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Foot posture development in children aged 5 to11 years: A three-year prospective study

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ABSTRACT

Background: The paediatric flatfoot is a common presentation but it is unclear whether the condition will resolve on its own as the child gets older or whether treatment is required. Therefore, the study objective was to evaluate paediatric foot posture, and anthropometry, in children at two time points, three years apart.
Material and methods: A sample of 1032 healthy children (505 boys, 527 girls; aged 5–11 years) was recruited for foot posture index (FPI) and anthropometry assessment (weight, height and body mass index, BMI). Assessment was repeated when the children were aged 8 years to 14 years. Paired *t*-tests, Anova, frequency tables and a multiple regressions were conducted.
Results: Initially, approximately 70% had a neutral FPI range, 20% pronated, 3% highly pronated, and 4% supinated. Initial mean FPI was 3.6 ± 2.8, being higher in boys 3.7 ± 2.8 than in girls 3.4 ± 2.7 ($p = 0.034$). All FPI categories changed over time, with supinated and neutral FPI increased by 19.5% and 4.7% respectively. In contrast, pronated and highly pronated FPI reduced by 10.6% and 55.6% respectively. Regression showed only 1% FPI change was explained by increased height. FPI scores were significantly reduced after three years (3.57 to 3.33; $p < 0.001$).
Conclusion: Children's foot posture shifts toward neutral as age increases. There is minimal relationship with weight, height or BMI. Appreciation of developing foot posture could reduce over diagnosis and unnecessary treatment of paediatric flatfeet.

1. Introduction

Flatfoot is a common presentation in children, and a frequent concern for parents [1]. Although most cases are physiologically normal and resolve with growth and development, without any treatment, discriminating feet that resolve from those that remain flat, is difficult. Changes in the anthropometric characteristics have been implicated as a predictor of this natural history, with research citing increased body mass as a risk factor to perpetuated flatfoot [2].

Clinicians often over-diagnose, and consequently over treat paediatric flatfoot. Whilst the intention may be prevention of future pain associated with flatfoot as a deformity, there is little evidence to support such a pre-emptive approach [3,4]. Some flatfeet can impact negatively on quality of life [5], and may be associated with foot problems including, hallux valgus[6–9] hammer toes [10,11], osteoarthritis [12], and there has long been association between flatfeet as defining military recruits as 'unfit for active service' [13]. This last tenet has been grossly misinterpreted over many decades, since the original findings of Ilfeld [14], which identified that whilst some recruits with foot pain also had flatfeet, many more recruits had flatfeet and no foot pain [15].

The debate regarding treatment of the asymptomatic paediatric flatfoot was spurred by a review article [16], which also proposed an evidence-based approach, culminating in the development of the paediatric flatfoot proforma [17]. This pragmatic approach did not fill basic gaps in knowledge that maintain paediatric flatfoot as a common paediatric health concern. Until recently, there has been a lack of normal range reference data of foot posture versus age for clinicians to reference [18]. Further, there is still dissent regarding assessment methods, viz footprints versus foot posture and gait, the contribution of anthropometry which has been both supported and refuted [19,20],

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and the wider contributions which factors such as joint hypermobility, foot strength, and shoes may play. The absence of prospective data has long been observed [21].

The aim of this study was to assess foot posture prospectively in a large sample population (from two areas of Spain) of children aged between 5 years and 11 years at the beginning of the study, over a three-year period, noting any relationship with anthropometric factors (weight, height and BMI).

2. Material and methods

2.1. Participants

The sample consisted of 1032 participants, 505 boys (48.9%) and 527 girls (51.1%), with an age range between five and eleven years (mean age, 8.2 ± 1.5 years; boys 8.2 ± 1.5, girls 8.3 ± 1.5). Anthropometry of the study sample: mean height 1.29 ± 0.29 m (range 0.85–1.60 m; boys 1.28 ± 0.11, girls 1.28 ± 0.10), mean weight 30.5 ± 6.2 kg (range 16.7–61 kg; boys 30.5 ± 5.9, girls 30.4 ± 6.5), mean BMI 18.6 ± 3.6 kg/m^2 (range 12.5–39.1 kg/m^2; boys 18.7 ± 3.4, girls 18.5 ± 3.7).

The criteria for inclusion were: (a) asymptomatic feet; (b) symmetrical feet, with no evident joint deformities; (c) aged five to 11 years. The exclusion criteria were: a) foot pain b) injury to the lower limbs during the previous 6 months, c) congenital abnormalities, d) cerebral palsy, d) motor dysfunction, e) prior foot surgery (g) the use of foot orthoses. 48 of the initial participants were lost to follow-up and subsequently excluded from the study (due to a lower-limb injury during the three years).

The parents were informed about the characteristics of the study, and asked to complete a questionnaire and to provide signed consent to confirm the participation of their children in the study. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committees of the Universities of Extremadura (ID: 59/2012) and Malaga (CEUMA 26-2012H), Spain.

