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ORIGINAL ARTICLE

Overweight, obesity and foot posture in children: A cross-sectional study

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Aim: The aim of this study is to examine the relationship between obesity and foot posture in children.

Methods: This cross-sectional study is based on a sample population of 1798 schoolchildren (873 boys and 925 girls) aged between 6 and 12 years. The height and weight of each subject was measured and the body mass index (BMI) was calculated. Foot posture was described by means of the foot posture index (FPI). The differences among various foot postures in relation to BMI, for the total sample, were tested using the Games-Howell test. In addition, cross tabulation for different gender groups and BMI categories was applied and tested using χ^2.

Results: The mean BMI was 18.94 (standard deviation (SD) 3.65 kg/m^2) in the boys and 18.90 (SD 3.64 kg/m^2) in the girls, and the FPI was 3.97 (SD 2.98) in the boys and 3.68 (SD 2.86) in the girls. The FPI results show that among the boys aged 6 years, the right foot was more pronated than among the girls (FPI 4.8–4.1, P = 0.034), while among the boys aged 7 years, this was true for the left foot (4.4–3.7, P = 0.049). For the other ages, there were no significant differences in the FPI between the sexes. There were no significant differences between the value, or categories, of BMI and the FPI in the different age groups.

Conclusion: In children aged between 6 and 12 years, body mass does not appear to have an important bearing on static foot posture. Furthermore, the variables gender and age are of scant importance in determining foot posture in children.

Key words: children; cross-sectional study; foot posture; obesity; overweight.

What is already known on this topic

1 Obesity is a pandemic and growing public health concern, and has been also found to be linked with different musculoskeletal disorders, as biomechanical overload disorders of the lower limb.
2 However, the real impact of overweight and obesity on foot posture in children remains unclear.
3 Several studies have suggested that appropriate tools are needed to ensure validity and reliability in the diagnosis of flexible flatfoot in children.

What this paper adds

1 Obesity does not have any influence on foot posture in children so more research is needed in this direction.
2 This finding is in contrast with other studies that have observed an association between BMI and foot measurements.
3 Using FPI avoids possible influence of the volume of fat in the sole of the foot on the interpretation of the footprints.

In 2013, 42 million children under 5 years old had obesity or overweight,[1] which is one of the most serious healthcare problems of the twenty-first century.[2–4] Obesity and overweight are often related to musculoskeletal disorders, particularly of the lower limbs and feet.[5,6] In the UK, pain in the low back is the most prevalent in all age groups, whereas in children, the most common area of pain is the foot.[7]

The foot is a functional unit of the human body that plays a key role in balance[8,9] and movement.[9,10] The morphological and functional development of children's feet can be influenced by internal factors (sex, age and genetics) and by external ones (shoes, body weight and physical activity). The fact that obese children have a strong tendency to suffer flat feet is both predictable and well documented.[11–15]

It is a normal evolutionary process that children have flat feet when they start walking, as intrinsic ligamentous laxity and the lack of neuromuscular control result in a flattening of the foot under load.[16] In children aged between 1 and 5 years, there is an increased thickness of fat under the medial longitudinal plantar arch, which disappears from the age of about 5 years, when the foot structure approaches its mature form.[11] From 6 years of age, children develop an internal longitudinal arch that is very similar to the adult form.[17] However, it should be noted that the value of the 50th percentile for FPI increase in the children aged 12 years,

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in both genders, a circumstance that might indicate a point of transition from childhood to adolescence.[18,19]

However, many of the studies that have investigated the correlation between weight and foot posture in children have used the footprint as an objective assessment, parameters such as Clarke's angle (1933),[20] the Chippaux index (1947)[21] and the Arch index (Staheli, 1987)[18] have been used to study foot posture for over 25 years.[12,22] However, the footprint is only the contact area between the sole of the foot and the ground; it provides no information about bone structure.[23] In consequence, these measurements might confound excess plantar fat with a real decrease in the medial longitudinal arch.[24]

By contrast, the foot posture index (FPI) is a clinical assessment instrument consisting of six items used to assess the position of the foot in the three spatial planes, in order to measure the three functional units, namely the hindfoot, midfoot and forefoot, requiring no additional measuring instrument. It has acceptable validity[25] and has demonstrated good reliability both in adults[26] and in children.[27]

The aim of this study was to determine the relationship between the value of the body mass index (BMI) and its different categories and static foot posture in children aged between 6 and 12 years.

Methods

Participants

In this cross-sectional study, we examined and analysed schoolchildren aged between 6 and 12 years. The measurements were taken during 2013 and 2014. The examinations took place at eight schools randomly selected from 25 centres in the Spanish provinces of Malaga, Granada and Plasencia. The average age of the sample population was 8.29 ± 1.72 years, the average weight was 33.05 ± 9.35 kg, the average height was 1.31 ± 0.12 m and the average BMI was 18.90 ± 3.64 kg/m^2. A total of 93% of children were right-footed.

