Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Assessment of the ankle joint in clubfeet and normal feet to the age of four years by ultrasonography

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Abstract

Purpose To establish reproducible posterior ultrasonographic projections for evaluation of the movement in the talocrural joint in clubfeet and normal feet from the perinatal period up to the age of four years.

Methods The feet in 105 healthy children and 46 patients (71 clubfeet and 21 normal feet) were examined. In all, 14 feet in seven patients were examined twice by two examiners independently to evaluate the repeatability of the ultrasonography scans. A posterior sagittal projection was used. The distance from the posterior aspect of the tibial physis to the posterior border of the talocalcaneal joint (Tib. phys – TCJ) was measured with the foot in neutral position and dorsiflexion. In plantar flexion the shortest distance between the tibial physis and the calcaneus was measured. The distance from the skin to the tibial epiphyses and the talus was measured in neutral position. The intraclass correlation coefficient (ICC) was calculated to evaluate the repeatability of the measurements.

Results The interexaminer reliability was 0.71 to 0.89 ICC. The intra- and interobserver reliability measured as ICC was 0.68 to 0.99 for all measurements. The correlation between Tib. phys. – TCJ and clinical dorsiflexion varied much between the age groups.

Conclusion Ultrasonography of the posterior aspect of the ankle joint can be done with high interexaminer reliability. The repeatability of image evaluation was high. Correlation to clinical measurements varied, therefore dynamic ultrasound in real time is clinically more useful than single measurements on frozen ultrasound images.

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Level of Evidence III

Cite this article: Johansson A, Aurell Y, Romanus B. Assessment of the ankle joint in clubfeet and normal feet to the age of four years by ultrasonography. *J Child Orthop* 2018;12:262-272. DOI 10.1302/1863-2548.12.170217

Keywords: Clubfoot; Ponseti treatment; ultrasonography; congenital foot-deformity; repeatability

Introduction

Clubfoot is one of the most common congenital deformities (1 to 6/1000).[1] Clubfoot is a complex 3D deformity. The foot is in equino-varus-adductus position because of stiffness of the soft tissues at the medial and posterior aspect of the lower leg and the foot. Treatment according to the Ponseti method usually starts during the first weeks of life with weekly redressions and serial castings until the foot is corrected (usually five to seven casts). The redressions and castings have to be done accurately to avoid spurious correction.[2] Percutaneous tenotomy of the Achilles tendon is performed in 85% to 97% of all clubfeet.[3-6] To prevent relapse after the correction, foot-abduction-orthoses are used 23 hours/day during the first three months and after that when sleeping until the age of four years.[1,3] When the treatment of clubfeet takes place during the first years of life a large portion of the foot skeleton is still not fully ossified. Therefore plain radiographs give limited information of the tarsal bones. To follow the progression of treatment an imaging method that visualizes the cartilaginous parts of the skeleton is needed. For this purpose, ultrasonography is very suitable and it has the advantages that dynamic images can be obtained without radiation and no sedation is needed.[7]

Because the treatment continues from the first weeks of life to the age of four years, it is essential to have normal values for the whole of this period based on standardized and reproducible imaging protocols. During the clubfoot treatment it is crucial to obtain and maintain plantar and dorsiflexion mobility in the talocrural joint for a normal gait. A lack of dorsiflexion will provoke inadequate loading with varus tilting of the foot in the stance phase of gait which increases the risk of a relapse of the clubfoot deformity.[1] If the Achilles tendon is too tight and the foot is forced into dorsiflexion it may result in a rocker bottom deformity. In an infant clubfoot this can be masked by a thick soft-tissue heel pad (empty heel sign in the Pirani score) and the high standing calcaneus is not revealed without a thorough palpation.[8] Ultrasonography can be very helpful to visualize the movement in the ankle joint dynamically and the position of the calcaneus. Previously published ultrasound studies have mainly focused on the 3D deformities in the midfoot.[9-13] In the literature the dorsal sagittal ultrasonography projection has been described, mainly focusing on children less than 12 months of age, but no measurements of the mobility in the ankle joint with normal references have been presented.[14-17]

Purpose

The purpose of this study is to establish reliable variables for the posterior projection which are independent of the age-related size of the ossified nucleuses and can be used from the perinatal period to the age of four years. We will evaluate the correlation between these variables and clinical measurements and if the movement in the talocrural joint can be assessed by using these measurements with the foot in neutral, plantar-flexed and dorsiflexed positions. We also aim to establish normal values for the age span from new-born to the age of four years and to compare the measurements of clubfeet with the controls.

Materials and methods

Materials

A cross section study design was chosen to get two age stratified study groups, patients with clubfeet and controls, covering the age span from new-born to four years of age.

The control group, 105 healthy children (45 boys and 60 girls), was recruited from the Child Care Centre, Billingens Vårdcentral, Skövde, Sweden and the Maternity Department, Skaraborg Hospital, Skövde, Sweden. Ten age groups (newborn, three, six, 12, 18, 24, 30, 36, 42 and 48 months of age) with a minimum of ten children in each group were recruited. The patients in the clubfoot group were all recruited from the Department of Orthopaedics, Sahlgrenska University Hospital/Östra, Gothenburg, Sweden and included all children who were under treatment for idiopathic clubfoot in 2007 and who had not reached four years of age. The clubfoot cohort included 46 children (33 boys and 13 girls) with 71 clubfeet (25 bilateral and 21 unilateral). The same age groups as the controls were used, but the number of patients in the groups varied. For age correlated statistical calculations the limit for the groups was set to ± 2.6 months (Tables 1 and 2).

Method

The children were sitting on the caregiver's lap during the ultrasonography examination. The child's foot was held by the orthopaedic surgeon (AJ) in three different positions at the ankle joint (neutral, maximal dorsiflexion and maximal plantar flexion) during the scanning. The probe was placed sagittally on the heel over the Achilles tendon (Fig. 1). For each foot-position one to three frozen ultrasonography images were saved and the images of best quality were chosen for measurement.

The examinations were performed with a high-frequency linear transducer (8 MHz to 15 MHz and 5 MHz to 17 MHz) with an Acuson, Sequoia (Acuson, Mountain View, California) ultrasonography machine.

