# Anthropometric and Psychomotor Development Factors Linked to Foot Valgus in Children Aged 6 to 9 Years

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**Abstract**

Background: Estimates of the prevalence of planovalgus foot vary widely (from 0.6% to 77.9%). Among the many factors that may influence the development of planovalgus foot, much attention has been paid to the body mass index, and especially that of children's feet, although factors related to the psychomotor development, have been less studied. The aim of this study was to determine the presence of planovalgus foot in children and its association with anthropometric parameters, and psychomotor development.

Methods: Case-control study conducted in Málaga (Spain), during 2012-2013, of 104 schoolchildren (in their first three years of primary education). Their average age was 7.55 years (SD: 0.89), and 45.2% were boys, and 54.8% girls. Age, sex, body mass index, presence of valgus (valgus index, obtained by pedigraphy), personal history related to psychomotor development of the lower limbs (presence/absence of crawling, age at onset of crawling, age at onset of walking, use of mobility aids such as a walking frame or brace) were evaluated.

Results: In the children with obesity, 53.7% had valgus deformity in the left hindfoot, while 46.3% did not ($p<0.0001$), OR 6.94 (95% CI: 2.72 to 17.70). In the right foot, the corresponding values were 54.5% vs. 45.5% ($p<0.0001$), OR 9.08 (95% CI: 3.38 to 24.36). Multivariate logistic regression showed there was an increased risk of left planovalgus foot in males, in children with overweight or obesity and in those who began walking later. For the right foot, the same risk factors apply, except for the age of onset of walking.

Conclusions: These results corroborate data from previous studies, which report an association between the presence of overweight and obesity and the onset of planovalgus foot in children. In addition, we identify a new risk factor: the age of onset

of walking.

**Key words:** Flatfoot, Infant obesity, Overweight, Child Development, Gait

## Introduction

Obesity is a chronic, complex and multifactorial disease, which usually begins in childhood and adolescence, and originates from a genetic and environmental interaction, in which the most important aspect is environmental or behavioural (lifestyle). It becomes established by an imbalance between energy intake and expenditure, and is characterised by excess body weight and volume, with an accumulation of body fat (1).

Obesity and overweight pose a global public health problem, and among children, the prevalence is increasing rapidly, throughout the world (2). In May 2004, the 57th World Health Assembly declared obesity the epidemic of the century and approved the creation of a strategy on nutrition, physical activity, obesity and health (3,4).

Diverse methods can be employed to assess obesity in childhood and adolescence, but the approach most commonly used in clinical practice and epidemiology is to study the relation between age, sex, weight, height and body mass index (BMI) (1). In adulthood (from age 18 years), a BMI cutoff value of 25 $kg/m^2$ is generally taken to define overweight, and one of 30 $kg/m^2$ for obesity (2). For children and adolescents, percentile curves (cutoff points between BMI and age) are normally used (2,5).

To date, no consensus has been agreed upon by the international scientific community concerning the definition of obesity for these age groups (5,6). There is controversy around the cutoff point in this definition (p95 or p97, depending on the country), and diverse reference tables are used, making it difficult the comparisons between studies performed in different countries (5-8).

For children, the two criteria that have received greatest international acceptance are those proposed by the WHO and by the International Obesity Task Force (IOTF). The WHO defines overweight according to percentiles, as P≥85 to P<95, and obesity as

P>95 (6), while the IOTF has published the following BMI reference values for adults: overweight ≥25 kg/m$^2$ and obesity ≥30 kg/m$^2$ (2,6).

In 2012, the WHO reported that about 44 million (6.7%) of the world's children aged under 5 years were overweight or obese (9). In 2012, according to the IOTF, overweight or obesity affected 64% of girls and 54.3% of boys in Mexico (10,11), 35.2% of girls and 33.2% of boys in the USA (10,12) and 25.4% of girls and 25.2% of boys in the UK (10). In 2012, the ALADINO study reported that 26.2% of children in Spain were overweight and that 18.3% were obese, while other studies have reported overweight and obesity values ranging from 30.8% to 44.5% (13).

Longitudinal studies suggest that childhood obesity, when present after the age of three years, is associated with an increased risk of obesity in adulthood and increased long-term morbidity and mortality, together with many cardiovascular and metabolic pathologies, and even cancer (14,15). In addition, overweight and obesity provoke important psychosocial consequences such as low self-esteem, social isolation, discrimination and abnormal behaviour (14).

