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Brief report

Static postural differences between neutral and flat feet in children with and without symptoms

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ABSTRACT

Background: Flatfoot is a common variant of foot posture. Whilst usually benign, in some children flatfoot is accompanied by pain and functional complaints. Comparisons between the posture of asymptomatic and symptomatic flat feet are few. If a difference does exist, it may help understand symptoms and guide management.
Methods: This paper investigated differences in lower limb posture between neutral and flat feet with and without symptoms during standing using the multi-segment Oxford Foot Model. 97 children between five and 18 years old were assessed by a physiotherapist; each foot was classified into one of four categories: asymptomatic neutral (n = 88), asymptomatic mild flatfoot (n = 47), asymptomatic flatfoot (n = 29), or symptomatic flatfoot (n = 30). For each child, Oxford Foot Model markers were applied, and mean values of 11-Euler angles at the foot, ankle, and knee joints during standing were calculated. Analysis of variance and post-hoc tests were used to identify differences between groups.
Findings: Hindfoot eversion was significantly increased ($P < 0.001$) in children with asymptomatic and, to a greater extent, symptomatic flatfoot. The forefoot was significantly more abducted ($P < 0.001$) in the symptomatic than asymptomatic groups, and in the flat than neutral group. The forefoot was more supinated relative to the hindfoot in the flatfoot groups ($P = 0.023$), although post-hoc analysis did not identify specific group differences.
Interpretation: Hindfoot eversion and forefoot abduction were much greater in the symptomatic population. The differences in foot alignment may relate to the presence of symptoms.

1. Introduction

Flatfoot is usually thought of as “significant” flattening of the arch, potentially accompanied by a variety of other possible structural deviations. It was noted as early as 1896 that flatfoot was not necessarily debilitating, but sometimes it was extremely so, and that the presence of symptoms did not necessarily correspond to the appearance of the foot (Lovett and Dane, 1896; Whitman, 2010). Although flatfoot is often asymptomatic, in some cases idiopathic flatfoot is associated with contracted tendo-Achilles, pain in the foot, leg, and knee, decreased endurance, and gait disturbances which develop during childhood (Harris et al., 2004; Benedetti et al., 2011); longstanding cases may progress to rigid flatfoot as the ligaments stretch beyond recovery (Gervis, 1970). The precise aetiology of the symptoms remains unclear.

Flat feet are usually judged by a visually-based assessment of arch height during static standing, with some cut off point beyond which the foot is classified as flat (although arch height itself is a continuous variable). In addition, a functional test may be used, for example the heel raise test to determine if the arch reconstitutes. Flat feet may not necessarily exhibit any symptoms, either at the time of assessment or in the future. Most treatments intend to alleviate any symptoms and/or correct a symptomatic flatfoot to more closely resemble a neutral foot. Therefore there is a question as to whether current treatments actually target the cause of symptoms.

Three previous radiographic studies have investigated the difference between asymptomatic and symptomatic flatfoot. They all attempted to correlate radiographic properties with symptoms: Pehlivan et al. (Pehlivan et al., 2009) concluded that the talar first metatarsal angle is increased in symptomatic young males (n = 28, 56 feet, mean age 22 years); Moraleda and Mubarak (Moraleda and Mubarak, 2011) found increased lateral displacement of the navicular in symptomatic patients (n = 135, mean age 11 years); Yan et al. (Yan et al., 2013) also found increased lateral displacement of the navicular to be related to the onset of symptoms in children (n = 100, mean age 11 years).

The use of X-rays to assess foot posture has some disadvantages: planar measurements of a three-dimensional deformity are dependent on perspective; coronal plane measurements at the foot are not possible; and due to the radiation dose, the use of X-rays in children can be difficult to justify, especially in research studies. In some cases, it could be helpful if some symptom-specific signs of flatfoot could be identified by objective, non-ionising techniques. Given the previous differences

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found in radiographic studies, it is reasonable to predict that there will be differences between the symptomatic and asymptomatic groups (at the mid-foot) in the transverse and sagittal planes.

This study investigated whether symptomatic flat feet display specific characteristics distinct from those of asymptomatic flat feet or of asymptomatic neutral feet. A non-radiographic, objective method – the Oxford Foot Model (OFM) (Stebbins et al., 2006) – was used to analyse foot posture, and the results were compared between different foot types and the presence of symptoms. It was hypothesised that forefoot abduction and plantarflexion would be greater in the symptomatic group.

2. Methods

The asymptomatic children were recruited as part of a larger study to describe typical gait in children. This data collection was approved by NRES Committee London – South East (Ref 09/H1102/88). Of these asymptomatic children, 82 were selected as being aged between five and eighteen years old (mean 10.7, SD 3.5); according to World Health Organization guidelines (World Health Organization, 2011), one was obese, eleven overweight, three thin, and sixty-seven within the normal BMI range for their age. The age of five was selected as a minimum cut off because this is the age at which most children have developed an arch (Pfeiffer et al., 2006), and the fat pad has been absorbed and the foot bones ossified (Maier, 1961).

