Original Clinical Article

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The significance of foot length at the initiation of the Ponseti method: a prospective study

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Abstract

Objectives We sought to evaluate foot length (FL) and forefoot circumference (FC) and their impact on the severity of idiopathic clubfoot (CF) and results of treatment. We hypothesized that a smaller foot size at birth that represents a lesser than term newborn may affect the response of the CF to the treatment.

Methods We conducted a prospective study documenting FL and FC of all neonates presented with idiopathic CF. Additional demographic information was collected. Outcome measures were number of casts needed for correction, need for recasting, additional surgery and functional score.

Results In all, 52 children with 73 CF with a minimum mean follow-up of two years (2.0 to 5.6; sd 1.08) were evaluated. Mean gestational age was 38.63 weeks and mean birth weight (BW) was 3184 g. The mean FL at presentation was 74 mm (5.70 to 9.00), initial Pirani score was 5.5 (2.5 to 6.0) while number of casts was 6.9 (4.0 to 11.0). The FL was significantly correlated both to initial Pirani score ($r = -0.35$; $p < 0.01$) and number of casts ($r = -0.33$; $p < 0.05$). Positive correlation was found between the number of casts to Pirani score and number of additional procedures ($r = 0.39$; $r = 0.36$; $p < 0.01$, respectively). A foot size of up to 8 cm, needed 7.3 casts (4 to 7) compared with a FL of 8 cm or longer who needed 4.7 casts (4 to 6; $t = 7.11$; $p < 0.001$).

Conclusion FL is a simple approach to identify preterm babies. It can be used as part of the initial evaluation of CF and help in predicting the course of treatment. We recommend adding FL to the existing classification.

Level of evidence I - Prognostic study

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Introduction

The Ponseti method is the most popular approach for the initial treatment of idiopathic clubfoot (CF) around the world.[1]

The classification of CF is based on the evaluation and documentation of clinical features such as severity of CF, rigidity of the foot, depth of posterior and medial skin creases and tightness.

The most commonly used classification systems described by Dimeglio et al[2] and Pirani[3] apply a point system based on physical features of the foot trying to differentiate between mild, moderate and severe affection which has direct implications on the length and extent of treatment required, i.e. number of casts, need for tenotomy, etc. Good correlation has been found between the two classification systems.[4] Both well adopted scores describe the foot deformity at presentation; however, they lack information and do not deal with the maturity of the neonate with CF and its effects on the length of treatment and outcome.

Gestational age (GA) is the common term used during pregnancy to describe how far along the pregnancy is in weeks. A normal pregnancy can range from 38 to 42 weeks and infants born before 37 weeks are considered premature. GA is a critical factor in the management decision-making, prognosis and follow-up of newborn infants. Miscalculation may lead to misclassification of the newborn as a preterm, full-term and post-term baby. GA is the easiest way to describe foetal and neonatal growth and maturation. GA can be estimated from last menstrual period, antenatal ultrasound or neonatal estimates. Ultrasound-based dating is considered the benchmark. Neonatal estimates represent a postnatal scoring system based on physical and neurological maturation parameters. Foot length (FL) has been used in antenatal ultrasound scanning as an alternative method to estimate GA and has been validated in many antenatal[5] and postnatal studies.[6-8] It has also been recognized by the World Health

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Organization[9] as a simple approach to identify preterm babies. It was shown that postnatal FL measurements can accurately determine GA.[10-13]

Delayed development and ossification process of the tarsal bones in CF has been shown in many studies[14-20] to have resulted in a smaller foot size. Furthermore, the three muscle compartments of the CF leg are shorter and thinner than normal in unilateral CF compared with the unaffected side[21] while the leg muscular atrophy is a primitive pathological component of CF and is present at an early stage of foetal development.[22]

Our prospective study shows that there are direct relationships and significant correlations between the neonatal FL and the severity of the CF and the treatment outcome of Ponseti-treated idiopathic CF.

We recommend using FL in the initial evaluation and classification of idiopathic CF in newborn babies.