Overweight and obesity have also been associated with orthopaedic problems, accompanied by reduced physical mobility and inactivity (14,15). Excess weight in childhood, as well as age, sex, race, joint laxity, place of residence, footwear and physical activity, are considered risk factors for paediatric planovalgus foot (PPVF) (16-21). Obesity can have negative consequences on the development of the musculo-skeletal system of the lower limbs, and especially on that of children's feet, due to the immaturity of their structures (22-24).

There is no universally-accepted definition of PPVF. This condition consists of a valgus deformity of the hindfoot associated with a reduction or flattening of the inner longitudinal arch. Flatfoot takes diverse forms: it may be painful or painless, flexible or rigid and functional or nonfunctional (25,26). Pathologic or rigid PPVF is often characterised by stiffness of the foot, which is incapacitating and requires treatment,

while physiologic or flexible PPVF is a normal variation, which causes no disability and tends to improve over time (26,27).

The estimated prevalence of PPVF varies widely, from 0.6% to 77.9%, due to the lack of criteria on distinguishing a pathologic condition from normality and to the absence of a universally-accepted definition. For preschool children, the estimated prevalence is around 45%, which falls to 15% for older children (at an average age of 10 years). In other words, the prevalence tends to fall with increasing age (20,21).

In 1999, García-Rodríguez et al. reported a prevalence of 2.7% among 1181 children aged 4-13 years (28). In contrast, in 2005 Pfeiffer et al. recorded 44% (among 835 children aged 3-6 years). The latter study observed an inverse relation between age and PPVF (3 years, 54%; 6 years, 24%) and a gender bias, with 52% of boys and 36% of girls being affected. Moreover, body weight was a relevant factor: PPVF was present in 51% of children with overweight, in 62% of those with obesity and in only 42% of those with normal body weight (29).

Further research is needed to reduce the disparity of criteria regarding the prevalence of PPVF because the absence of consensus means that the information provided is of very limited use in clinical practice. In addition, studies should be conducted of the factors that influence the appearance and development of PPVF. The focus has been centred in the body mass index, although factors related to the psychomotor development, have been less studied. Due to the increasing incidence and prevalence of obesity and overweight in children, and the lack of knowledge about how psychomotor development can influence in PPVF, there is a rising need of evaluating these factors, to enlighten decision making in the provision of podiatric care to this population group. Accordingly, in this study we aim to determine the prevalence of PPVF and to analyse the association between various anthropometric parameters, and the psychomotor development of children, as risk factors.

## Material and Methods

In 2012-2013, a case-control observational study was performed of a population of schoolchildren in the first, second and third years of primary school education (32.7%, 26.0% and 41.3%, respectively), at five schools in the city of Málaga (Spain). No sampling was performed; the entire study population was initially selected. Children were included if they belonged to any of the courses defined, their parents gave consent to their participation and they had no previous surgery on the foot, or that of any congenital malformation of the foot.

Cases were defined as those children with planusvalgus foot, and controls as those with normal foot. The presence or otherwise of valgus deformity was determined in each foot (for the diagnosis of planovalgus foot; although it is often associated with flatfoot, in the present study we considered only valgus deformity of the hindfoot, as reflected by the valgus index (32), calculated by pedigraphy of each foot in situ, differentiating the left foot from the right). The pedigraphy was performed using an ink pedigraph (reliability versus pressure platform obtained an intraclass correlation coefficient among 0.797 to 0.829 (33) with the child in a standing position, arms close to the body and standing evenly on both feet on a flat surface, the base angle of which The main exposure variables were body mass index (BMI) and age at onset of walking. BMI was obtained by anthropometric measurements of weight and height, taking into account international standardisation measures (30) and by reference to the WHO international definition, namely overweight in the range P≥85 - P<95 and obesity P>95 (6), and to the reference tables published by the Orbegozo foundation (31), which are frequently used in primary healthcare by paediatricians in Spain). These measurements were obtained using electronic scales (calibrated periodically) and with the children in their underwear and without shoes. Height was measured using standard portable measuring boards.

The children's parents or guardians were asked to complete a questionnaire on personal background related to psychomotor development of the lower limbs (performance or otherwise of crawling, age at which crawling began, age at onset of walking, and the use of mobility aids such as a walking frame or a brace. This questionnaire was designed specifically for the study and was previously subject to expert content validity by a panel integrated by seven podiatrists and one expert on clinimetrics research methods. A pilot version was tested among ten parents before its definitive use in the study.

Age in months (obtained from the administrative record of each school), and gender were also identified.

