CHAPTER **41**

NEWBORN PEDAL RANGE OF MOTION EXAMINATION

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Early diagnosis of an abnormality would seem to have certain implications on early treatment. Orthopedic problems in the neonate, unless grossly deforming, tend to be pushed aside and deemed unimportant. There is a noticeable scarcity of literature on the newborn orthopedic examination when compared to other age groups or other neonatal problems. It is difficult to predict the implications of problems in the newborn if there are no standards of "normal." Gross abnormalities have been identified and researched, with grading of the severity of some of these deformities. Yet, there are many milder forms of these deformities which often are ignored or considered to be within the range of normal, that progress to become symptomatic pathology in adulthood. This study attempts to define normals for newborn feet, compare different methods of measurement, and establish a reproducible way to measure for metatarsus adductus.

MATERIALS AND METHODS

Newborns from Mercy Hospital, San Diego, California, born between January 1996 and May 1996 were evaluated in the well-baby nursery. The study population consisted of a random selection of one hundred newborns. All pertinent birth history was obtained such as race, date and time of birth, weight, length, gestational age, Apgar scores, and type of delivery. A brief history of the mother's prenatal care and prior pregnancy and birthing history were also obtained.

Fifty female and fifty male babies were evaluated within 72 hours after delivery. All newborns were 37 weeks or greater in gestational age. There was one set of fraternal twins, a male and a female. Of the one hundred babies, 55 were Hispanic, 25 Caucasian, 10 Black, 5 Filipino, 3 Asian and 2 Indian. Twenty-two babies were born by cesarean section, and all other babies were born by spontaneous vaginal delivery. Prenatal care varied from none, less than 3 visits, to full care. Birth weight ranged from 2585g to 4743g. Apgar scores at one and five minutes were no less than 7 for all newborns studied.

A general cursory examination was performed for any gross abnormalities, and a hip evaluation performed for hip clicks, dislocations and general range of motion. Evaluation of the knee was also performed for gross deformity. The pedal examination consisted of ankle joint range of motion, subtalar joint range of motion, first metatarsophalangeal joint range of motion and malleolar position. Forefoot adductus was also evaluated and measured in three different fashions and compared.

MEASUREMENTS

All measurements were taken by the same examiner. A tractograph with two degree intervals was used. The patients were evaluated in a supine position with hip, knee, and foot held in approximately 90° of flexion.

Ankle Joint: Measurements were made for dorsiflexion and pantarflexion of the ankle joint. Reference lines were made using the lateral bisection of the leg and the bisection of the fifth metatarsal (Figs. 1A, 1B).

Subtalar Joint: Inversion and eversion measurements were made again using a tractograph. The posterior bisection of the leg and bisection of the posterior aspect of the heel were used as the reference lines (Figs. 2A, 2B).

First Metatarsophalangeal Joint: Reference lines for this evaluation consisted of the medial bisection of the first metatarsal and the proximal phalanx of the hallux. Dorsiflexion, plantarflexion and total range of motion were measured (Figs. 3A, 3B).

Malleolar Position: The central aspect of the medial and lateral malleolus was identified, and

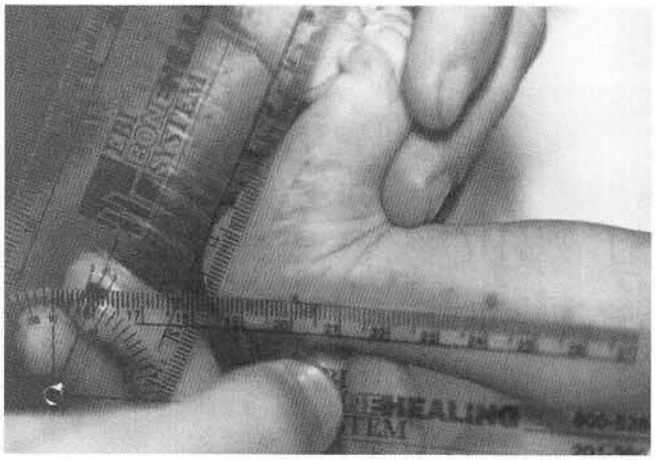


Figure 1A. Using the lateral bisection of the leg and the bisection of the fifth metatarsal, the foot is dorsiflexed to its maximum and a measurement is made.