The following inclusion criteria were applied: age between 6 and 12 years, no pain in the foot at the time of examination, informed consent of parent/guardian. The parents were previously informed about the study, completed a questionnaire and signed the consent form to confirm the participation of their children. Participants with any of the following conditions were excluded from the study: recent injury to the leg, alterations in the foot bones, congenital structural changes that affected distal zones to the ankle joint, and flatfoot caused by cerebral palsy, surgical treatment in the foot or lower leg, or damage of a genetic, neurologic or muscular nature. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committees of the Universities of Extremadura and Malaga (Spain).

Weight classification

Body mass index

The height of each subject was measured to the nearest millimetre using a calibrated portable SECO 7710 with a spirit level attached to the arm for greater accuracy. Body mass was measured to the nearest 0.05 kg using calibrated Digital Pegasus Scales

Table 1 Characteristics of the sample in each body mass index (BMI) group by age and gender

Age (years)	BMI group														
	Total					Male					Female				
	Underweight ($P_{<3}$) *n* (%)	Normal ($P_{3–90}$) *n* (%)	Overweight ($P_{90–97}$) *n* (%)	Obesity ($P_{>97}$) *n* (%)	Total	Underweight ($P_{<3}$) *n* (%)	Normal ($P_{3–90}$) *n* (%)	Overweight ($P_{90–97}$) *n* (%)	Obesity ($P_{>97}$) *n* (%)	Total	Underweight ($P_{<3}$) *n* (%)	Normal ($P_{3–90}$) *n* (%)	Overweight ($P_{90–97}$) *n* (%)	Obesity ($P_{>97}$) *n* (%)	Total
6	7 (2.8)	222 (87.4)	18 (7.1)	7 (2.8)	254	3 (2.30)	110 (85.90)	12 (9.4)	3 (2.3)	128	4 (3.2)	112 (88.9)	6 (4.8)	4 (3.2)	126
7	10 (2.8)	312 (87.4)	25 (7)	10 (2.8)	357	3 (1.80)	148 (87.60)	12 (7.1)	6 (3.6)	169	7 (3.7)	164 (87.2)	13 (6.9)	4 (2.1)	188
8	10 (2.8)	316 (87.3)	26 (7.2)	10 (2.8)	362	5 (2.60)	170 (86.70)	16 (8.2)	5 (2.6)	196	5 (3)	146 (88)	10 (6)	5 (3)	166
9	7 (2.7)	230 (87.5)	19 (7.2)	7 (2.7)	263	4 (3.10)	110 (85.90)	9 (7)	5 (3.9)	128	3 (2.2)	120 (88.9)	10 (7.4)	2 (1.5)	135
10	7 (2.7)	222 (86.7)	20 (7.8)	7 (2.7)	256	4 (3.50)	99 (87.60)	8 (7.1)	2 (1.8)	113	3 (2.1)	123 (86)	12 (8.4)	5 (3.5)	143
11	7 (2.6)	233 (87.6)	18 (6.8)	8 (3)	266	6 (4.8)	109 (86.5)	6 (4.8)	5 (4)	126	1 (0.7)	124 (88.6)	12 (8.6)	3 (2.1)	140
12	1 (2.5)	35 (87.5)	3 (7.5)	1 (2.5)	40	1 (7.7)	11 (84.6)	0 (0)	1 (7.7)	13	0 (0)	24 (88.9)	3 (11.1)	0 (0)	27
	49	1570	129	50	1798	26	757	63	27	873	23	813	66	23	925

with subjects wearing minimal clothing (a T-shirt and shorts or skirt). The BMI was calculated from the subjects' height and weight (BMI = weight/height^2). Since the subjects were all from Spain where the Orbegozo classification is widely used, the subjects were then classified by their BMI score, using the classification system proposed by Orbegozo[28] divided into four categories as follows, underweight: percentile less than 3 ($P_{<3}$), normal weight: percentile between 3 and 90 ($P_{3–90}$), overweight: percentile between 90 and 97 ($P_{90–97}$) and obesity: percentile greater than 97 ($P_{>97}$), based on BMI according to age. Table 1 shows the number of children classified in each BMI group, by age.

Foot posture index

The FPI values were measured double-blind, by two podiatrists (JMA and PAG), both experienced in the use of this instrument, with good inter-rater reliability (0.852–0.895). Both podiatrists were blinded to the intentions of the study and to the identity of the participants. The same protocol as in other studies[29] was used. The subjects were evaluated in a relaxed standing position, on a bench at a height of 50 cm, to facilitate visual and manual inspection.