Materials and methods

We have conducted a prospective consecutive study, approved by our institutional review board, of 52 children with idiopathic CF treated by Ponseti method in our CF clinic between May 2012 and December of 2015. The minimum follow-up period from the last cast change was two years. Only children treated from the first cast in our clinic were included. Children with non-idiopathic or atypical CF or children with CF who had started treatment in other centres were excluded. At the first visit the following parameters were collected and recorded: neonatal information: GA, sex, birth weight (BW), family history of CF, uni- or bilaterality, age at presentation to clinic, FL and forefoot circumference (FC). During the treatment and follow-up the following parameters were recorded: Pirani score at presentation and before each casting visit, number of casts, need for tenotomy, compliance with foot abduction brace protocol, functional evaluation at the last visit, need for additional treatment such as recasting, need to repeat tenotomy and/or additional surgery.

Cast changes were performed by an experienced paediatric orthopaedic surgeon (YH) familiar with the Ponseti protocol and running the CF clinic in our hospital for more than a decade.

Foot measurements of all neonates included in the study were taken on their first admission to the clinic before first casting. Measurements were performed using a measuring tape. Length was measured from the tip of the heel to the tip of the great toe while circumference was measured at the level of the head of the metatarsi. All measurements were taken and recorded separately by two experienced independent observers (YH, AY) in two separate rooms. One observer was the treating paediatric orthopaedic surgeon while the second one was a well-trained physiotherapist running the CF clinic.

Outcome measures

The primary outcome measures assessed the Pirani score at presentation before first cast, number of casts needed for correction before the FAB prescribed, need for tenotomy and the need for additional treatment during the follow-up period, such as recasting, surgery to re-do tenotomy, tibialis anterior tendon transfer (TATT) or posterior release.

Tenotomies

All primary Achilles tenotomies were performed in our outpatient clinic under local anaesthesia. In patients where re-do tenotomy was indicated it was performed under general anaesthesia.

Functional assessment

Function was evaluated according to the Ezra et al[23] modification of the Laaveg and Ponseti method.[24] It was performed by our trained physiotherapist at the last office visit. The Ezra functional scale comprises of: range of movement, position of the heel, appearance of the forefoot, presence of cavus, supination, pattern of gate, shoe type and parents' satisfaction. The final score integrates the separate score of each parameter. A maximum score of 150 points reflects optimal functioning.

Statistical analysis

Intraobserver and interobserver reliability of FL and FC were calculated. The intraclass correlation coefficients (ICCs; two-way random effects model, single-measure reliability) were calculated for each parameter. Reliability was scored according to the method described by Altman,[25] with a score of 0.81 to 1 rated as very good, 0.61 to 0.8 rated as good and 0.41 to 0.60 as moderate. Data were analyzed by calculating means and percentages for establishing the trends. The relationship between two continuous variables was tested by calculating the Pearson correlation coefficient. The average difference between the continuous variables between groups was tested by the t test. A two-sided p-value < 0.05 was considered as being statistically significant. Statistical analysis was performed using SPSS, version 24.0 (SPSS Inc., Chicago, IL).

Results

In all, 52 children that fulfilled our inclusion criteria were included in the study. There were 41 boys and 11 girls with 73 feet, 21 with bilateral involvement. The mean

follow-up duration was 3.9 years (2.0 to 5.6; SD 1.08). Eight of the 52 children had a first generation relative with CF (15.3%). The children were first to seventh born babies in their families. Mean gestational age was 38.63 weeks (33 to 42; SD 1.8). There was no difference between boys and girls in respect of the CF with which they presented.

Vertex presentation was present in 88.4% of pregnancies (46 babies, breech presentation in 9.61%, five babies), while one was unknown. Delivery mode was vaginal in 40 babies (76.92%) while 12 (23.08%) were born by caesarean section.

Mean BW was 3184 g (2170 to 4140; SD 49.2) without difference between sexes. First cast was applied at a mean 1.5 weeks of age (1 to 6; SD 1.1) and was similar for boys and girls.

Table 1 summarizes foot parameters of the 73 CF and includes FL, foot circumference, Pirani score at presentation, number of casts needed for correction and the functional score. No difference was found between boys and girls. Achilles tenotomy was performed in all the 73 feet. It was performed at an average age of 8.15 weeks (5 to 13; SD 2.11) and was similar for boys and girls.

Failure of correction during the follow-up period was defined as a re-do tenotomy and/or surgery such as TATT and/or posterior release was 15% (11/73). In most patients preliminary casting was performed.