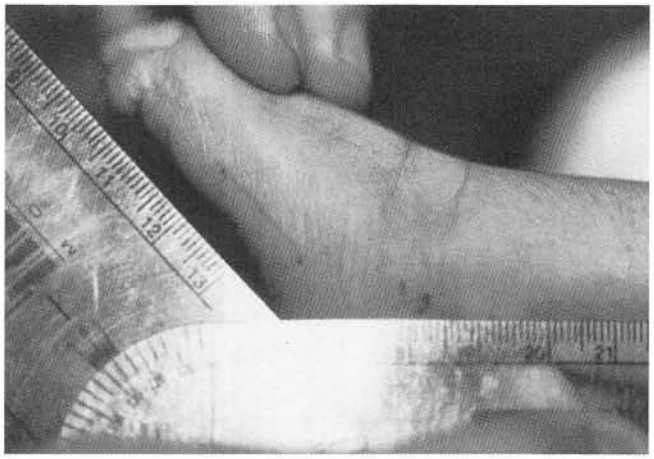


Figure 1B. The foot is then plantarflexed to its maximum, where a measurement is made.

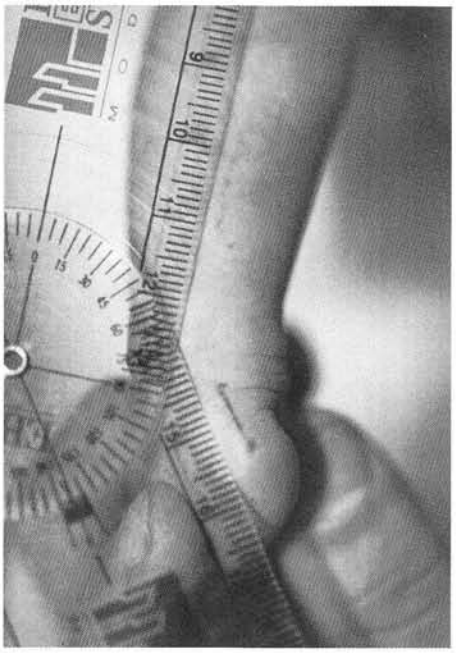


Figure 2A. In the maximally everted subtalar joint position, the bisection of the heel is measured in relationship with the bisection of the leg.

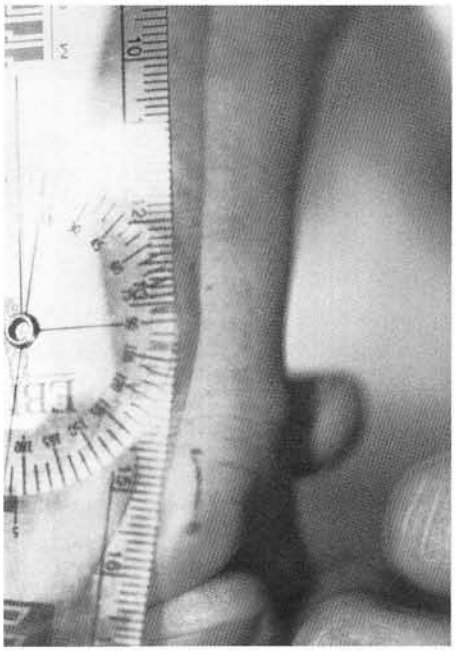


Figure 2B. The relationship is also measured with the subtalar joint maximally supinated.

Figure 3A. The relationship of the medial bisection of the proximal phalanx of the hallux and medial bisection of the first metatarsal was measured in the most dorsiflexed position.

Figure 3B. The relationship was measured in the most plantarflexed position.

Figure 4. Malleolar position was measured by connecting an imaginary line between the malleoli as viewed from the plantar surface of the foot in its relationship to a perpendicular of the bisection of the heel.

viewed to form an imaginary line when observed from the plantar aspect of the foot. The degree of angulation of this line compared to the perpendicular of the bisection of the heel plantarly, gave a measurement of external tibial torsion in degrees (Fig. 4).

Forefoot Adductus: Three different methods were used to evaluate the forefoot position in the transverse plane. The first consisted of using the lateral border of the foot when viewed plantarly. The lateral border of the forefoot was measured compared to the lateral border of the rearfoot. The dividing border between forefoot and rearfoot being the base of the fifth metatarsal (Fig. 5A).

The second method was the bisection of the forefoot compared to the bisection of the rearfoot on the plantar surface of the foot. Again, the dividing border between the forefoot and rearfoot being the base of the fifth metatarsal (Fig. 5B).

