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The relationship between quality of life and foot function in children with flexible flatfeet

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ABSTRACT

Flat feet in children are common, and at times symptomatic, but the relationship between function and symptoms or impairment is still unclear. We undertook a prospective, observational study comparing children with paediatric flexible flat foot (PFF) and children with neutral feet (NF) using three dimensional gait analysis (3DGA). It was hypothesised that children with PFF would demonstrate differences in both spatio-temporal parameters of gait and foot and ankle kinematics compared to the NF group and that these differences would correlate with impaired quality of life (QoL). The kinematic differences were expected to be most marked in hindfoot coronal plane motion and forefoot sagittal and transverse plane motion. Eighty-three children between the ages of 8 and 15 were recruited in this study: Forty-two were classified as having PFF and forty-one as NF. Each child underwent 3DGA and completed the Oxford Ankle Foot Questionnaire for Children (OxAFQ_C). Reduced OxAFQ_C physical domain scores in the PFF children were associated with slower walking speed ($p = 0.014$) and reduced normalised stride length ($p = 0.008$). PFF children also demonstrated significantly increased hindfoot eversion and forefoot supination during gait. Significant differences between groups were not observed for other foot and ankle joint motions. Increased maximum hindfoot eversion and increased forefoot supination correlated strongly with lower QoL scores in PFF children. These data further our understanding of the functional characteristics that lead to impaired QoL in PFF children. These findings will help guide the surveillance and management of children with this ubiquitous condition.

1. Introduction

Paediatric flexible flat foot (PFF) occurs in up to 20% of children and adolescents [1,2]. However, there continues to be controversy about whether this represents a normal variant or is a pathological presentation. It is estimated that 10–60% of children with PFF develop symptoms and up to 63% have functional impairment [3,4]. Flat feet have also been associated with a number of pathologies including hallux valgus, tarsal tunnel syndrome and metatarsal stress fractures. In children whose symptoms are refractory to conservative management, surgical intervention is sometimes undertaken [5].

Paediatric flexible flatfoot is a multi-plane deformity, primarily consisting of a reduced medial longitudinal arch (MLA) and increased hindfoot eversion. Increased forefoot abduction, dorsiflexion and supination may also be observed. Interventions for PFF often involve either supporting or recreating the MLA and controlling hindfoot eversion [6]. However it remains unclear how the structure and function of PFF relate to symptoms. Children with symptomatic PFF often only exhibit symptoms during activity, thus it appears that functional assessment may be more informative than static alignment [7].

Function of the foot and ankle complex is best assessed using three-dimensional gait analysis (3DGA). The use of multi-segment foot models, like the Oxford Foot Model (OFM), allows precise quantification of dynamic foot and ankle joint motion [8]. Hösl et al. [9] used this technique to investigate functional differences between symptomatic PFF, asymptomatic PFF and children with typically developing feet. They found that PFF children had limited

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hindfoot motion in the sagittal plane associated with increased forefoot mobility and a hypermobile hallux. However no kinematic differences, between PFF children with and without symptoms, were found. Twomey et al. [10] undertook a descriptive study of gait in children with PFF, but study participants were all asymptomatic.

Of the few studies that investigated children with symptomatic flat feet, the majority classified children as either having symptoms or not having symptoms. Benedetti et al. [4] demonstrated that symptoms were variable between patients and suggested that a binary classification may therefore be insufficient. An alternative approach is to assess the effect that symptoms have on quality of life (QoL) in these children in a continuous manner. The Oxford Ankle Foot Questionnaire for Children (OxAFQ_C) is a validated questionnaire that has been developed to assess QoL in such a population [11]. This tool not only assesses the burden of disease, but can also be used to record clinical change over time. The use of such measures is becoming increasingly popular in research and in clinical practice.

To mandate treatment of children with PFF it is important to further define the link between structure, function and QoL. The aim of this prospective, observational study was to compare the function of PFF and neutral feet using 3DGA and to correlate findings with QoL. We hypothesised that increased hindfoot eversion and forefoot mobility would be observed in the PFF group, and that both of these changes would correlate directly with the OxAFQ_C scores.

2. Methods

2.1. Subjects

Eighty-three children between 8 and 15 years of age were recruited into this ethically approved study, over a period of 18 months (ref: OxREC 12/SC/0334). Informed assent from participants and consent from parents was obtained. Inclusion criteria were to either have a neutral or flat foot posture and to not be using any foot or ankle orthoses. Exclusion criteria were any previous lower limb surgery, any coexistent musculoskeletal pathology or behavioural problems. Children were recruited from the paediatric orthopaedic clinic, orthotic clinic and from the community. Demographic and physical examination data is provided in Appendix 1.

