

Research

Is the same brace fit for all? The length of abduction bar in Steenbeek foot abduction brace for Indian children—A pilot study



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ABSTRACT

Purpose: We measured the foot size and shoulder width in North Indian children with idiopathic clubfoot and calculated the corresponding metal rod length for abduction brace. The differences in the foot length in unaffected, unilateral and bilateral clubfeet were also measured.

Patient and methods: Two sets of measurements were taken on each child: feet size and shoulder width. Using statistical analysis, the following were compared: Differences in the manual prescribed and our calculated SFAB bar length, foot size in unilateral clubfoot and unaffected foot and both feet in bilateral clubfoot.

Results: There were 156 patients with 76 unilateral (37 left + 39 right) and 80 bilateral feet. The mean prescribed bar length for foot sizes 8–14 in the Steenbeek manual is 30.18 cm. The mean predicted bar length worked out to be 22.33 cm in our series ($p < 0.001$). In unilateral clubfoot, the mean foot length (11.9 cm) when matched with unaffected foot (12.6 cm) was comparable ($p = 0.08$). Bilateral clubfeet lengths (12.29 cm versus 12.3 cm) were also comparable ($p = 0.978$).

Conclusions: There was significant difference between the prescribed and the predicted bar length in foot sizes 8–14 with a smaller bar length measurement of Indian children. The Ponseti treated unilateral club foot length matched the unaffected foot. The foot lengths in bilateral feet disease were also similar.

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1. Introduction

Foot correction achieved by Ponseti's method for treatment of clubfoot should be maintained using a well-designed Foot Abduction Brace (FAB) to prevent relapses.^{1,2} Several types of foot abduction braces are available in market.¹ The Steenbeek foot abduction brace (SFAB) developed by Michiel Steenbeek is one of the most widely used, easy to use brace and has earned sound reputation from mass clubfoot campaign across several countries like Uganda, Ethiopia, Malawi, Zambia, Tanzania, Rwanda, Haiti, Honduras, Paraguay, Laos, Kenya, Nepal, India and Bangladesh.^{3,4} Besides other characteristics, one of the important component of the SFAB is its abduction bar which keeps the two shoes apart and helps maintain the abduction and dorsiflexion of the corrected feet. For the child's comfort, this bar should be of sufficient length so that the heels of the shoes are at shoulder width (Fig. 1). The prescribed length of abduction bar for different foot and shoe sizes

are detailed in 'Steenbeek brace for clubfoot' manual (Table 1).⁵ The validation of bar's dimensions described in the manual were probably based on experiences from the African continent where the first successful Clubfoot Programme was implemented. To the best of our knowledge, any further quantification of abduction bar length has yet not been documented in English literature.

There are known skeletal and ethnic differences in African and Asian children.^{6,7} We investigated the applicability of the manual's SFAB abduction bar length with respect to Indian population in a pilot study. We measured the foot size and shoulder width in North Indian children with idiopathic clubfoot and calculated the corresponding metal rod length for a foot abduction brace. The difference in the foot dimensions between the unilateral club foot/ the unaffected foot and between the two clubfeet in bilateral cases was also measured to study the effect of the disease on foot dimensions.

2. Material and methods

This cross sectional study was conducted in a CURE Clubfoot Clinic at a tertiary care paediatric super speciality hospital in Northern India. Measurements in 156 patients with corrected idiopathic clubfeet were obtained for study (1st April –15th May

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Fig. 1. In SFAB, the distance from one shoe heel to the other shoe heel, is approximately equal to the shoulder distance of the child. The metal rod is in fact slightly larger than the actual shoulder width (see arrow). (Approximate representation of child's shoulder width and corresponding bar length according to the Steenbeek Manual; not to scale).

Table 1

Prescribed bar length according to foot size in 'Steenbeek brace for clubfoot' manual⁵.

Length of foot (in cm)	Brace size	Length of metal rod (inches)	Length of metal rod (in cm)
6.5 to 7.5	6	9.5	23.75
7.5 to 8	7	10	25
>8	8	10.5	26.25
9	9	11	27.5
10	10	11.5	28.75
11	11	12	30
12	12	12.5	31.25
13	13	13	32.5
14	14	14	35

2016). All the measurements were taken by a single orthopaedic surgeon during the morning outpatient clinics. A full and free consent was obtained from patients' parents or guardians for the study to be published, to which they did not have any objection.