All images were stored in the same regional radiological archive and measurements were performed using the

Table 1 Number of feet included per age group

Age months	0	3	6	12	18	24	30	36	42	48	Total
Controls	20	26	20	20	22	22	20	20	20	20	210
Clubfeet	0	2	12	3	8	8	12	5	6	13	69
Normal in unilateral cases	0	2	2	1	2	2	4	1	4	3	21

When the statistical calculations were done the limit for the age groups was set to ± 2.6 months, hence one nine-month-old bilateral case was excluded in the calculations. In the 48-month group three children (six clubfeet) had passed the age limit 48 months + 2.6. See statistics and discussion.

Table 2 Number of examinations measured

Measurement	1 (interpreter AJ)	2 (interpreter AJ)	3 (interpreter YA)
Controls, feet 210	210	60	66
Clubfeet 71	71	36	71
Normal in unilateral cases	21	0	21
Two examiners	14 feet	Both examinations were measured once by interpreter AJ.	

Fig. 1 Transducer position over the posterior aspect of the ankle mortis parallel to the Achilles tendon.

Picture and Archiving System (PACS) software (Centricity PACS, GE Healthcare Integrated IT Solutions, Barrington, IL and SECTRA PACS, Linköping, Sweden).

The control group as well as the children with clubfeet were examined once by one of three experienced ultrasonography examiners: Stina-Britta Haux, Gudmundur Einarsson and Karin Steneryd.

To evaluate the reproducibility of the scanning of the posterior ultrasonography projection, 14 feet in seven patients (ten clubfeet and four normal feet, age 47 days to two years and two months) were examined by two experienced ultrasonography examiners (YA and Stina-Britta Haux) on the same day. The two ultrasonography scans were performed independently, one following the other. The images produced by the two investigators were measured once at separate times by a third evaluator (AJ).

Evaluation of repeatability of measurement: control group

All images from the investigation of the 210 feet in the control group were analyzed once by one of the authors (AJ) and the images of 60 of these feet, chosen to represent different ages (three, six, 12 and 48 months), were analyzed by the same author at another occasion with at least one month's interval to get intraobserver repeatability measurements. The images from 66 of the 210 feet in the controls, chosen to represent different ages (three, six, 12 and 48 months) were analyzed a third time by YA in order to get interobserver repeatability measurements (Table 2).

Evaluation of repeatability of measurement: clubfoot group

All examinations of the 71 clubfeet were interpreted by two of the authors (AJ and YA) separately to get interobserver repeatability measurements. Half of the clubfeet, chosen to represent different age groups (six, 18, 24 and 48 months of age) were analyzed a third time by AJ to get intraobserver repeatability measurements (Table 2).

Variables evaluated on the ultrasonography images

1. To evaluate the movement in the ankle joint the distance from the posterior border of the distal tibial physis to the posterior border of the talocalcaneal joint, tibial physis – talocalcaneal joint distance (Tib. phys. – TCJ), was measured with the foot in neutral position and in maximal dorsiflexion (Fig. 2).
2. The shortest distance from the tibial physis to the cranial surface of the calcaneus was measured with the foot in plantar flexed position, tibial physis – calcaneal distance (Tib. phys. – C) (Fig. 3). This variable was also used for clubfeet with remaining equinus (Fig. 4a).
3. The perpendicular distance from the skin to the tibial epiphysis was measured with the foot in neutral position or as near neutral as possible in feet with remaining equinus, skin – tibial epiphysis distance (Skin – Tib. E) (Fig. 2a).
4. The perpendicular distance from the skin to the posterior border of the talus was measured with the foot in neutral or as near neutral position as possible, skin – talus distance (Skin – Talus) (Fig. 2a and Fig. 4).
5. The position of the posterior border of the talus in relation to the posterior border of the tibial epiphysis was evaluated with the foot in neutral position or as near neutral as possible in feet with remaining equinus, posterior alignment. If the posterior border of the talus was in line with the tangent of the posterior surface of the tibial epiphysis it was classified as aligned. If the posterior border of the talus was anterior to the tangent of the tibial epiphysis it was classified as not aligned, indicating some equinus or plantar flexion in the ankle joint (Fig. 5).

The following clinical variables were registered

1. Foot length.
2. Plantar flexion and dorsiflexion measured by a handhold goniometer.
3. Position of the heel: neutral, varus or valgus.

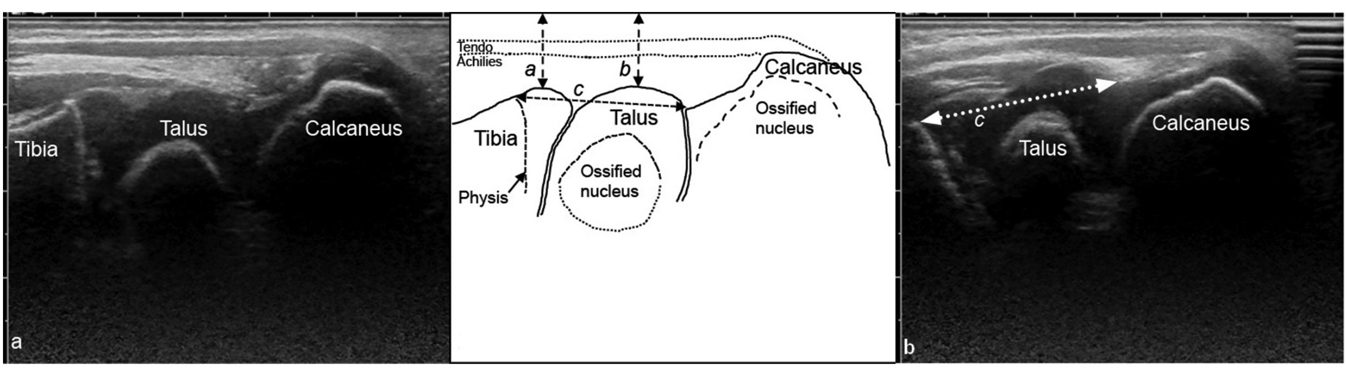

Fig. 2 (**a**) Posterior ultrasonography scan of the left foot in neutral position in a 1.5-year-old boy with bilateral clubfeet (*a* skin – tibia distance, *b* skin – talus distance, *c* tibial physis – talocalcaneal joint distance) (Tib. phys. – TCJ); (**b**) the same foot as in (a) in dorsiflexion (*c* Tib. phys. – TCJ).