Statistical analysis

The sample size was estimated assuming a prevalence of children of 6–12 years of age 10%,[22] with an accuracy of 1.5%, and an alpha value of 0.05. For a total population of 200 922 children in the three provinces, a sample of 1525 children was necessary. This size was overestimated up to a 15% to cover potential drop-outs.

The SPSS 22.0 program (IBM Corp., Armonk, New York, USA) was used for the statistical analyses. After checking the normality (Kolmogorov–Smirnov) and homoscedasticity (Levene) of the data, a descriptive analysis of the variables was carried out. Bivariate analysis was performed using the Student t and the χ^2 tests for normally distributed data. Otherwise, the Mann–Whitney U and Kruskal–Wallis non-parametric tests were used. Analysis of variance was conducted to determine the association between the different BMI groups (underweight, normal, overweight and obesity) and the FPI values for both feet, applying the Games-Howell post hoc correction to identify significant differences. The significance level was set at $P < 0.05$ and all the analyses and tests were two-sided.

Results

The sample was integrated by 1798 schoolchildren (873 boys and 925 girls) aged between 6 and 12 years. The mean BMI was 18.94 ± 3.65 kg/m^2 in the boys and 18.90 ± 3.64 kg/m^2 in the girls, with no statistically significant difference by gender ($P = 0.834$) and age ($P = 0.785$).

Globally, FPI values in the right foot were slightly higher in boys compared with girls: 3.94 (standard deviation (SD) 2.99) versus 3.61 (SD 2.86) ($P = 0.026$). For FPI in the left foot, this difference remained, although it was not statistically significant: 4.01 (SD 2.97) versus 3.74 (SD 2.87) ($P = 0.072$).

Among the boys aged 6 years, the right foot was more pronated than was the case among the girls (4.8 ± 2.9; 4.1 ± 2.8, $P = 0.034$). Similarly, among the boys aged 7 years, the right foot was more pronated than among the girls (4.4 ± 2.8; 3.7 ± 3.1, $P = 0.049$). Only in the group aged 12 years did the girls have a more pronated foot than the boys (5.1 ± 2.1; 3.9 ± 1.8, $P = 0.037$). For the other ages, there were no significant differences in the FPI between boys and girls ($P > 0.05$, Table 2).

Table 2 Characteristics of the sample by age, foot posture index (FPI) score and gender

Age	FPI total score	*n*		Mean (SD)		*P*-value
		Male	Female	Male	Female	
6	Right	128	126	4.8 (2.9)	4.1 (2.8)	<0.05
	Left	128	126	5 (2.9)	4.2 (2.7)	0.068
7	Right	169	188	4.3 (2.9)	3.7 (3)	0.086
	Left	169	188	4.4 (2.8)	3.7 (3.1)	<0.05
8	Right	196	166	4.1 (3.1)	3.8 (2.7)	0.383
	Left	196	166	4.0 (3)	3.9 (2.8)	0.523
9	Right	128	135	3.3 (2.9)	3.2 (2.8)	0.792
	Left	128	135	3.3 (2.8)	3.4 (2.8)	0.728
10	Right	113	143	3.2 (2.8)	3.4 (2.8)	0.515
	Left	113	143	3.3 (2.8)	3.6 (2.9)	0.301
11	Right	126	140	3.5 (3.1)	3.1 (2.8)	0.214
	Left	126	140	3.7 (3.2)	3.2 (2.7)	0.214
12	Right	13	27	3.6 (2.2)	4.7 (2.5)	0.156
	Left	13	27	3.9 (1.8)	5.1 (2.1)	<0.05

SD, standard deviation.

The comparative analysis of the FPI, for the different categories of BMI, revealed no significant differences in the foot posture of the children (Table S1, Supporting Information). Among the subjects with underweight, the mean FPI was slightly higher than among the other groups, with 4.4 (SD 2.9) and 4.1 ± 2.9 for the left and the right foot, respectively, while among the other groups, this value decreased toward normal levels; thus, in subjects with normal weight the FPI was 3.8 ± 2.9 for the right foot and 3.9 ± 2.9 for the left foot; among those with overweight, the FPI was 3.5 ± 3 for the right foot and 3.7 ± 3 for the left foot; finally, among those with obesity, it was 3.2 ± 2.9 for the right foot and 3.1 ± 2.9 for the left foot. Thus, the latter BMI category presented the lowest degree of pronation.

Figure 1 shows the pattern of FPI for the different groups, according to their BMI.

Discussion

This paper addresses a reasonable, often-expressed doubt in the scientific literature, namely the existence or otherwise of a relationship between overweight/obesity and foot posture.