2.2. Anthropometric measurements

Height was measured using a calibrated altimeter [SECA 217 stadiometer, SECA, Hamburg Deutschland]. Weight was measured using calibrated digital scales [Pegasus, Salter Brecknell DCSB, Avery Weigh-Tronix, Fairmont, USA] with subjects wearing minimal clothing (t-shirt, shorts or skirt). The BMI was then calculated (weight kg/height m2).

2.3. FPI measurement

The FPI was assessed in relaxed stance using the standard method [22]. The six criteria of the FPI were evaluated – talar head palpation, supra and infra malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch and abduction/adduction of the forefoot on the rearfoot. Scoring for each criterion was scaled: −2, −1, 0, +1 or +2. The FPI cut-of points, defining foot type category were used, viz. a) highly supinated −12 to −4, b) supinated −3 to 0, c) neutral 1 to 7, d) pronated 8 to 10 and e) highly pronated 11 and 12 (7).

The FPI has good intra-rater reliability and moderate inter-rater reliability [22]. Accordingly, the same examiners made all measurements (PAG, Plasencia; JMA, Malaga). To confirm intra and inter-rater reliability of the FPI measurement between both researchers, intra-class correlation coefficients (ICCs, two factors mixed effects) were calculated from three repeated trials of the first 30 children. A folding screen was placed between the subject and the assessor, revealing only the foot and 15 cm of the lower leg. Participants FPI was assessed in relaxed stance, on a 50 cm bench height for inspection. The intra-observer ICC was 0.92-0.94, and the inter-observer reliability was 0.86–0.89. The minimal detectable change (MDC) with 95% confidence bounds was calculated. The MDC has been defined as the minimal amount of change that is required to distinguish a true performance change from a change due to variability in performance or measurement error. The MDC was found to be 0.13.

2.4. Prospective assessment

All anthropometric and foot posture assessments were performed at baseline and with prospective intent, repeated three years later, by the same investigators, repeating the initial protocol.

2.5. Statistical methods

To preserve independence of data [23], and given strong correlation between FPI scores on left and right feet in healthy individuals [24], although both were measured, for further statistical analysis only one foot (the right, chosen at random) was included in the statistical analyses.

The FPI was expressed as mean ± standard deviation, and frequencies plots were conducted to explore groups. Differences in FPI scores and individual criteria were analysed using the Student *t*-test (independent groups, boys-girls; paired sample, initial and later repeated scores). ANOVA was used to compare the mean ΔFPI (reduction of FPI, Post-Pre) between three defined age groups (5–7, 7–9, 9–11). The age and anthropometric characteristics (height, weight and BMI) were input as the independent variables for multiples regressions analysis (at baseline and at final follow-up period) to predict dependent variable, the whole value of FPI (pre and post). The regressions were run following the backward stepwise elimination procedure, with significance level, $p < 0.05$. Statistical analysis was performed using SPSS software v21.0 (SPSS, Chicago, IL).

3. Results

The mean FPI at baseline was 3.6 ± 2.8 (range, from −4 to +12), while at final follow-up 3.3 ± 2.7 (range, from −3 to +12). The initial and final FPI assessments are summarised in Fig. 1 and frequency plots between whole FPI by gender at the two moments is presented in Fig. 2. A significant difference ($p = 0.034$) was found in the initial FPI between genders, being higher in boys (3.7 ± 2.8) than girls (3.4 ± 2.7). However, no difference was found at final follow up (boys 3.4 ± 2.6 vs girls 3.2 ± 2.7, $p = 0.112$). Clinically, this difference would be indistinguishable, as FPI scores of 3 ± 3. The FPI was significantly reduced after three years, from the initial mean FPI 3.57 to a mean FPI of 3.33 after three years ($p < 0.001$).

There were significant reductions in two (of six) FPI criteria: talar head palpation ($p < 0.001$); curves around lateral malleolus ($p = 0.038$) (Table 1). The reduction – Delta (Post-Pre) of the FPI total score was not significant between defined age groups ($p = 0.624$, Table 2).

The contingency table and chi-square test showed a statistical difference between the distributions in the FPI group, initial versus repeated (Table 3). It was found that, 82 of the pronated group were neutral after three years. Similarly, 29 of the highly pronated group at initial assessment reduced to pronated (n = 26) and neutral (n = 3), after three years. Conversely, the neutral group also shifted, with 21 supinated, 40 pronated, 2 highly pronated across the three years. The initially supinated group shift resulted in 13 moved to the normal foot posture category (Table 3).

Exploring percentage change by age groups (Table 4) revealed consistent trends in all foot posture categories at all ages over the three-year period. There was increase in both supinated and neutral foot posture categories with mean percentage change of +0.7% and +3.5% respectively. A similar but inverse trend was seen in both the pronated and highly pronated foot posture categories, which both reduced across the three-year period, by −2.2% and −2.0% respectively.