(teenager)，盛行率(prevalence)，身體質量指數(BMI)

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