The third method of measurement of the forefoot adductus was measured according to Bleck.[1] When viewing the foot plantarly, a bisection of the heel was drawn and extended out distally past the forefoot. Normal forefoot to rearfoot position defined by Bleck with this method was the heel bisector exiting between the second and third digits. A mild deformity was defined as exiting through the third digit. Moderate deformity was classified as exiting between the third and fourth digits or through the fourth digit. A line drawn between the fourth and fifth digits was defined as severe. A quick clinical method of determining metatarsus adductus is to place two fingers (one on each side of the foot) along the medial and lateral borders of the foot to see if the borders are a straight line. If the forefoot is adducted significantly, then the lateral border does not contour to the finger (Figs. 5C, 5D). This is difficult to measure statistically.

Figure 5A. The lateral border of the forefoot was measured compared to the lateral border of the rearfoot, with the base of the fifth metatarsal being the dividing border.

Figure 5B. Bisection of the forefoot was compared to the bisection of the plantar surface of the rearfoot. (Note Bleck's method can also be used in the same fashion.) If the extension of the bisection of the heel extends out between the second and third digits, this is considered normal. Mild deformity occurs if the extension passes out through the third digit, a moderate deformity was classified as existing between the third and the fourth digits, and severe deformity occurs at the line that extends out between the fourth and fifth digits.

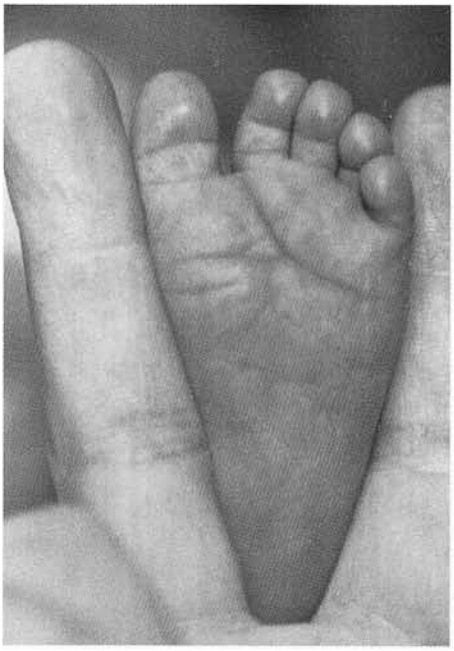


Figure 5C. Clinically, if the index and middle fingers are placed along the medial and lateral border of the foot and appears to be in contact with the fingers, it is relatively normal.

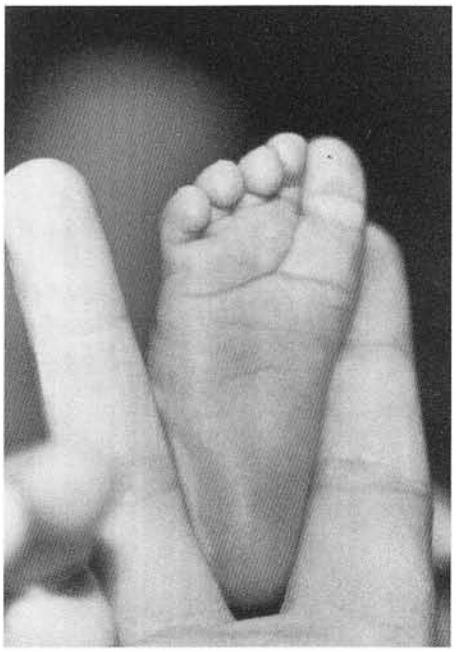


Figure 5D. Metatarsus adductus is present when the v-shape of the index and middle finger is in close contact with the rearfoot, but there is adduction away from the finger along the lateral border. In this case, you can see that a metatarsus adductus is apparent.

RESULTS

All measurements were averaged with the median and range calculated, and a comparison of females to males, and right and left limbs using the student t-test. For all measurements, there was no statistical significance between measurements for females and males, or between right and left limbs.

Ankle joint range of motion (Table 1) for all 200 extremities ranged from 34 to 80 degrees of dorsiflexion, with an average range of 57 degrees. Plantarflexion measurements ranged from 10 to 60 degrees, averaging 38.8 degrees (Figs. 6A-6C).

Measurements of the subtalar joint (Table 2) had a fairly large range of total motion of 20 to 67 degrees. In the majority of the patients, there was more inversion motion compared to eversion motion, but only by a few degrees. The average amount of subtalar inversion was 21 degrees, with a range of 8 to 42 degrees. Eversion ranged from 8 to 32 degrees and averaged 16.2 degrees (Figs. 7A-7C).