Two sets of measurements were taken on each child:

1. Foot size of both feet. The size was measured in centimetres after marking the outline of child's foot placed flat on a white paper sheet. The longest toe to heel distance was measured as foot size (length).⁸ (Fig. 2)
2. Shoulder width. It was measured in centimetres as the distance between the tips of two acromions on either side with the measuring tape held between these two bony prominences posteriorly.

3. The Steenbeek foot abduction brace (SFAB) bar⁵

The foot abduction bar in SFAB is made from three parts: A piece of 6–7 mm metal rod/round bar and two pieces of flat metal plates of 2" × 3/4" × 1.5–2 mm thickness. The metal bar is cut such that after assembling the SFAB, the distance from one shoe heel to the other shoe heel, is about the same as the distance between the (lateral side of the) shoulders (deltoids) of the child (Fig. 1). Both metal plates are positioned at an angle of 45° external rotation at each end of the metal bar, with the tip of the bar positioned in the middle of the plate. The plates are then welded to the bar. The metal bar is further bend just before the metal plates (25°), so that the metal plates are now at a final angle of 70° abduction in relation to the metal bar. Lastly, the bar is moulded in the frontal

plane. The metal plate edge is placed 1/2" from the posterior edge of the outer sole, whereby the plate follows the middle line of the outer sole. The flat metal plates are attached to the shoe using two drill holes. The final position of shoe and bar is such that both shoes will be in 70° abduction in relation to bar.

4. Calculations and statistical methods

As seen in Fig. 1, the bar length is made slightly longer than the child's shoulder width to compensate for the heel (outer sole) width, the rod's distal placement on the heel, shoe angulations both in axial and frontal planes and the moulded posterior part of heel cup. For the purpose of calculations in present study, the attachment of metal bar to the shoe component was assumed to be angled at 70° rather than the two different angles of 45° (metal bar attachment to the metal plate) and metal bar bend of 25° to achieve final 70° brace abduction (see description above, Fig. 3).

The manual has described only SFAB bar length (not shoulder width) (called as *prescribed* bar length for our series) and that too for 6–14 foot sizes (Table 1).⁵ There were total of 156 patients in our series with foot sizes varying from 8 to 22 cm. Therefore only 140 patients with foot sizes upto 8–14 were used for statistical comparisons with the prescribed bar length in the manual i.e. there were 16 children whose feet size was greater than 14 and these were excluded from the final statistical analysis. The approximate *predicted* (calculated by us) SFAB bar length for our population was arrived by adding 2.5 cm to the measured shoulder width (see legend Fig. 3).

The following pairs of measurements were compared with statistical analysis:

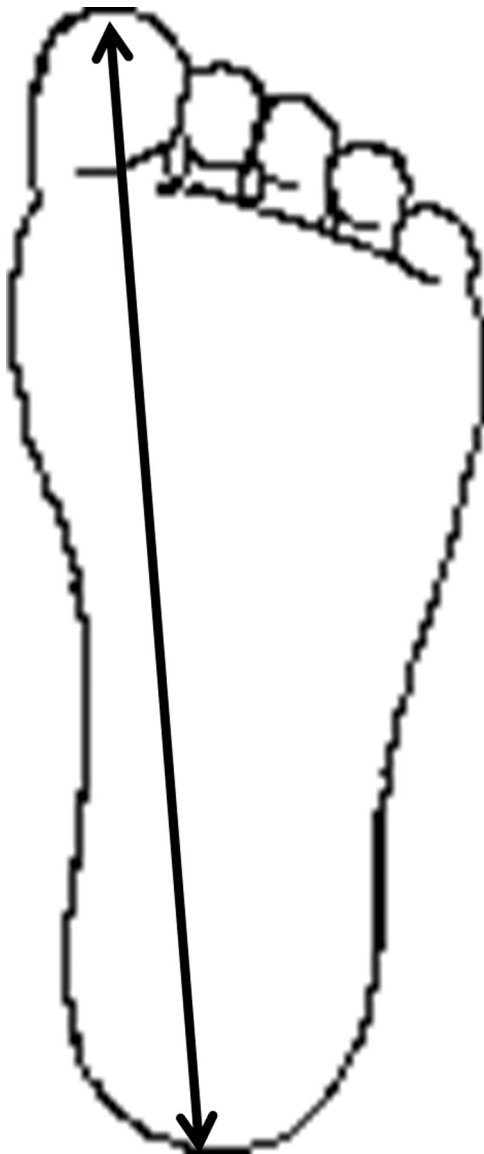


Fig. 2. Measurement of foot size: the longest toe to heel distance was marked on the paper and measured.