Our sample of 1798 children presented an average FPI of 3.8, which coincides with the findings of Redmond[19] and Evans *et al.*[30], of 3.8 and 4, respectively, and which are within normal parameters. This foot posture is almost one point more pronated than in the adult population, for which the average FPI is 3 among the general Spanish population.[31]

Among the boys aged 6 or 7 years, the feet were more pronated than was the case among the girls of the same age. This is

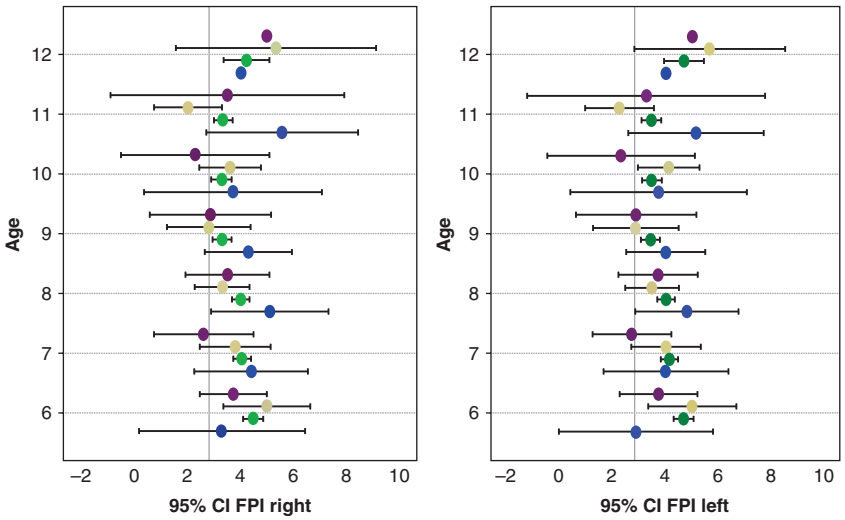

Fig. 1 Foot posture index (FPI) for the different groups according to body mass index. (⊢●⊣), Underweight; (⊢●⊣), normal; (⊢●⊣), overweight; (⊢●⊣), obesity. CI, confidence interval.

accounted for by the fact that at this age, the foot is still developing, and evolves naturally from a flattened (pronated) posture to a more neutral one.[16,17] Since girls develop earlier than boys, they seem to have already completed this stage of development and thus present lower FPI scores than the boys. At ages 8, 9, 10 and 11 years, no significant differences in the static foot posture were observed between boys and girls. This situation changed again at the age of 12, when the trend was reversed, with the girls having more pronated feet than the boys, because of a greater degree of laxity in female feet.[32]

The BMI results for our sample of schoolchildren are close to those obtained by Orbegozo in a similar sample,[28] in which around 10% of the population was overweight. However, the National Statistics Institute[33] recorded a higher percentage (15%) of obesity in Spanish children between 5 and 9 years. In the age range of 10–14 years, our sample contained 3% of subjects with obesity, which is in line with the values reported by the National Statistics Institute.[33]

Contrary to expectations, our results reflect no relationship between BMI and FPI. Thus, the feet of subjects with a lower BMI present a greater degree of pronation, while the results for obese subjects are closer to the criteria of normality defined in the evaluation criteria for the FPI. Presumably, the use of the FPI could influence the results, as it includes measurements taken in the three spatial planes and considers the three functional units of the foot (hindfoot, midfoot and forefoot). This finding is in contrast to studies that have observed an association between BMI and foot measurements. In these previous studies, however, the analysis performed was based on a single plane and used a different measuring element, that of the footprint.[12,13,22,34,35]

The FPI was used as a measurement instrument in order to obtain data enabling us to analyse the foot posture in all three spatial planes. Thus, we were able to quantify the overall position of the foot, while avoiding the possible influence of the volume of fat in the sole of the foot on the interpretation of the footprint.

In view of the results obtained, we suggest a more extensive, improved study should be performed, taking into account the family background, with data such as foot type, or pathological conditions such as joint hypermobility. We believe that some variables could be used in conjunction with BMI as a predictive instrument for musculoskeletal disorders in schoolchildren with overweight or obesity. Nevertheless, these results should be taken with caution, and we stress their limited scope of use; although a large population sample was analysed, it still constitutes a small proportion of the population in a very specific location. One potential limitation of our study is that the differences race and areas of the rest of the countries is not represented in the sample, so the data do not represent the global of population. Moreover, a study should be performed of a sample of children without weight limitations, which would improve the results, making them more representative and enabling us to confirm whether overweight has a direct impact on foot posture. We can not conclude whether footwear could influence or not in our results, as well as genetic predisposition, hence, future investigations should be focused on determine the influence of both aspects. In addition, healthcare programmes should be instituted to analyse the impact of this type of problem in the child population in the medium and long term.

Conclusion

In a general population of children aged between 6 and 12 years, with an incidence of 10% overweight, foot posture, measured by the FPI, becomes less pronated with increasing BMI, although the relationship is not statistically significant. Neither age nor gender is significantly associated with BMI or foot posture.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Analysis of the FPI and the different categories of BMI.