Interobserver and intraobserver reliability of the FL and FC were studied and were highly rated. The ICC for interobserver reliability for length was very good (0.817) and good (0.763) for FC. The ICC for intraobserver reliability was very good for both parameters (0.9).

Table 2 describes the Pearson correlation between study variables. Significant correlation was found between FL and the initial Pirani score before casting ($r = -0.35$; $p < 0.01$, Fig. 1).

The number of casts needed to full correction was significantly correlated to the FL measured at presentation ($r = -0.33$; $p < 0.05$; Fig. 2). There was no significant correlation between FL and functional score or rate of additional procedures. As expected, FL was positively correlated to BW and gestational age ($r = 0.493$; $r = 0.348$; $p < 0.01$, respectively). Positive correlation was found between the number of casts needed and the Pirani score and the rate of operations ($r = 0.39$; $r = 0.36$; $p < 0.01$, respectively).

Table 1 Foot and treatment parameters (73 feet)

Parameter	Mean (SD; range)
Foot length, cm	7.40 (0.62; 5.70 to 9.00)
Foot circumference, cm	9.32 (0.78; 8.00 to 11.80)
Initial Pirani score	5.55 (0.74; 2.50 to 6.00)
Number of casts	6.93 (2.25; 4.00 to 11.00)
Functional score	125.56 (18.48; 53.00 to 145.00)

Table 2 Pearson correlations between study variables

	Pirani score	Cast number	Birth weight	Gestational age	Circumference	Functional score	Secondary procedures
Foot length	-0.352*	-0.329*	0.493*	0.378*	0.661*	-0.141	0.194
Initial Pirani score		0.393*	0.101	-0.076	-0.041	-0.023	0.021
Number of casts			0.000	-0.067	0.038	-0323**	0.356**

*p < 0.01

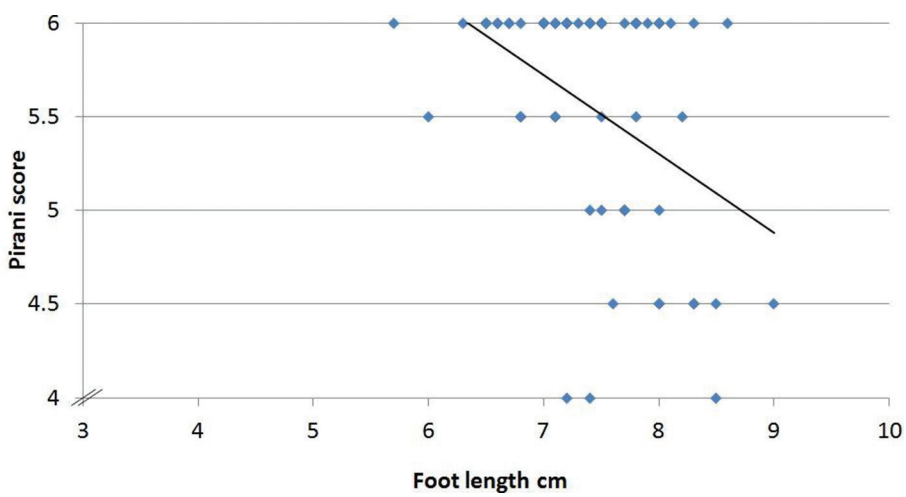

Fig. 1 Foot length and Pirani score at presentation.

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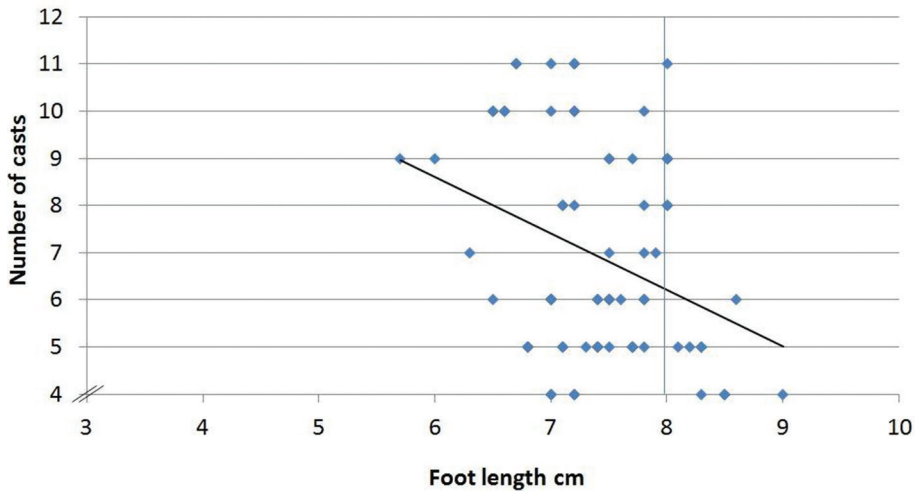

Fig. 2 Foot length and number of casts needed for correction.