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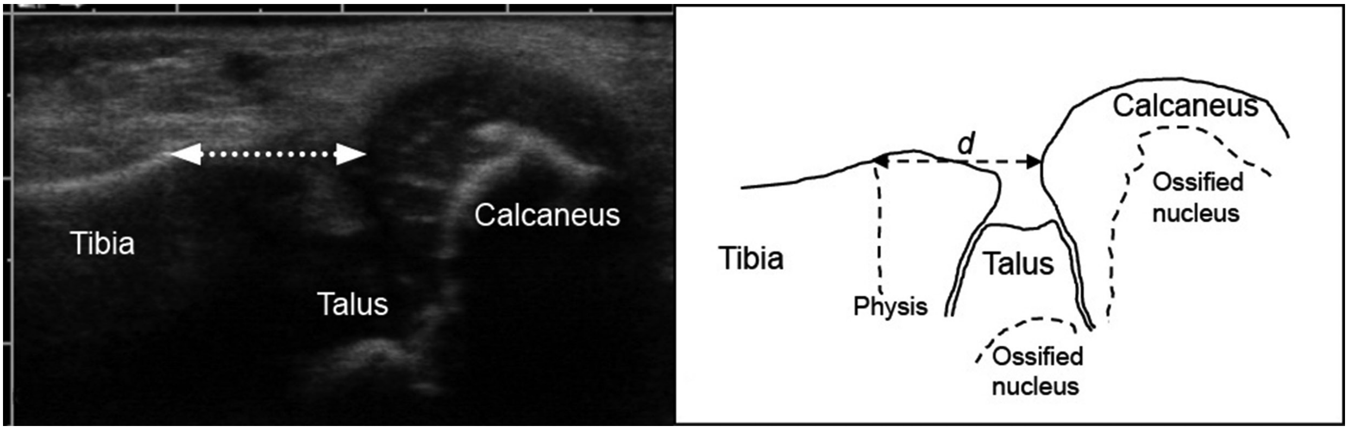

Fig. 3 Left foot in plantar flexion in a six-month-old girl with bilateral clubfeet (after initial correcting treatment) (*d* the tibial physis – calcaneus distance).

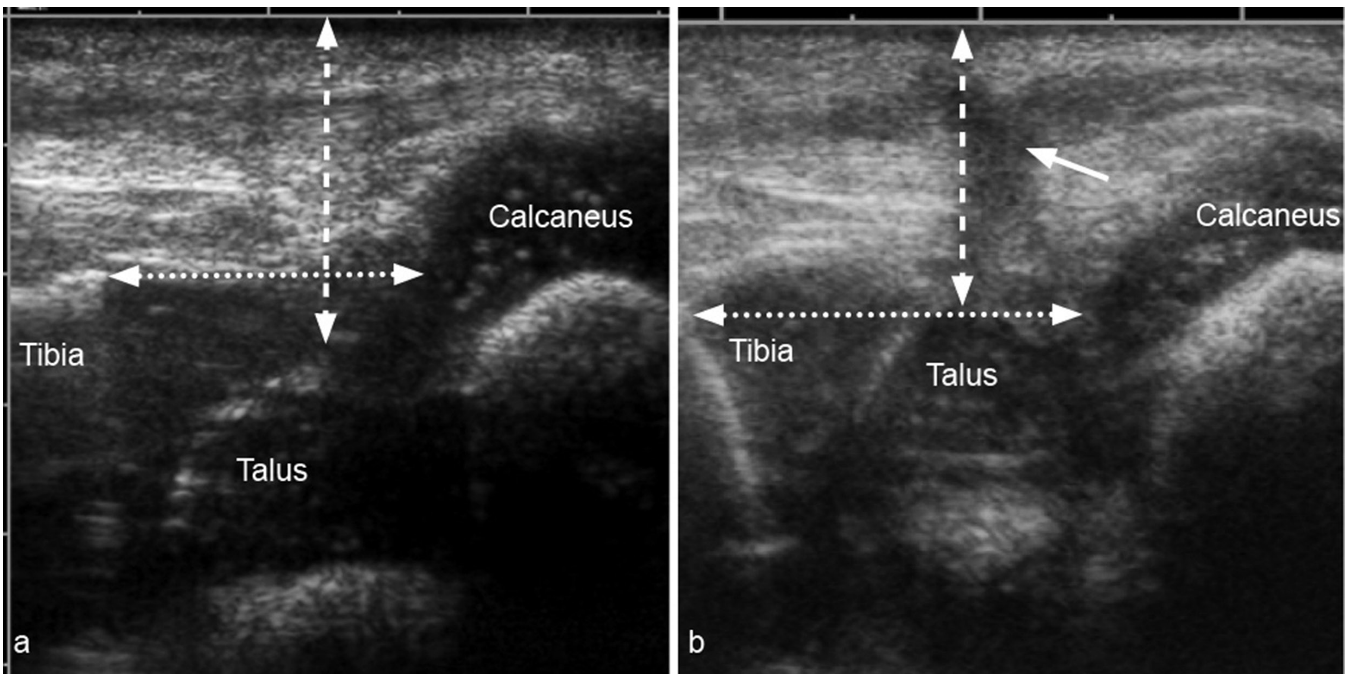

Fig. 4 Posterior sagittal projection of the left foot in a 10-week-old boy with bilateral clubfeet before percutaneous tenotomy of the Achilles tendon (**a**) and three weeks after the tenotomy (**b**). Notice the more dorsal position of the posterior border of the trochlea tali in relation to the tibia and the shorter skin – talus distance (dashed arrow), the increased distance between tibial physis and calcaneus (dotted arrow) and the scar after the tenotomy (solid arrow). Before the tenotomy the posterior border of the talus was not aligned with the posterior surface of the tibial epiphysis but after the tenotomy it was aligned.