1. Differences in the *predicted* and the *prescribed* SFAB bar length when foot size was comparable (pair 1)
2. Difference in foot size in unilateral clubfoot and unaffected foot (pair 2)
3. Difference in foot size in bilateral clubfoot (pair 3)

The data was recorded on Microsoft Excel[®] and statistical relationships between measurements were calculated using paired *t*-tests on online GraphPad software[®].

5. Results

There were a total of 156 patients with age range 3 months–12 years. There were 76 unilateral (37 left + 39 right) and 80 bilateral feet. The male female ratio was 2.5:1. In 140 patients with foot size upto 14, there were equal number (70 each) of unilateral (34 left + 36 right) and bilateral feet.

The mean *prescribed* bar length for foot sizes 8–14 in the Steenbeek manual is 30.18 cm (SD 3).⁵ In our series for similar foot sizes, the *predicted* mean bar length worked out to be 22.33 cm (SD 3) with significant statistical difference ($p < 0.001$). When foot

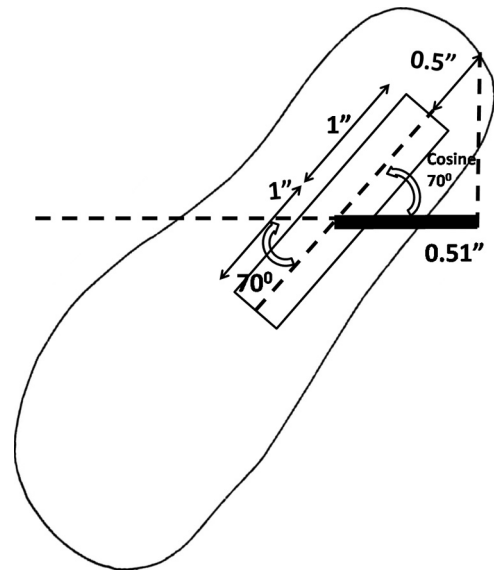


Fig. 3. Measurement of bar size from the shoulder width. The shoe is placed approximately 70° abduction to the rod. The metal plate measures 2" and is placed 1/2" proximal from the tip of heel. The metal rod is welded halfway of the metal plate. Applying simple trigonometry principles, the right angled triangle at heel has one angle 20° and other 70° (abduction). Using the cosine 70° (=0.34) values with the hypotenuse measuring 1 1/2" (half of metal plate + distance from tip of heel to plate), the base comes out to be .51". For two shoes, this distance totals (.51" × 2) (2.5 cm). This portion of metal rod was assumed to compensating for the distal placement of rod from the tip of heel, width of heel, flare of heel cup and the shoe angulations with respect to rod. The predicted bar length was derived by adding 2.5 cm to the measured shoulder width.

sizes 8–14 were compared individually, the difference was significant in all groups implying requirement of a shorter rod in Indian population (Table 2).

In unilateral clubfeet patients ($n = 76$), the mean affected foot length was 11.9 cm (SD 2.4) and unaffected foot was (12.6 cm; SD 2.6). This difference was not significant statistically ($p = 0.08$). Similarly, in bilateral clubfeet patients ($n = 80$), both feet sizes (12.29 cm; SD 2.5 versus 12.3 cm; SD 2.4) were comparable ($p = 0.978$).

6. Discussion

Since the recognition of importance of foot abduction brace in preventing relapse in clubfoot, many types of braces have been devised.¹ These braces although differ in many aspects, yet the bar length of the brace being equivalent to child's shoulder width has been a constant feature (e.g. SFAB, Markel brace, Mitchell, Dobbs).^{4,5,9} Child's comfort is the main reason cited for bar length to be equivalent to child's shoulder width.^{4,5,9}

The SFAB brace established its usefulness from the African Clubfoot programmes. The same brace was therefore used for Asian clubfoot population in India, Bangladesh and Nepal. Major skeletal differences are described in the human races from different continents.¹⁰ Our study indicated a statistically significant smaller bar length when same foot sizes were compared ($p < 0.001$). An indirect important inference of this observation is that the SFAB probably needs customization for its dimensions according to the regional racial characteristics.