2.2. Assessment of foot posture

Foot posture was formally classified on the basis of specific radiological, anthropometric, footprint and gait analysis parameters. Children were classified into two groups as either having a flat foot (PFF), or neutral foot posture (NF). A full description of the foot posture classification method can be found in the supplementary material associated with the article by Kothari et al. [12]. The foot posture measurement indices for each group were consistent with previously published literature [13–18]. As well as fulfilling these objective criteria, a pre-requisite for qualifying as PFF was that the lowered MLA observed in a standing position had to be recreated when the participant stood on tiptoes. A lower age limit of eight was used to ensure that no developmental flat feet were recruited into the study.

2.3. Data collection and processing

Participants each completed the OxAFQ_C to assess QoL [11,19]. This disease non-specific, validated questionnaire has been developed to assess the burden of foot and ankle problems in a paediatric population. It consists of 15 questions, with the first 14 spread over three domains (physical, school and play and emotional), and a final question pertaining to shoewear. Each domain score is converted to a percentage and assessed individually. A low score represents poorer functioning and a worse QoL.

Subjects walked at a self-selected speed along a 10 m walkway and a minimum of six trials were captured. The root mean squared difference (RMSD) between each curve and the mean curve for each OFM angle was computed, and the trial with the overall minimum average RMSD was selected as the representative trial. A 12 or 16 infra-red camera system (Vicon MX/T40, Vicon, Oxford UK) collected 3DGA at 100 Hz using the plug-in-gait and the Oxford Foot Model marker sets [8,20]. Data were processed in the Vicon Nexus (v1.7, Vicon, Oxford, UK) software environment. Gaps in marker data were filled using cubic spline interpolation and trajectories filtered using the Woltring algorithm [21]. Dedicated pipelines were used to compute lower limb kinematic quantities. The OFM is a multi-segment foot model which subdivides the foot and ankle into tibia, hindfoot, forefoot and hallux segments. The model output provides joint angles between adjacent segments in the sagittal, transverse and coronal planes. Spatio-temporal parameters were measured from the 3DGA, including walking speed (m/s), cadence (steps/min) and stride length (m). Cadence (c) and stride length (SL) were normalised to leg length (LL) according to the method described by Hof et al. [22]. Thus, normalised cadence was taken to be $\sqrt[c]{g/LL}$, and normalised stride length was calculated as SL/LL. Walking speed was not normalised as per the reasons outlined by Dixon et al. [23].

2.4. Statistical analysis

Data normality was ascertained using standard tests assessing skewness and kurtosis. All variables were normally distributed except for OxAFQ_C questionnaire domains. OxAFQ_C domain scores were treated as a continuous variable in accordance with previous literature [24].

Stepwise multiple linear regression was used to assess how foot posture, age and sex affected the spatio-temporal parameters, in all subjects. The effect of OxAFQ_C physical domain scores, age and sex on spatio-temporal parameters, solely in the PFF group, was also assessed using a stepwise multiple linear regression approach. As the OxAFQ_C was non-normally distributed, regression diagnostics were used to ensure that model residuals were normally distributed and that the residual versus fitted values were not heteroscedastic.

The gait cycle from heel strike to heel strike was normalised to 100% and joint angles pooled within groups. Group differences were assessed using bootstrap confidence bands as per the method proposed by Lenhoff et al. [25]. OxAFQ_C domain scores were compared between groups using the Mann–Whitney U test. In cases where differences were found between the PFF and NF group kinematics, questionnaire domain scores were correlated with the requisite OFM angles at heel strike and toe off, as well as maxima and minima and absolute range of motion. Statistical testing was undertaken using Matlab (R2012b, The Mathworks Inc., Natick, USA 2012) and Stata v13.0 (Statacorp LP, Texas, USA). No correction for multiple comparison was made for reasons outlined by Poole [26].

3. Results

From the 83 subjects, 42 were classified as having PFF and 41 as having NF. There was no significant difference in mean age or BMI between groups, but there was a greater proportion of females in the PFF group compared to the NF group (Table 1).

3.1. Spatio-temporal parameters

There was a tendency for slower walking speed and a reduced normalised stride length in the PFF group compared to the NF group, but neither of these findings