No significant correlation was found between the initial Pirani score and the functional score or rate of operations. No significant correlation was found when FC or FC/FL ratio were used as variables for statistical analysis (data not shown).

It is important to note that neither BW nor GA has any significant correlation to Pirani score at presentation or with the number of casts need for correction. When controlling for GA we did not find changes in the Pearson correlation. Figure 1 is a scatter plot showing the Pirani score at presentation in relation to FL. It can be seen that a longer foot may have a better Pirani score. Looking at the scatter plot of the number of casts needed for correction in relation to the foot size (Fig. 2) one can see that children with a FL shorter than 8 cm need more casts to achieve correction. Therefore, we have used the t test to evaluate the differences between the number of cast changes needed for a FL of more than 8 cm or less.

We found that children with a FL of 8 cm or longer needed an average of 4.7 cast changes (4 to 6; $r = 7.11$; $p < 0.001$).

Discussion

Foot size at presentation may play an important role in the initial assessment and may create difficulties in manipulation and casting of a shorter foot. We have shown here that FL is significantly correlated to the Pirani score at presentation and the number of casts need for correction. This is important and useful information when planning treatment and advising parents. The small foot size may represent a less mature newborn with a lesser developed foot. Our data show that a smaller foot needs more casts changes to achieve correction. In our study, feet that were 8 cm long or more benefited from less casts and shorter treatment periods. We strongly believe that FL should be added to the commonly used classification systems and be documented as part of the initial evaluation of the neonate with idiopathic CF. It provides a simple and practical parameter with direct implication on length and extent of treatment.

A FL measurement is a valid proxy to identify at risk infants in their neonatal period in developing countries when more accurate information is missing. FL in the first days of life can evaluate low BW and prematurity among newborns babies.[11-13] Wyk and Smith[10] have shown that FL correlates with GA. Interobserver and intraobserver variability of FL measurements was low. Of interest is their finding that FL of 80.0 mm SD 4.0 correlates to the 40th week of gestation and it is not influenced by sex or race. They compared different neonatal FL studies and models that came to identical conclusions.

Many reports have been published describing structural and histological abnormalities in CF. Changes have been found in muscles, tendons, vascular anomalies as well as joint capsules and ligaments.[26-29] There are studies that report on a smaller size ossification centre of tarsal bones in CF, delayed ossification process or disturbed endochondral ossification sequence.[14-15,17,30-32] All result in smaller tarsal bones and a shorter foot. There are uncertainties regarding the nature of some of these pathological changes. Are they primary embryonic or acquired? Studies on foetuses suggest that many of the abnormalities are part of the primary underlying pathology of CF.[22]

We acknowledge that the weakness of our study may be the length of the follow-up. We strongly believe that meaningful CF studies should have a minimum of five- to six-year follow-up or even more.

Despite its weaknesses, the method of measurement is simple, easy, with low interobserver variability and

provides very useful predictive information. It is a very simple addition to the existing classification systems.

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COMPLIANCE WITH ETHICAL STANDARDS

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ETHICAL STATEMENT
Ethical approval: This study did not directly involve human participants and/or animals. This study was approved by the institutional review board (reference 0023-18-TLV).
Informed consent: In this study, retrospective data were extracted from patients' files so no informed consent was required.

ICMJE CONFLICT OF INTEREST STATEMENT
None of the authors has any potential conflict of interest to declare.

AUTHOR CONTRIBUTIONS
YH: Collecting and analyzing the data, reviewing the literature, writing the manuscript.
AY: Collecting and analyzing the data, reviewing the manuscript.
RG: Reviewing and editing the manuscript.
SW: Reviewing and analyzing the data, reviewing and editing the manuscript.

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