A lot of misconception is being circulated on internet regarding differences in foot sizes in clubfoot. The affected foot is supposed to be on average 1–1 1/2 size smaller.¹¹ These beliefs probably originated when extensive surgeries were the predominant modality for clubfoot treatment. Kesemenli et al. reported a

Table 2
Statistical comparisons between *predicted* and *prescribed* bar length (foot size 8–14).

Foot size (number of patients in current series) (n = 140)	Predicted bar length (cm) ^a	Prescribed bar length (cm) ^b	p value ^{c,d}
8 (n = 12)	17.63 (SD 1.1)	26.25	<0.0001
9 (n = 16)	19.22(SD 1.1)	27.5	<0.0001
10 (n = 22)	20.80(SD 1.7)	28.75	<0.0001
11 (n = 24)	21.73(SD 1.4)	30	<0.0001
12 (n = 25)	23.04(SD 1.9)	31.25	<0.0001
13 (n = 22)	24.60(SD 1.5)	32.5	<0.0001
14 (n = 19)	23.42(SD 2.3)	35	<0.0001

^a The predicted bar length in our study was calculated from measured shoulder width by adding 2.5 cm.

^b According to Steenbeek brace for clubfoot' manual⁵.

^c Paired student -t test.

^d p value ≤ 0.05 were taken as significant.

comparison between conservatively treated clubfoot and contralateral unaffected foot.⁸ The average age in author's series was 8.8 years (range 7–12 years). Although, the authors reported a significant difference between feet length, but the conservatively treated foot was on an average just 0.91 cm (0.4–2.1 cm) shorter than the contralateral foot. Evidence to the contrary has gradually started accumulating. In a prospective longitudinal study by Gamble et al., 23 patients treated with Ponseti method with follow up of 36 months showed a non-significant difference of 9% between the two feet.¹² Now, even in successfully treated surgical unilateral clubfeet, no significant foot length difference has been reported.¹³ In bilateral disease also, the feet tend to be equal in length, with a mean difference in length of only 3.76% (SD 2.38).¹⁴ Our study too supported similar conclusions with no significant difference between the two feet in bilateral clubfeet (p = .978). The Ponseti treated unilateral clubfoot was bit smaller (mean difference 0.7 cm), yet fared well compared to unaffected foot (p = 0.08).

There were several limitations to our study which we acknowledge. The attachment of metal rod to the shoe is in fact a complex 3 dimensional configuration which was simplified into an approximate triangular geometry for the purpose of measurement in our study. The outsole's width in different brace sizes, the welding length of rod on the metal plates, the frontal curve of the abduction bar, deltoid mass in children were not taken into account for measurements. There were chances of interobserver variations in shoulder and foot size measurements which were minimized by utilizing a single operator and same measurement tool for all the patients. Further, the metal rod calculations were done assuming a bilateral clubfoot involvement.

The strength of our study is that it is a first of its kind pilot study to quantify the exact SFAB metal bar length on actual measurement basis rather than manual based/assumptions. The *predicted* bar length for the Indian child calculated from this series has not yet been put to practical use. We moreover wish to emphasize that the currently available SFAB has been in use for National clubfoot programmes in Indian patients for nearly 8 years and has worked well for the masses.¹¹ Thus, there may be many other factors by which the brace works besides the bar length. Our pilot study suggests that the racial differences may necessitate customization of the SFAB dimensions and sizes. More thought and multicentre research is highly desirable to enhance our knowledge in orthotic science for clubfoot.

7. Conclusions

Our study suggests a smaller bar length measurement in Indian children than the Steenbeek manual's SFAB as the difference between the *prescribed* and *predicted* bar length was statistically significant in foot sizes 8–14. Further our study reemphasizes that

there is no significant difference in foot length between the unaffected foot, Ponseti treated clubfoot in unilateral and both clubfeet in bilateral CTEV cases.

Conflict of interest

None.

Financial conflicts

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.jcot.2017.10.014>.

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