First metatarsophalangeal joint range of motion (Table 3) was fairly symmetrical in dorsiflexion and plantarflexion with a total range of 138 to 210 degrees of motion. Dorsiflexion ranged from 60 to 120 degrees and averaged 92.5 degrees, and plantarflexion motion from 50 to 120 degrees, averaging 85.2 degrees (Figs. 8A-8C).

Malleolar position (Table 4) was fairly consistent, with most of the 200 limbs falling between 3 and 5 degrees of external rotation. Right feet had a slightly higher average than left feet although statistically, this was insignificant (Figs. 9A, 9B).

The three combined methods of forefoot adductus measurements (Table 5) were difficult to compare. The bisection method versus the lateral forefoot to rearfoot measurements were comparable methods to each other (Fig. 10). The range of forefoot adductus for both of the first two methods was 0 degrees to 20 degrees. Most of the population had an adductus from 0 to 8 degrees. The more moderate to severe adductus had higher degrees of angulation when compared to Bleck's method. Bleck's method did not correlate well with the degrees of angulation determined in the other two methods.

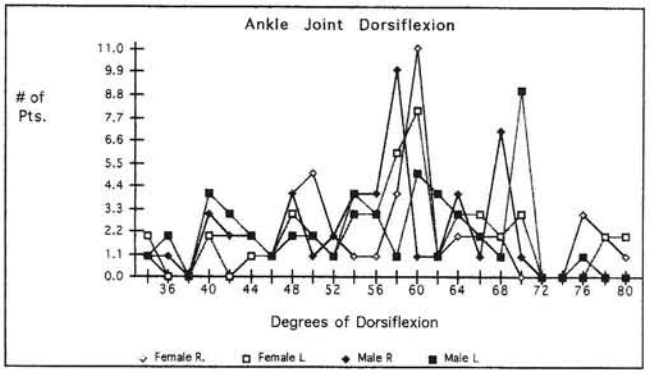


Figure 6A.

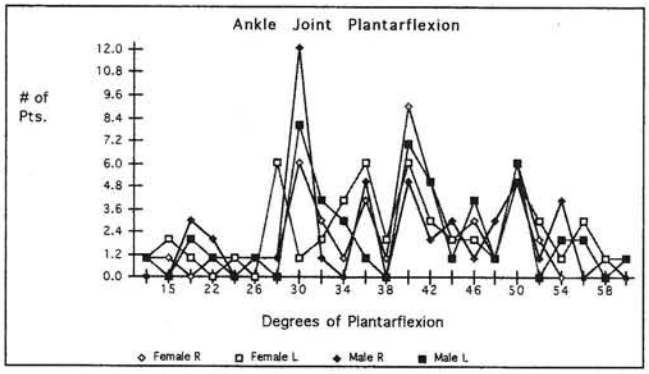


Figure 6B.

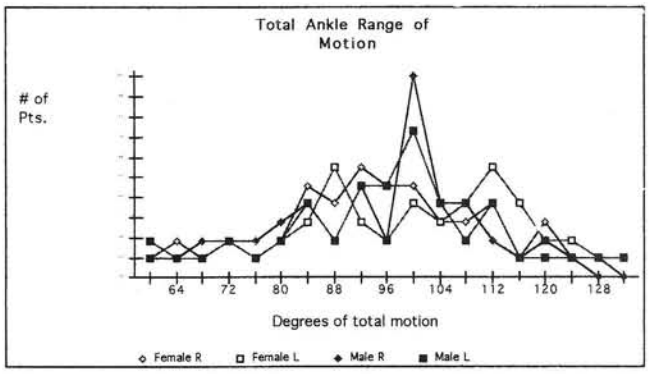


Figure 6C.

