



The contralateral foot in children with unilateral clubfoot, is the unaffected side normal?



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ABSTRACT

The unilateral unaffected clubfoot has previously been used as a control in longitudinal studies of clubfoot outcomes. However, we have observed that the unaffected clubfoot does not necessarily exhibit the same pedobarographic measurements as seen in normal control subjects. The purpose of this study was to evaluate whether the unaffected foot is indeed normal or if there are differences in the pedobarographic measurements of the unaffected foot compared to healthy normal controls. The Tekscan HR Mat™ was used to dynamically test the walking pattern of 103 subjects with unilateral clubfeet and compare the results to our previously published series of normal controls. Patients were divided into three groups: Group 1 (<2 years), Group 2 (2–5 years) and Group 3 (>5 years). An unpaired *t*-test ($p < 0.05$) was used to compare percentage of stance at initiation of force, the percentage of stance at maximum force, the percentage of stance at termination of force, the maximum percentage force and the average force/time integral between a group of normal age matched controls and the unaffected foot in patients with unilateral clubfoot. Significant differences were identified between the unaffected side and normal controls for the pressure distribution, order of initial contact and foot contact time. These differences evolved and changed with age. The pedobarographic measurements of patients with clubfoot are not normal for the unaffected foot. As such the unaffected foot should not be referred to as normal, nor should it be used as a control.

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1. Backgrounds

Clubfoot is one of the most common congenital deformities of the foot [1] with an incidence of 1 in 1000 [2–4]. Treatment options vary and include serial manipulation and casting [5–7], physiotherapy [8,9] and “a La Carte” surgery [10]. One of the difficulties of treating clubfoot is to assess the adequacy and maintenance of correction. Methods of doing so include clinical scoring systems [2–4], clinical examination, patient reported outcome measures [5–7] and radiographs [8,9]. These investigations can be limited since they only provide a static and possibly subjective assessment of the foot [10,11]. Therefore pedobarography and gait analysis have been suggested as a method of objectively assessing the dynamic function of the foot [12]. The unaffected foot has previously been used as a control in patients with unilateral clubfoot [5,13–15]. This is an appealing concept as it allows matching for age, sex and weight of individuals [11], however, it

has been noted that the unaffected side does not constitute a true control [11,15,16]. Previous studies have compared the pedobarographic results of the affected and unaffected side in clubfoot [11], however, the numbers have been small and only one study has looked at patients treated by the Ponseti method [16].

The purpose of this study was to evaluate whether the unaffected foot is indeed normal or if there are differences in the pedobarographic parameters of the unaffected foot compared to healthy normal controls (normal being defined as children with typical development). Specifically we compared the percentage of stance at initiation of force, the percentage of stance at maximum force, the percentage of stance at termination of force, the maximum percentage force and the average force/time integral between a group of normal age matched controls and the unaffected foot in patients with unilateral clubfoot.

2. Materials and methods

2.1. Study population

A total of 284 consecutive patients were identified from the British Columbia Children's Hospital (BCCH) clubfoot database. 78

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patients were excluded due to various reasons such as diagnosis of idiopathic toe walking, cerebral palsy, diplegia, metatarsus adductus, hemiplegia, peroneal nerve palsy, calcaneovalgus, nail patella syndrome, congenital vertical talus, arthrogryposis, positional clubfoot, cavovarus, ray deficiency and oblique talus. One hundred and three patients were excluded due to bilaterality, leaving 103 patients. The population was divided into three groups based upon age: Group 1 (<2 years) Group 2 (2–5 years), and Group 3 (>5 years). These age groups were determined by our previous study which identified significant variation in the pedobarographic parameters between these groups, but not within these groups [17]. 58 patients had multiple pedobarographic assessments during the course of their treatment. These patients were therefore assessed multiple times, but only one representative reading in each of the 3 defined age groups was included for the purpose of this study. A total of 177 pedobarographic examinations of 103 patients with unilateral clubfeet were analyzed, of which 117 were male and 60 were female. Out of a total of 38 clubfeet in age Group 1, 1 foot underwent a tendoachilles lengthening, 27 were treated by manipulation casting and Botulinum toxin method (MCB) and 10 had casting only. In age Group 2 out of 79 clubfeet, 7 underwent posteromedial release, 6 had a tendoachilles lengthening, 3 had a tibialis anterior tendon transfer, 54 were treated by MCB method and 12 had casting alone. In age Group 3, out of the 60 clubfeet, 19 had posteromedial release, 9 had a tendoachilles lengthening, 1 had a tibialis anterior tendon transfer, 3 had a midfoot or hindfoot osteotomy, 27 were treated by MCB method and 5 had casting alone. Three patients in Group 2 and 4 patients in Group 3 had more than one surgery on their clubfoot. All pedobarography visits included in this study were at least 3 months post-Botulinum A toxin injection and 6 months post-surgery (with the exception of 2 subjects who were 6 and 8 weeks post-Botulinum A toxin injection and 1 patient who was 4 months post-surgery). The MCB method is a modification of the Ponseti treatment utilizing Botulinum A toxin in place of the percutaneous tenotomy [18]. The mean age of the patients at the time of evaluation was 4.6 years (range 1.38–13.2). The control group consisted of our previously published cohort of 146 children (292 feet) recruited from BCCH and Sunny Hill Health Centre (British Columbia) who had no foot deformity or motor dysfunction [17]. An unaffected clubfoot was defined as a foot with a score of 0 by both the Pirani and Dimeglio classification for clubfoot [2,4]. Data for unaffected feet were compared to the control feet.