Statistical analysis

The diagrams and calculations were done by IBM SPSS Statistics 22 (IBM Corp., Armonk, New York). Intraclass correlation coefficient (ICC) was used for the calculation of interobserver, intraobserver and interexaminer reliability. The Mann-Whitney U test was used for the statistical comparisons. In the age-stratified comparative statistical calculations, the age group limits were set to ± 2.6 months, hence one nine-month-old child (two feet) and three children (six feet) who had passed the age of 48 + 2.6 months were excluded from the age-stratified comparative calculations. Sensitivity analyses were done with and without the three patients (six clubfeet) who had passed the age of 48 + 2.6 months, but this did not change the results of the sensitivity tests.

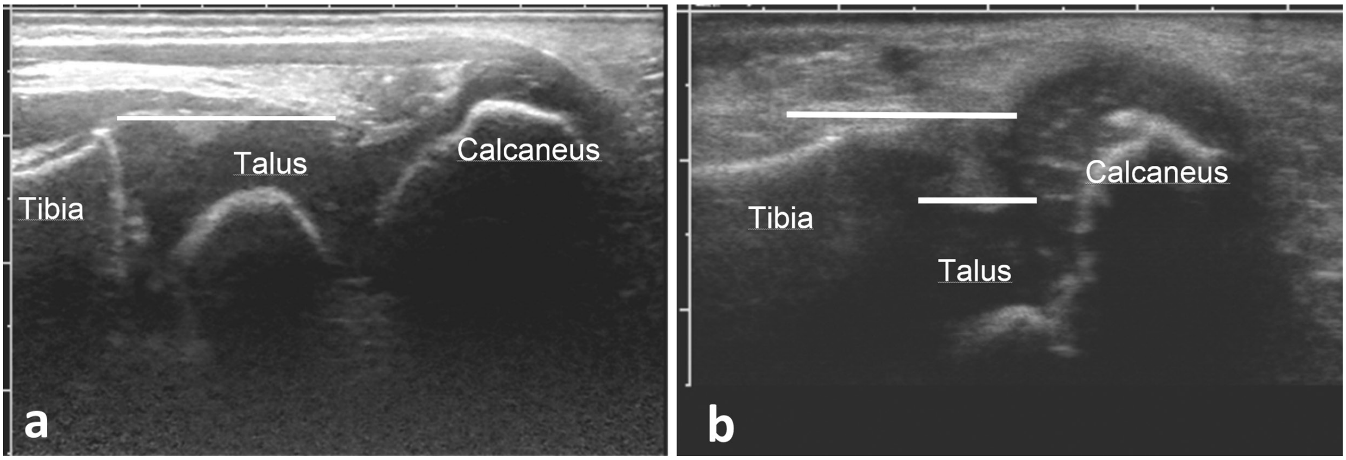

Fig. 5 Posterior alignment: (**a**) aligned, the posterior border of the talus is in line with the tangent of the posterior surface of the tibial epiphysis; (**b**) not aligned, the posterior border of the talus is anterior to the tangent of the tibial epiphysis.

Results

Ultrasonographic measurements

During the ultrasound scans, 85.7% of the children were relaxed, 8.7% strained the muscles a little, 4.5% strained much and 1.1% were rebellious, resulting in incomplete investigations.

The ICC for intraobserver agreement for all variables was ≥ 0.90 for controls and ≥ 0.86 for clubfeet. Interobserver agreement for controls was ≥ 0.8 for all variables, except for the Tib. phys. – C in plantar flexion (0.68). The interobserver ICC for clubfeet was ≥ 0.84 for all variables. The interexaminer agreement was 0.71 to 0.89 (ICC).

The Tib. phys. – TCJ distance in neutral position was shorter in the clubfeet than in the control group, statistically significant ($p < 0.05$) for the age groups six, 18, 24 and 30 months with a tendency in the other groups.

The Tib. phys. – TCJ distance in dorsiflexion was shorter in the clubfeet, indicating less dorsiflexion compared with the control group, was statistically significant ($p < 0.05$) in the age groups six, 18, 24, 30, 36 and 42 months and there was a tendency in the groups three, 12 and 48 months old (Fig. 6). There was no significant correlation between Tib. phys. – TCJ distance in dorsiflexion and clinical dorsiflexion measured with goniometer in clubfeet or in controls. The correlation coefficient for Tib. phys. – TCJ distance in dorsiflexion and clinical dorsiflexion measured by goniometer varied much between the age groups, from - 0.273 ($p = 0.274$) to 0.912 ($p = 0.011$).

The Tib. phys. – C distance in plantar flexion had a tendency to be longer in clubfeet than in the control group (less plantarflexion in the clubfeet). The numeric values increased in both groups with increasing age but the relative difference remained.

Both the Skin – Tib. E and the Skin – Talus distances were shorter in clubfeet than in normal feet ($p < 0.05$ in the six, 18, 24, 36, 48 months groups, and there was a tendency in the other age groups). The difference between the Skin – Talus distance and the Skin – Tib. E distance tended to be greater in the clubfeet than in normal feet. This means that the posterior border of the talus tended to be more anteriorly positioned in relation to the tibia in the clubfeet.

Posterior alignment

In this clubfoot cohort, already under treatment, only seven out of 69 were classified as not aligned in neutral position, i.e. the posterior border of the talus was anterior to the tangent of the posterior border of the distal tibial epiphysis (aligned means the posterior border of the talus and the tibial epiphyses are at the same level).

The normal values from the control group are presented in Table 3 and the clubfoot values are in Table 4.

Clinical measurements

The mean value for foot length was shorter (0.6 cm to 2.7 cm) in the clubfeet than in the corresponding control group except for the 36 months group where the mean value for the clubfeet was 0.25 cm longer.

From the age of six months (after the correction phase of clubfoot treatment) the mean plantar flexion calculated per age group was 6° to 19° less and the dorsiflexion was 4° to 15° less in clubfeet than in the corresponding control age groups (Fig. 7).