Analysis

Descriptive statistics were obtained as measures of central tendency (mean, median) and of dispersion (standard deviation and interquartile range) for the quantitative variables, depending on the normal distribution of variables. This normality was verified by the Kolmogorov-Smirnov test and by estimating the skewness and kurtosis of the distributions. For the qualitative variables, an analysis of percentages was performed. Bivariate analysis was conducted using Student's t test, the Wilcoxon test and the Mann-Whitney U test, depending on whether or not the variables fitted a normal distribution. Finally, we conducted a logistic regression, taking as dependent variables the development of valgus deformity on each foot, and as predictors, the presence of overweight or obesity, together with sex and age of starting walking. In addition, the adjusted odds ratios were calculated for each factor. Goodness of fit was evaluated with Hosmer and Lemeshow test. All analyses were conducted for a confidence level of 95% and using SPSS V.22 software.

Ethical questions

The study was approved by the Málaga Provincial Committee for Research Ethics. In all cases, the parents or guardians of the participating children were asked for written informed consent, and the data obtained were treated confidentially and anonymised. The study was conducted in accordance with the principles of the Declaration of Helsinki and its subsequent amendments.

## Results

The sample consisted of 104 children (47 boys; 45.2% and 57 girls; 54.8%), with an average age of 7.53 years (SD: 0.89). According to their BMI, 14.4% of the children were overweight and 29.8%, obese. Valgus deformity was more pronounced on the right foot than the left (42.3% and 39.4%, respectively). Table 1 details the characteristics of the sample by gender, showing that hindfoot valgus was more prevalent among the boys than the girls, for both feet.

By BMI, the children with obesity had a higher incidence of planovalgus foot than those with overweight. Thus, in the children with overweight, 80.5% had no valgus on the left hindfoot, while it was present in 19.5%, although these differences were not statistically significant (p=0.182). The same was true for the right foot, with values of 77.3% and 22.7% respectively (p=0.05) (Table 1).

As concerns hindfoot valgus in children with obesity, the opposite phenomenon was observed: thus, in the left foot, hindfoot valgus was present in 53.7% of the children and absent in the remaining 46.3% (p<0.0001), OR 6.94 (95% CI: 2.72 - 17.70). The same was true for the right foot, with values of 54.5% and 45.5% respectively (p<0.0001), OR 9.08 (95% CI: 3.38 - 24.36).

Multivariate logistic regression showed an increased risk of left foot valgus in males, in children with overweight or obesity and in those who began to walk later (Table 2). For

the right foot, the risk factors were the same except for the age of onset of walking (Table 3). The goodness of fit of both models was adequate: for the left foot, chi-square: 10.62 (df:8, p=0.224), and for the right foot chi-square 8.13 (df:8; p=0.421)

## Discussion

The aim of this study was to analyse the presence of planovalgus foot in children and the potential risk factors, in terms of anthropometry and psychomotor development. The data obtained clearly reflect a high frequency of PPVF (nearly half of the sample), with a greater presence on the right foot and among the male subjects, together with a significant association between overweight/obesity and valgus deformity.

In the development of the structure of children's feet, it is necessary to take into account the influence of factors such as overweight, age, sex, race, place of residence, joint laxity, footwear and physical activity (16-21,24).

The results obtained show that obesity, sex, age, unilateralism and the age of onset of walking are among the factors to be considered in the presence of hind foot valgus.

With respect to the obesity factor, our results coincide with those of most previous studies in this context. In 2012, Pfeiffer studied 835 children aged 3-6 years, and recorded a three times greater probability of PPVF in overweight children than in those with normal weight (29). Chen, in a sample of 1024 children aged 7-13 years, also detected a significant difference in prevalence among obese (56%) and overweight children (31%), compared to the 27% among those with normal weight (18). In another study, of 2083 children aged 7-12 years, Chan found PPVF prevalence values of 75%, 65% and 57% for subjects with obesity, overweight and normal weight, respectively (34).

However, studies carried out by Evans in 2011, with 140 children aged 7-10 years, and by García-Rodríguez in 1999, with 1181 children aged 4-13 years, failed to detect any

212 clear relation between these two variables (28,36). These differences between studies
213 may be due to the heterogeneity of inclusion criteria applied and/or to variations in the
214 study populations. If so, it would be necessary to conduct multicentre studies with
215 homogeneous samples, if possible randomised and population-based, in order to
216 establish a more definitive association between this factor and the presence of
217 planovalgus foot. Nevertheless, most studies do report a positive association in this
218 respect. In our own case, the results of the regression model, showing a strong
219 association between obesity and overweight, in both feet, after adjusting for sex, with
220 odds ratios greater than 8, suggest that this relationship is more than plausible.