Table 1

ANKLE JOINT RANGE OF MOTION

(in Degrees)

	Dorsiflexion			Plantarflexion			Total		
Extremity	Ave.	(Range)	Median	Ave.	(Range)	Median	Ave.	(Range)	Median
Female Right	57.0	(34-80)	58	38.5	(10-58)	40	95.5	(58-128)	96
Female Left	58.5	(34-80)	59	40.0	(10-60)	40	98.5	(55-130)	100
Male Right	56.9	(34-72)	60	38.0	(20-55)	40	93.9	(62-125)	98
Male Left	56.1	(35-76)	60	39.0	(12-60)	40	95.1	(56-132)	98
Combined	57.2	(34-80)	58	38.8	(10-60)	40	95.8	(55-132)	98

Table 2

SUBTALAR JOINT RANGE OF MOTION

(in Degrees)

	Inversion			Eversion			Total		
Extremity	Ave.	(Range)	Median	Ave.	(Range)	Median	Ave.	(Range)	Median
Female Right	21.3	(8-35)	20	16.3	(10-32)	14	37.8	(20-65)	38
Female Left	21.3	(10-35)	20	17.2	(8-32)	16	38.5	(22-67)	38
Male Right	20.7	(10-40)	20	15.6	(8-30)	16	36.3	(22-62)	36
Male Left	20.3	(10-42)	20	15.7	(10-32)	14.5	36.2	(22-63)	34.5
Combined	21.0	(8-42)	20	16.2	(8-32)	15.5	37.2	(20-67)	36

Table 3

FIRST METATARSOPHALANGEAL JOINT RANGE OF MOTION

(in Degrees)

	Dorsiflexion			Plantarflexion			Total		
Extremity	Ave.	(Range)	Median	Ave.	(Range)	Median	Ave.	(Range)	Median
Female Right	93.5	(76-120)	94.5	84.8	(50-100)	90	178.3	(140-210)	180
Female Left	93.2	(70-120)	94.5	84.8	(60-100)	90	178.0	(60-100)	180
Male Right	91.5	(60-114)	90	86.4	(60-100)	90	177.8	(140-204)	180
Male Left	91.8	(66-110)	90	84.7	(60-100)	90	176.5	(138-208)	178.5
Combined	92.5	(60-120)	90	85.2	(50-120)	90	177.7	(138-210)	180

Table 4

MALLEOLAR POSITION

(in Degrees of External Rotation)

Extremity	Ave.	(Range)	Median
Female Right	4.24	(2-8)	4
Female Left	4.06	(2-8)	4
Male Right	4.22	(2-7)	4
Male Left	4.04	(2-6)	4
Combined	4.14	(2-8)	4

Table 5

FOREFOOT ADDUCTUS

(in Degrees)

Extremity	Ave.	(Range)	Median
Female Lateral	4.88	(0-17)	4
Female Bisection	5.4	(0-18)	5
Male Lateral	5.28	(0-20)	4
Male Bisection	5.91	(0-20)	5
All Lateral	5.08	(0-20)	4
All Bisection	5.67	(0-20)	5

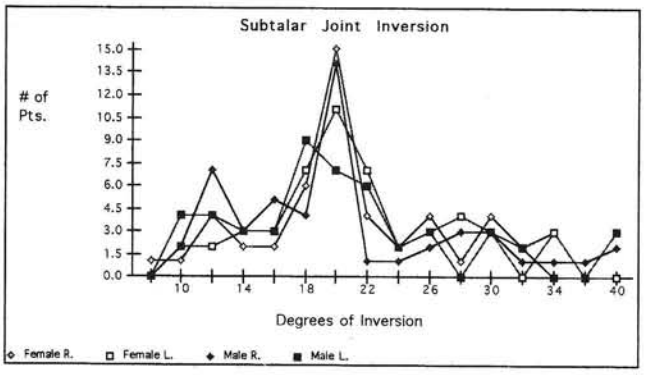
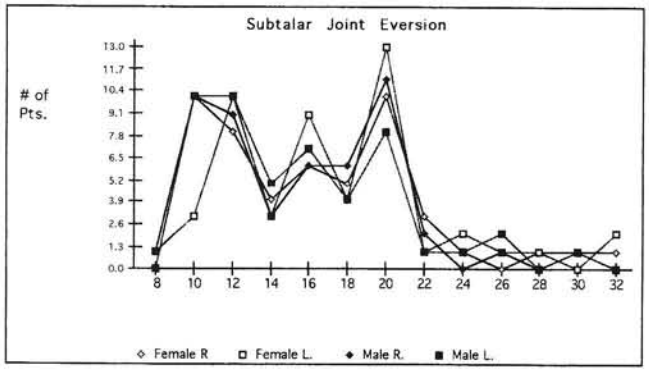


Figure 7A.