In terms of the mean range of movement, the sum of plantar flexion and dorsiflexion measured by goniometer for each foot, calculated per age group was 14° to 34° less

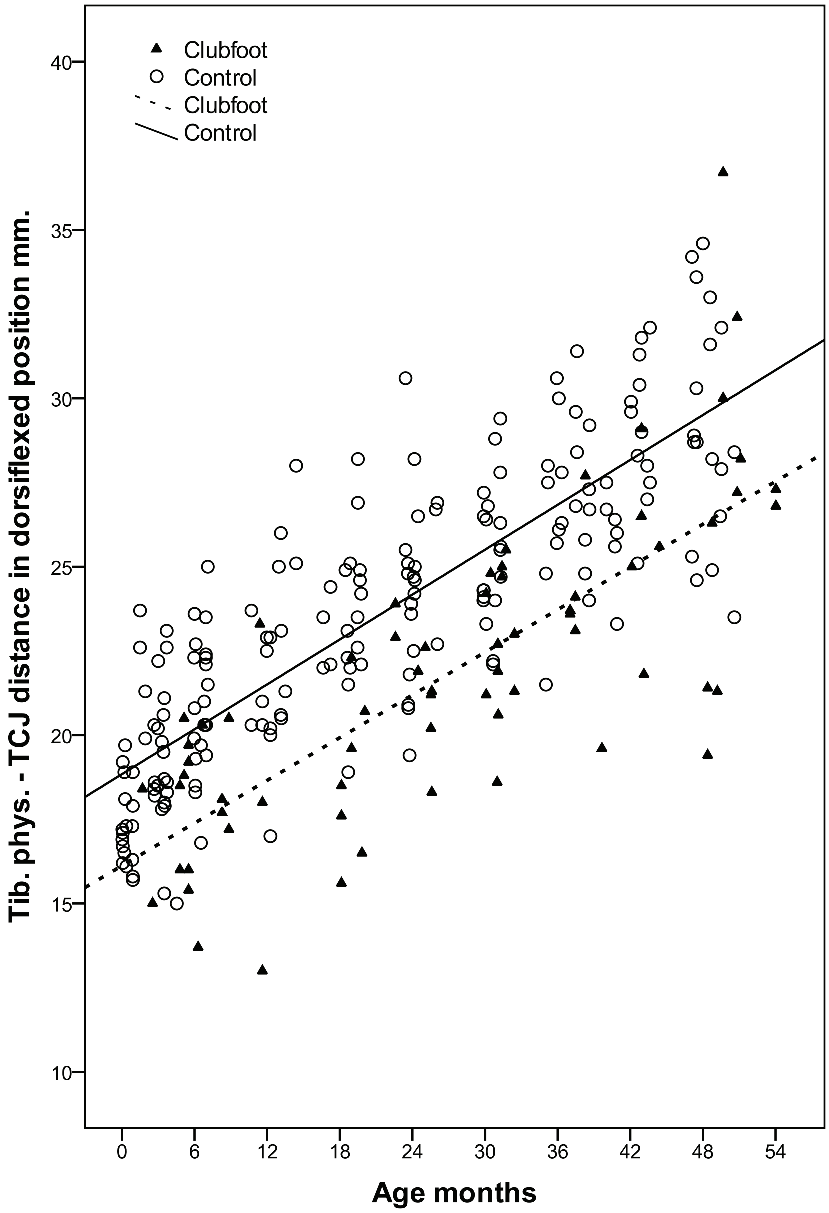

Fig. 6 Tibial physis – talocalcaneal joint distance (Tib. Phys. – TCJ) in dorsiflexed position in clubfeet and controls. The Tib. Phys. – TCJ distance was shorter in the clubfeet compared with the controls, statistically significant in some age groups and a tendency in the others.

Table 3 Measurements: controls

Age	Skin – Tib. E	Skin – Talus	Tib. phys. – TCJ	Tib. phys. – TCJ	Tib. phys. – C
Group (mths)	Neutral, mm (n)	Neutral, mm (n)	Neutral, mm (n)	Dorsiflexion, mm (n)	Plantarflexion, mm (n)
0	8.5 sd 2.8 (20)	7.8 sd 1.5 (20)	15.1 sd 1.9 (20)	17.9 sd 2.1 (20)	12.6 sd 1.6 (19)
3	10.9 sd 1.3 (26)	9.7 sd 1.5 (26)	17.4 sd 1.5 (23)	19.3 sd 2.0 (23)	12.6 sd 2.1 (23)
6	11.9 sd 2.0 (20)	10.5 sd 1.8 (19)	18.0 sd 1.8 (15)	21.0 sd 2.0 (20)	12.2 sd 2.0 (16)
12	12.5 sd 2.0 (19)	11.8 sd 1.6 (18)	19.6 sd 2.5 (17)	22.2 sd 2.7 (18)	13.2 sd 2.7 (16)
18	13.8 sd 1.6 (21)	13.3 sd 1.6 (21)	20.7 sd 2.3 (19)	23.5 sd 2.1 (19)	13.5 sd 2.6 (19)
24	14.3 sd 2.5 (21)	13.5 sd 2.1 (21)	21.0 sd 2.0 (20)	24.4 sd 2.7 (20)	13.1 sd 2.5 (17)
30	13.9 sd 2.0 (20)	13.9 sd 2.0 (20)	21.7 sd 2.6 (20)	25.4 sd 2.1 (19)	13.8 sd 2.9 (18)
36	15.0 sd 2.6 (19)	15.2 sd 2.0 (18)	23.1 sd 2.1 (16)	27.1 sd 2.4 (20)	14.9 sd 2.3 (13)
42	15.4 sd 2.4 (20)	15.9 sd 2.0 (19)	23.8 sd 2.2 (17)	28.1 sd 2.4 (18)	15.5 sd 1.8 (14)

Measurements in relation to age, distances in mm mean sd 1; n = number of images with good enough quality to permit adequate measurement of the specific variable

Skin – Tib. E, skin – tibial epiphysis distance; Skin – Talus, skin – talus distance; Tib. phys. – TCJ = tibial physis – talocalcaneal joint distance; Tib. phys. – C, tibial physis – calcaneus distance