221 As regards the relation between sex and the presence of planovalgus foot, our results
222 are consistent with those of other studies that have investigated this association
223 (18,28,29,34,36). The differences in prevalence are generally around 15%, with higher
224 values for boys than for girls, although in our study these differences were somewhat
225 greater.

226 Although the age factor is addressed in most studies, reporting an inverse relation
227 between age and valgus (16,21), our own results in this respect were not statistically
228 significant. However, when the sample was divided by age into three homogeneous
229 groups (<78 months, 78-89 months, >89 months) then for both the left and right feet
230 there was a higher percentage of planovalgus foot in the oldest group. Chenen (2013),
231 in a longitudinal study performed with 580 children aged 3-6 years in 2012, found that
232 9.9% of children with normal feet later developed planovalgus foot. Clarification of this
233 issue, therefore, requires further a posteriori longitudinal studies.

234 Another important fact to consider is that there is a statistical association between
235 PPVF and the age of onset of walking, although a weaker one than for the
236 anthropometric parameters. Thus, children who start walking later are at greater risk of
237 presenting planovalgus foot at age 6-9 years, especially in the left foot. This aspect,
238 too, requires longitudinal studies to be carried out in order to determine more precisely

the extent to which this association may be influenced by other confounding factors or by interaction.

As regards the possible relationship between the presence of PPVF in terms of dominance and laterality, a factor that has received little research attention, we disagree with Wozniacka (36), according to whom there is a greater prevalence in the left foot (14.5%) than in the right (8.9%). In contrast, our own data reflect a stronger prevalence in the right foot (42.3%) than in the left (39.4%). This discrepancy calls for specific analysis in further studies, in order to investigate possible explanations for these differences in the biomechanics and functionality of gait, balance and posture.

Finally, we acknowledge that this study has some limitations: first, its cross-sectional design did not allow us to determine precisely the causal sequence of exposure factors and outcome. Moreover, the sample population was obtained from a particular location in Spain; a broader, more international sample might present variations, due to factors such as lifestyle and the level of physical activity, areas that are strongly linked to variations in cultural patterns.

## Conclusions

These results corroborate the data reported in previous studies, as regards the existence of an association between overweight and obesity and the onset of planovalgus foot in children, but it highlights a new risk factor: the age of onset of walking. For clinical practice, these findings underline the importance of strategies to avoid overweight and obesity in early childhood, as the main instrument of intervention, and the need to perform early podiatric evaluations in this at-risk child population. The combination of these factors could help clinicians and parents to focus attention on these higher risk situations to start early preventive measures either orthopaedic, manipulative or surgical in the extreme cases.

**Financial Disclosure**

None declared

**Conflict of interest**

None declared

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Tables and figures

**Table 1: General characteristics of the sample**

| | **Boys (n=47; 45.2%)** | **Girls (n=57; 54.8%)** | |
|---|---|---|---|
| | n(%) or Mean (SD) | n(%) or Mean (SD) | **p** |
| Age | 7.56 (0.84) | 7.54(0.94) | 0.932 |
| Valgum Index (Right) | 26 (55.30) | 18 (31.60) | 0.012 |
| Valgum Index (Left) | 26 (55.30) | 15 (26.31) | 0.020 |
| Overweight | 4(8.50) | 11 (19.30) | 0.163 |
| Obesity | 19 (40.40) | 12(21.10) | 0.050 |
| Age of onset of walking (months) | 12.62 (2.20) | 12.78 (2.76) | 0.754 |
| Crawling | 33 (73.30) | 36 (66.70) | 0.516 |

**Table 2: Risk factors for valgum (left foot)**

| | B | p | OR (95% CI) |
|---|---|---|---|
| Gender: Male | 1.30 | 0.013 | 3.67 (1.31 to 10.26) |
| Overweight | 2.17 | 0.002 | 8.75 (2.16 to 35.41) |
| Obesity | 2.43 | 0.000 | 11.41 (3.68 to 35.37) |
| Age of onset of gait | 0.19 | 0.041 | 1.21 (1.00 to 1.46) |
| Constant | -4.66 | 0.001 | 0.00 |

**Table 2: Risk factors for valgum (right foot)**

| | B | Sig. | OR |
|---|---|---|---|
| Gender: Male | 1.18 | 0.029 | 3.25 (1.12 to 9.40) |
| Overweight | 2.88 | 0.000 | 17.90 (4.07 to 78.73) |
| Obesity | 2.69 | 0.000 | 14.75 (4.66 to 46.71) |
| Age of onset of gait | 0.13 | 0.159 | 1.14( 0.94 to 1.38) |
| Constant | -3.95 | 0.005 | 0.01 |