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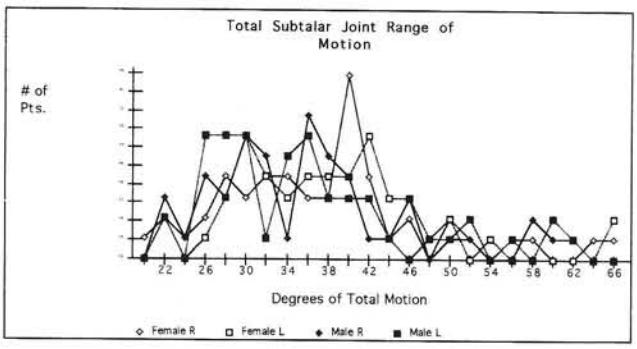

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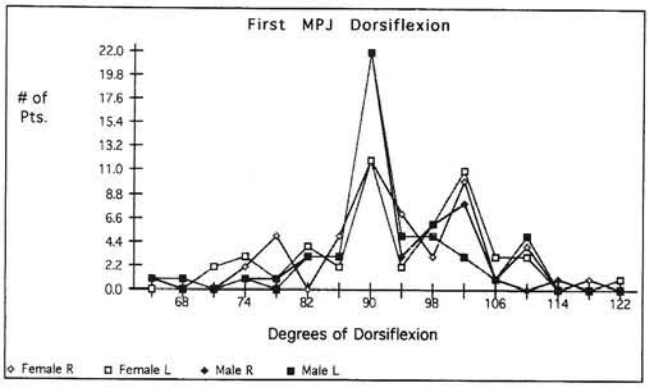

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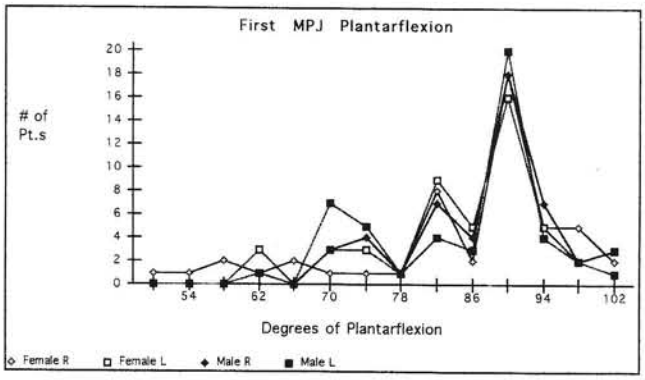

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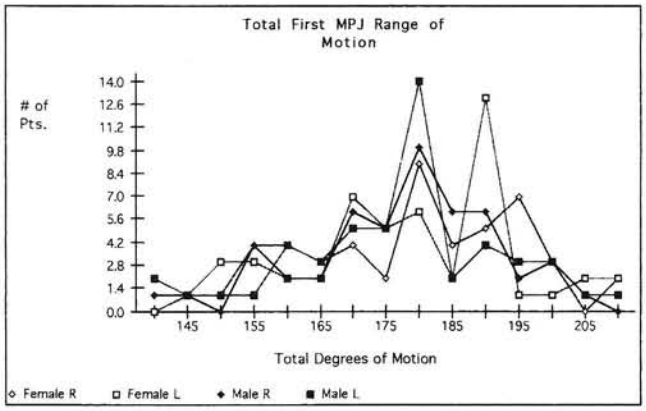

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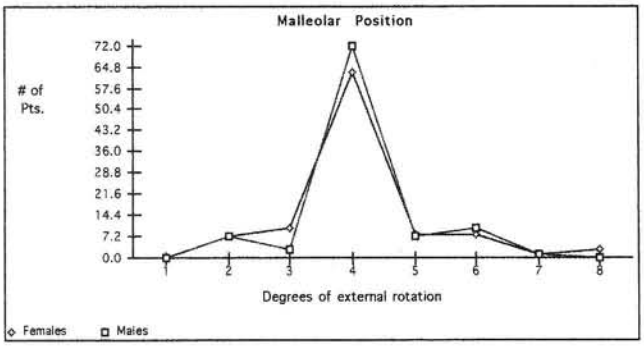

Figure 9A.

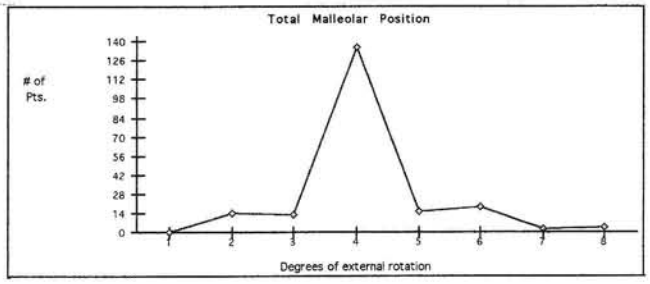

Figure 9B.