Table 4 Measurements: clubfeet

Age	Skin–Tib. E	Skin–Talus	Tib. Phys.–TCJ	Tib. Phys.–TCJ	Tib. phys.–C
Group (mths)	Neutral, mm (n)	Neutral, mm (n)	Neutral, mm (n)	Dorsiflexion, mm (n)	Plantarflexion, mm (n)
0	(0)	(0)	(0)	(0)	(0)
3	9.0 sd 1.0 (2)	8.8 sd 1.8 (2)	16.1 sd 0.5 (2)	16.7 sd 2.4 (2)	13.5 sd 1.7 (2)
6	10.0 sd 1.2 (12)**	9.2 sd 1.4 (12)*	15.8 sd 1.9 (11)**	17.8 sd 2.1 (12)**	13.2 sd 2.4 (11)
12	12.5 sd 1.2 (3)	11.1 sd 1.1 (3)	17.2 sd 3.7 (3)	18.1 sd 5.1 (3)	13.5 sd 3.5 (3)
18	9.7 sd 0.9 (8)**	10.8 sd 1.3 (8)**	17.0 sd 3.0 (8)*	18.7 sd 2.4 (7)**	14.4 sd 2.1 (5)**
24	11.5 sd 1.7 (8)*	12.0 sd 1.9 (8)	19.1 sd 1.7 (8)*	21.5 sd 1.7 (8)**	16.2 sd 1.8 (8)
30	12.6 sd 2.2 (12)	13.6 sd 1.9 (11)	19.2 sd 2.5 (11)*	22.8 sd 2.1 (12)**	16.4 sd 2.3 (11)*
36	12.3 sd 0.8 (5)**	13.1 sd 0.7 (5)*	21.5 sd 1.7 (5)	24.4 sd 1.9 (5)*	17.3 sd 1.0 (4)
42	14.6 sd 1.2 (6)	15.6 sd 1.2 (6)	21.5 sd 3.1 (6)	24.6 sd 3.4 (6)*	17.2 sd 3.5 (3)
48	13.4 sd 2.7 (12)**	14.9 sd 1.3 (12)*	22.1 sd 5.2 (11)	27.0 sd 5.1 (11)	18.1 sd 3.7 (11)

Measurements in relation to age, distances in mm mean SD 1; n = number of images with good enough quality to permit adequate measurement of the specific variable

* p <0.5

** p < 0.01; statistically significant differences compared with controls

Skin – Tib. E, skin – tibial epiphysis distance; Skin – Talus, skin – talus distance; Tib. phys. – TCJ = tibial physis – talocalcaneal joint distance; Tib. phys. – C, tibial physis – calcaneus distance

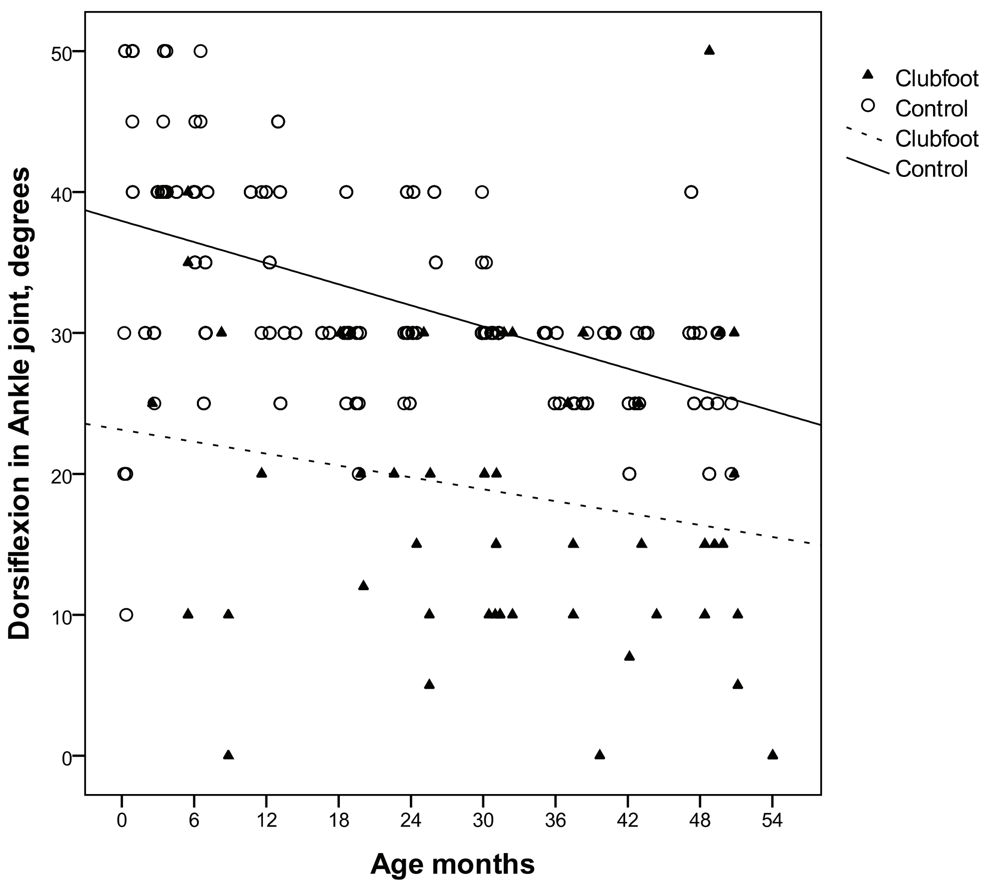

Fig. 7 In the controls the dorsiflexion in ankle joint measured by goniometer decreases slowly during the first four years of life. After the initial correction phase of clubfoot treatment, the dorsiflexion decreases slightly over time also in clubfeet.

in the clubfeet than in the corresponding control group (Fig. 8).

The heel was in varus position in four and in valgus in three of the clubfeet. The heel was in valgus in one foot in the control group, all the others were in neutral position.

Discussion

This paper focuses on the posterior projection, but of course it should be used together with the medial and lateral coronal projections and the dorsal sagittal projection for global 3D evaluation of the foot.