Data about symptomatic children were collected retrospectively from patient records in the Oxford Gait Laboratory. Fifteen patients (mean age 11.5, SD 2.2 years) were included; according to World Health Organization guidelines (World Health Organization, 2011), one was obese, two overweight, three thin, and nine within the normal BMI range for their age. They had all the necessary data collected and were selected as cases of idiopathic flatfoot with symptoms including foot or ankle pain that were attributed to the condition.

A physiotherapist assessed the weight-bearing position of the hindfoot, midfoot and forefoot and provided a description of each foot. While relying on observational classifications of foot posture may not be the most objective system, it is a comprehensive and the most commonly used and trusted technique (Chuckpaiwong et al., 2009). The descriptions were simplified into four categories:

- "Neutral", where no serious deviation from a perceived norm was noted;
- "Mild", where a pronated/flat foot structure was noted, but was described as mild;
- "Flat", where a pronated/flat foot structure was noted;
- "Other", where a different type of description was given.

The feet were then assigned to one of four groups:

- Asymptomatic Neutral Foot (AN),
- Asymptomatic Mild flatfoot (AM),
- Asymptomatic Flatfoot (AF),
- Symptomatic Flatfoot (SF).

The "Others" had been excluded from analysis. All SF subjects had bilateral flatfoot.

Retroreflective markers of radius 5 mm were applied to the feet and limbs of the children at known anatomical landmarks including the landmarks of the OFM (Stebbins et al., 2006). To collect the data, 12 infra-red cameras (Vicon-MX, Oxford, UK) were used to track the positions of the markers at 100 Hz. Data was recorded during three seconds of steady-state quiet standing.

Table 1
n, mean, standard deviation (SD), and ANOVA significance of OFM angles during standing between groups. $P < 0.05$ highlighted in bold. AN — Asymptomatic Neutral, AM — Asymptomatic Mild flat, AF — Asymptomatic Flat, SF — Symptomatic Flat feet, FE — Femur, TB — TiBia, HF — HindFoot, FF — ForeFoot, and HX — HalluX.

Angle Positive direction	Groups	N	Mean	SD	ANOVA Sig.	Angle Positive direction	Groups	N	Mean	SD	ANOVA Sig.
	AN	88	−5.12	6.96			AN	88	−2.33	3.44	
FE–TB	AM	47	−5.38	6.55		FF–HF	AM	45	−3.06	3.21	
Flexion	AF	29	−4.66	6.66		Dorsiflexion	AF	29	−2.37	3.43	
	SF	30	−3.04	6.99			SF	30	−3.28	4.82	
	All	194	−4.79	6.82	0.471		All	192	−2.66	3.63	0.511
	AN	88	−0.04	2.73			AN	88	1.01	5.24	
FE–TB	AM	47	−0.27	3.55		FF–HF	AM	45	−0.07	5.59	
Varus	AF	29	−0.93	2.52		Adduction	AF	29	−3.43	4.41	
	SF	30	−1.11	4.05			SF	30	−8.42	6.83	
	All	194	−0.4	3.15	0.314		All	192	−1.39	6.41	**0.000**
	AN	88	−17.47	8.43			AN	88	6.63	4.89	
FE–TB	AM	47	−17.43	9.75		FF–HF	AM	45	7.98	6.56	
Internal	AF	29	−16.68	8.67		Supination	AF	29	9.11	5.76	
Rotation	SF	30	−12.91	9.59			SF	30	10.15	7.37	
	All	194	−16.64	9.06	0.102		All	192	7.87	5.98	**0.023**
	AN	88	1.74	4.01			AN	82	−2.68	6.12	
HF–TB	AM	45	1.13	3.94		HX–FF	AM	45	−0.03	8.46	
Dorsiflexion	AF	29	2.42	4.15		Dorsiflexion	AF	29	−1.97	6.48	
	SF	30	1.24	5.3			SF	30	0.34	8.67	
	All	192	1.62	4.23	0.580		All	186	−1.44	7.3	0.112
	AN	88	7.28	6.15			AN	82	−1.14	4.83	
HF–TB	AM	45	8.94	6.31		HX–FF	AM	45	−1.37	5.71	
Internal	AF	29	8.38	4.94		Adduction	AF	29	0.06	6.42	
Rotation	SF	30	9.7	7.64			SF	30	0.87	6.52	
	All	192	8.21	6.3	0.240		All	186	−0.68	5.62	0.262
	AN	88	−0.93	4.35							
HF–TB	AM	45	−4.03	5.23							
Inversion	AF	29	−4.15	4.84							
	SF	30	−8.38	6.6							
	All	192	−3.31	5.65	**0.000**						