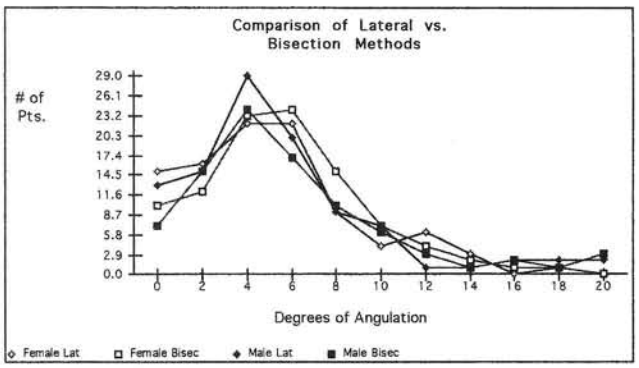

Figure 10.

DISCUSSION

The normal ranges of motion for this newborn population have been established. The findings in this study are consistent with the few other studies in the literature however, no normal ranges of motion of the foot have been previously studied, thus there is no comparison. According to Haas and Epps,[2] in their study on newborn hips, they found no significant difference in right versus left limb examination. This is also the case for newborn feet. This study also demonstrated no significant difference between patients of differing sex.

The ankle joint examination was consistent with the Gilmore-Waugh et al. study on newborn hip, knee, and ankle examination.[5] They found from a similar population of 40 patients that dorsiflexion averaged 58.9 degrees and ranged from 36.7 to 71.7 degrees. Their plantarflexion measurements averaged 25.7 degrees with a range of 10.0 to 41.7 degrees. Hoffer[4] noted ankle dorsiflexion of up to 80 degrees and plantarflexion no greater than 30 degrees. On follow-up examination, plantarflexion gradually increased. He noted hip, knee, and ankle contractures were normally present at birth, but tended to resolve spontaneously in the first two years of life, except for hip flexion contractures which persisted longer. Plantarflexion of less than neutral is an indication of an abnormality, and is supported by Bernbeck and Sinios[5] and Gilmore-Waugh et al.[6]

Measurements for the subtalar joint were fairly symmetrical in inversion and eversion motion. In comparison to normal adult ranges of motion, there seemed to be fewer patients with the standard two-thirds inversion and one-third eversion. Equal amounts of inversion and eversion motion or even more eversion than inversion was not uncommon in this patient population.

First metatarsophalangeal joint ranges of motion were very similar to the normal adult population, with the exception of the increased amount of plantarflexion motion. There were minimal differences in the amount of dorsiflexion versus plantarflexion ranges in this study. There are no studies which assess the changes in first metatarsophalangeal joint motion with age. The adult range of motion is less than in the neonate, but whether this decrease in motion occurs with the onset of weight bearing is unknown.

Malleolar position measurements were consistent with prior studies, most commonly ranging from 3 to 5 degrees of external rotation in the first year of life.[6-9] Internal tibial torsion is often of little clinical significance until the child begins to walk, and this problem also tends to gradually improve spontaneously without treatment.[8,10] All patients in this population had some degree of external tibial torsion. An excess of external tibial torsion is less common than internal tibial torsion, and is seldom clinically problematic in the newborn. This is often a problem of over-correction of internal tibial torsion or a problem at

the femoral level.[10,11] Fabray, MacEwen, and Shands[12] correlated 75% of children with metatarsus adductus also had internal tibial torsion. In this study, there were patients with some degree of metatarsus adductus, but none with internal tibial torsion.

Metatarsus adductus has been described using many different terms such as hooked forefoot, metatarsus varus, forefoot adductus, pes varus, etc. Metatarsus adductus or forefoot adductus are the most accurate terms to describe the deformity. This deformity is the most common congenital foot deformity.[8] Rushforth[13], noted the second born child was the most common. McDonough studied 51 consecutive infants referred by pediatricians. Thirty-nine percent had some metatarsus adductus with 17.6 percent left-sided. Ponsetti and Becker[14] studied 379 patients and showed a slight male predominance with bilateral deformity in two-thirds of the patients. The authors' study did not have a preponderance for males, and feet were fairly symmetrical in the amount of deformity, without a statistical significance between contralateral feet. The differences between both methods of measurement with bisection of the rearfoot and forefoot compared to the lateral aspect of the foot were statistically insignificant. The method described by Bleck did not tend to correlate with the most common ranges of degrees of angulation by the previously mentioned two methods of measurement. There was a direct correlation between larger degrees of angulation between forefoot and rearfoot, and classification of a severe deformity according to Bleck's method.