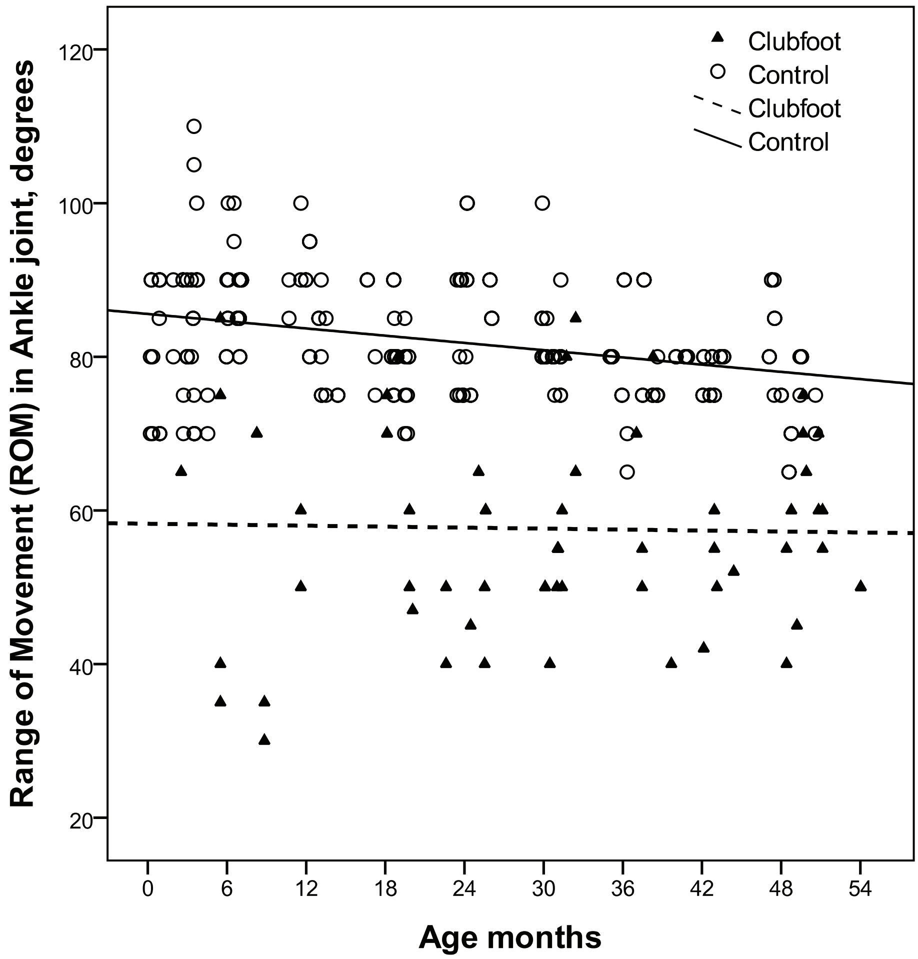

Fig. 8 Clinical range of movement (ROM) in the ankle joint (ROM, sum of plantar flexion and dorsiflexion measured by a handhold goniometer). The ROM was approximately 20° less in clubfeet compared with the controls.

Examination circumstances

To get reliable and repeatable examinations it is essential to have a relaxed child. If the child is straining the muscles it is difficult to get images with the foot in the desired position (neutral, maximal dorsiflexion and plantar flexion). At ages one to 2.5 years it is most difficult to get the children relaxed and co-operative. In the interexaminer study, five out of seven children belonged to the 12 and 24 months age groups. Although the examination circumstances were not optimal the interexaminer ICC was good (0.71 to 0.89).

Methods

The intention was to perform the ultrasonography examination within ± one month of the planned age. This was difficult to achieve in some cases for different reasons (illness, parents work, etc), therefore, ± 2.6 months was accepted for the comparative statistical analyses.

In order to obtain measuring points, which are reproducible over time when the child grows, the posterior border of the talocalcaneal joint (in neutral position and dorsiflexion) and the cartilaginous cranial surface of the calcaneus (in plantar flexion) were chosen for the measurement of the distance to the distal tibial physis. The ossified nucleus in the calcaneus is easier to visualize and has been used in some studies, but with increasing age it comprises a larger proportion of the calcaneus, thus the measurement point would not be constant over time.[14-16] Therefore, in this study the posterior border of the talocalcaneal joint and the cartilaginous surface of the calcaneus were chosen as measuring points. It is more demanding regarding image quality but this can be overcome by proper adjustment of the equipment especially in modern ultrasound machines. At the tibia side the posterior border of the physis was chosen because it is not hidden by ossified surrounding bone in older children and can be easily identified also at the age of four years.

Limitations

No untreated clubfeet were included. This was a cross section study of the patients who were under treatment when the study started, and there were no newborn patients with clubfoot at that moment.

The number of clubfeet in some of the age groups were too few to permit statistical calculations (Table 1).

The Tib. phys. – TCJ distance cannot be measured in plantar flexion as the talocalcaneal joint is hidden between the tibial epiphysis and the calcaneus. Thus, this variable cannot be used in the whole range of movement. Therefore, the shortest distance from the posterior border of the tibial physis to the cranial surface of the calcaneus (Tib. phys. – C) was measured in plantar flexion but in neutral, and especially in dorsiflexion it would be oblique and give a false too high value (Figs 2 and 3). The Tib. Phys. – C makes it possible to compare the variable in different feet and to do repeated examinations of the same foot, but not to compare with the Tib. phys. – TCJ distance in neutral position and dorsiflexion; this is a limitation.

The fact that the clubfoot cohort was under treatment and had passed the initial phase of correction meant that only seven out of 69 feet were classified as not aligned, and a reliable intra- and interobserver calculation could not be performed for the variable posterior alignment.

The great variation of correlation between Tib. phys. – TCJ distance and the dorsiflexion measured by goniometer in the different age groups (correlation coefficient -0.273 to 0.912) is the clinically most important limitation. The Tib. Phys. – TCJ distance increases with age because of growth of the foot (Fig. 6). The clinically measured dorsiflexion decreased with age from the neonatal period in controls and from the age of six months in clubfeet (after the initial correction phase) to the age of four years (Fig. 7). This may explain the negative correlation between the Tib. phys. – TCJ distance and dorsiflexion over the entire period (newborn to four years of age). The negative correlation within some of the age groups is more difficult to explain. Possible explanations may be the fact that the Tib. phys. – TCJ distance is influenced by the size of the foot, the dorsiflexion was measured at 5° intervals and the age span in each group was 5.2 months (± 2.6 months).