2.2. Pedobarography protocol

All measurements were performed using the Tekscan HR Mat™ pressure measurement system and Research Foot Module (South Boston, MA) to collect pedobarography data [19].

The pressure-sensitive floor mat measured 488 mm by 422 mm and contained over 8000 sensels with a sensel spatial resolution of 3.9 sensels/cm². Data were collected at 60 Hz. The child was asked to walk on a 3 m long walkway which included the pressure sensitive floor mat at a self-determined speed. A minimum of three passes per foot were obtained [20]. In younger subjects, a greater number of passes was required to ensure that unsatisfactory trials could be excluded. Foot length and foot width dimensions were obtained as part of the protocol for all subjects [17]. Pedobarography data collected were analyzed using a software custom designed by Tekscan (South Boston, MA) and the describe previously by Bowen et al. [21]. A custom written software as described previously by Bowen et al. divided the foot geometrically into equal thirds along the longitudinal axis of foot and also into two equal halves along the medial axis. Data was recorded for 5 foot segments obtained as described above: heel (H), medial midfoot (MMF), lateral midfoot (LMF), medial forefoot (MFF), and lateral forefoot (LFF). For each of the 5 foot segments, 5 pedobarograph variables describing the foot were obtained including percent (%) of stance at initiation of force, percentage of stance at termination of force, percentage of stance at maximum force, force/time integral (Newton-second), and maximum percentage force. Maximum percentage force is the percentage of maximum force applied to the whole foot based on the percentage of each patient's body weight. The pedobarographic studies were performed exactly as previously described in our earlier publication [17].

2.3. Statistical analysis

Data was prospectively collected and entered into the BCCH clubfoot database. This data was extracted and imported into SPSS vs. 20 (IBM). The Shapiro–Wilk test and Q–Q plots of normality were performed which confirmed the data was normally distributed. Consequently an independent sample *t*-test was used to compare means. The level of significance was set at $p < 0.05$.

3. Results

The demographic characteristics of study population are shown in Table 1.

Table 1
Subject characteristics by age group.

Characteristic	Group 1 (<2yr)			Group 2 (2–5 yr)			Group 3 (>5 yr)		
	Normal	Unaffected	<i>p</i> value	Normal	Unaffected	<i>p</i> value	Normal	Unaffected	<i>p</i> value
N (feet)	20	38		126	79		146	60	
Age (year)**	1.56 ± 0.18	1.72 ± 0.2	0.003*	3.68 (4.23–2.64)	3.84 (4.16–3.12)	0.542	6.25 (7.99–5.60)	7.08 (8.81–6.01)	0.024
Gender									
M	12	25		28	53		45	39	
F	8	13		35	26		28	21	
Weight (lbs)	24.75 (25.90–23.00)	24.0 (27.25–12.60) (N=26)	0.389	35.00 (39.68–29.70)	20.65 (34.90–15.43) (N=66)	0	50.00 (62.00–41.30)	34.35 (62.20–22.73) (N=56)	0.001
Height (cm)**	80.5 ± 3.7	81.6 ± 4.7 (N=27)	0.401*	101.00 (104.40–92.10)	99.00 (104.50–95.40) (N=65)	0.738	116.80 (130.0–110.50)	122.90 (137.9–115.4) (N=56)	0.006
Foot width (cm)	5.75 (6.0–5.0)	5.50 (5.95–5.40) (N=26)	0.736	6.50 (7.10–6.00)	6.30 (6.50–6.00) (N=64)	0.03	7.50 (8.50–7.00)	7.15 (8.20–6.60) (N=56)	0.091
Foot length (cm)	13.25 (13.88–12.00)	12.50 (13.25–12.00) (N=27)	0.307	15.88 (16.95–14.53)	15.00 (15.70–14.00) (N=65)	0	19.00 (20.75–17.60)	18.20 (20.28–17.15) (N=56)	0.24

** Age and height for Group 1 are normally distributed and hence mean and standard deviations are reported. For rest of the data, median and interquartile ranges are reported.

* *p* values from *t*-test, all other *p* values are obtained from Mann–Whitney's test.

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