Measurements

The clinical measurements of the foot length showed shorter mean values in clubfeet compared with the controls in all age groups except in the 36 months group. Therefore, by measuring distances on ultrasonography images, the differences between the clubfeet and the normal feet can to some extent be explained by the difference in foot size. In the 13 unilateral cases, where both foot length and the Tib. phys. – TCJ values in neutral position were available, the mean difference in foot length was 4.1% (sd 2.8) and the mean difference in Tib. phys. – TCJ was 12.3% (sd 18.8). Provided that the size difference is equally distributed in the whole foot, only about one-third of the difference can be explained by the difference in foot size, and there was a much larger variation among the clubfeet than in the contralateral normal feet. It would be of interest to add images of the metatarsals to find out if the size difference is proportional in the tarsal bones and the metatarsals. Beck et al[18] reported that the percentage hypoplasia of the ossified structures was greater in the hindfoot than in the forefoot compared with the contralateral normal foot in unilateral clubfeet. This indicates that the Tib. pys. – TCJ and Tib. phys. – C distances will be proportionally shorter than expected from the difference in foot length compared with the normal foot in children with unilateral clubfoot or compared with controls. Histological analyses have revealed fibrosis in the soft tissues in the hindfoot but normal soft tissues distal to the navicular bone. In addition, there were skeletal deformities in the tarsal bones while the metatarsals were normally shaped in the clubfeet.[1,8]

The fact that the Tib. phys. – C distance is longer in clubfeet indicates less plantar flexion in the treated clubfeet than in the controls. The tendency for lesser difference between Tib. phys. – TCJ in dorsiflexion and neutral position indicates less dorsiflexion in the clubfeet. Thus the total range of movement in the ankle joint was less in the clubfeet. This is in accordance with the clinical measurements by a handhold goniometer in connection to the ultrasonography examinations.

When normal feet are in neutral position the posterior border of the talar trochlea is aligned with the posterior border of the tibial epiphyses, and there were no significant differences between the clubfeet and the control group. The reason for this is probably that all the clubfeet were already under treatment when the examinations were performed, and therefore, the difference between clubfeet and controls was small. In untreated clubfeet there would probably be a difference.[16]

It was not possible to correlate the clinical range of movement to the measurements on ultrasound images because different distal measure points were used in plantar flexion and dorsiflexion (Tib. phys. – TCJ and Tib. phys. – C).

To evaluate the interinvestigator reliability and intra- and interobserver reliability of image evaluation frozen images were used, but in clinical practice dynamic investigation in real time is easier and less time consuming. By using dynamic images in real time it is easy to visualize if the talus is moving unrestrictedly in the ankle mortis or not, and this is, in our opinion, clinically useful information.

Relevance in clinical practice

Ultrasound acts as complementary to the clinical evaluation and the results should always be considered together with the clinical findings. Dynamic ultrasound images can be a valuable tool in education and training on clubfoot treatment, as it gives the examiner an instant view of what they can feel. Some examples are shown in the animations (supplementary material): normal foot (Video 1) and a clubfoot before and three weeks after percutaneous lengthening of Achilles tendon (Video 2). Visual comparison (without measurements) of frozen images in neutral position, plantar flexion and dorsiflexion also gives a good estimate of the movement in the ankle joint (Figs 2 to 5).

The main contribution of the ultrasound imaging might be its unique possibility to acquire a true dynamic visualization of motions in the ankle joint. The technique is widely available and the learning curve for performing dynamic ultrasound is reasonable, according to our experience. We suggest that the dynamic imaging can give a more confident assessment of decreased dorsiflexion to the treating clinician. Further studies have to be performed in order to show if relapses will be detected earlier by using dynamic ultrasound in difficult cases.

Conclusions

Ultrasonography images of the posterior aspect of the ankle joint can be achieved with good interexaminer reliability. Evaluation of the ultrasound images of normal feet and clubfeet can be done with good intra- and interobserver agreement, but the correlation to clinical measurements were not as good because of too many confounding factors. Therefore, single measurements on ultrasound images of the posterior aspect of the ankle joint cannot be used for clinical decisions, but dynamic ultrasonography provides a good visualization of the movement in the ankle joint and can be a valuable tool in education and at follow-up if there is doubt about the movement in the ankle joint during the first four years of life.

Supplementary material

Animations showing movement in the ankle joint in a normal foot (Video 1) and in a clubfoot before and after percutaneous lengthening of the tendo Achilles (Video 2) can be found alongside the online version of this article.

Received 04 January 2018; accepted after revision 21 April 2018.

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

The study was financially supported by The Research Fund at Skaraborg Hospital, The Health & Medical Care Committee of the Regional Executive Board, Region Västra Götaland and The Skaraborg Institute for Research and Development.

ETHICAL STATEMENT

Ethical approval: The study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments. The study was approved by The Regional ethical review board in Gothenburg, Sweden (ref. 031-06 and T397-07).

Informed consent: All caregivers of the children included in this study signed an informed consent.

ICMJE CONFLICT OF INTEREST STATEMENT

None declared.

ACKNOWLEDGEMENTS

We thank all the children and their parents for participating in the study.

We thank the staff at the Department of Orthopaedics, Sahlgrenska University Hospital/Östra, Gothenburg and the Department of Orthopaedics, Skaraborg Hospital, Skövde for referring patients for the study, the staff at the Child Care Centre at Billingens Vårdcentral and the Maternity Department, Skaraborg Hospital, Skövde for referring healthy children for the control group.

We thank Stina-Britta Haux, Gudmundur Einarsson and in memoriam Karin Steneryd for performing the ultrasonography examinations, Salmir Nasic for statistical support, Peter Johansson for photographing for the illustrations and Anna-Lena E-son Loft for technical support.

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