Treatment for forefoot adductus when diagnosed early, and with adequate flexibility has included passive stretching exercises, and plaster casts or strapping. Early treatment in infancy is advocated by most authors.[13,15,16] Most authors also agree that very mild and flexible deformities will resolve spontaneously, or with only passive stretching. Ponsetti and Becker treated 11.6% (44 patients) of 379 patients with plaster casting, all others resolved without treatment. Most resolved within the first 2 to 4 years of life. Rushforth[13] categorized 130 feet with metatarsus adductus at birth with photographs as being severe, moderate or mild. There was no treatment of any kind given to these patients. Follow-up continued for 7 years, noting 86% of the patients were classified as normal, and most by the age of 4 years. Ten percent had moderate deformity, but remained asymptomatic, and 4 percent with stiffness and persistent deformity. These severe cases were identified before three years of age. Persistent deformity beyond 2 to 3 years of age tended to not respond to conservative measures.

Other foot deformities seen in newborns include clubfoot, calcaneal valgus and vertical talus. Of these three deformities, calcaneal valgus, sometimes referred to as flexible flatfoot is the most common.[17] Calcaneal valgus is more common in first born children and young mothers, and is believed to be secondary to in-utero packing. Incidence has been reported as 1 in 1000 live births,[15,18] and may be associated with other neurological abnormalities. On examination, the foot is held in dorsiflexion, and varying degrees of abduction and valgus heel position. The foot is usually able to be plantarflexed to neutral position. This deformity rarely requires treatment beyond stretching exercises.[17-20] Crawford and Gabriel[18] advocate gentle manipulation of the ankle joint to neutral position with "breaking" the midfoot and subluxing the talonavicular joint or calcaneocuboid joint. They also believe stretching the hip in external rotation is necessary as part of the correction. The deformity usually corrects by 2 to 4 months of age. If this abnormality remains past the second or third week, Funk[19] advocates application of serial casts. This deformity must be differentiated from vertical talus or congenital rocker-bottom foot.

Vertical talus is also described as "Persian slipper foot" or rocker-bottom foot. This deformity is rare, and affects males more commonly. There is usually a high association with other neurological abnormalities, mental retardation myelodysplasia, Turner's syndrome, and arthrogryphosis. The foot is rigid, with contraction of the posterior capsule of the ankle and Achilles tendon. The talar head can often be palpated on the plantarmedial aspect of the foot because of the rotation of the head over the sustentaculum tali and incompetent spring ligament.[18] The anterior muscle groups are usually contracted as well as the peroneals, with subluxation of the peroneal tendons anterior to fibular malleolus, causing the foot to dorsiflex and abduct.[15] Vertical talus can often be confused with calcaneal valgus. The main differentiating factor is that the calcaneus is in equinus, thus the name convex pes valgus equinus.[17] Radiographic evaluation of the foot in a lateral view shows the calcaneus in equinus and the talus plantarflexed with dorsal subluxation of the

navicular and forefoot. When a stressed plantarflexion lateral view is taken, the talar bisection passes plantar to the metatarsal axis. In the normal foot, the talar bisection on stress plantarflexion would remain parallel or through the metatarsal axis.

Treatment options include conservative measures such as stretching and serial casting to stretch the skin and soft tissues to aid in necessary surgical correction. Conservative treatment alone is not recommended and is unsuccessful in correction. Surgical correction is often performed in two stages and requires lengthening of the extensor tendons and capsulotomy of the ankle, subtalar, and talonavicular joints. In patients older than 30 to 36 months, subtalar arthrodesis is done with the previously mentioned procedures. The second stage involves tendo Achilles lengthening, posterior capsulotomy, advancement of tibialis posterior tendon under the spring ligament and navicular.

Clubfoot deformity or talipes equinovarus has an incidence of 1 in 1,000 live births. There is a 20 times higher risk of having the deformity if a first degree relative has the deformity. If a sibling has clubfoot, there is a one in thirty-five chance of having the deformity.[10] The foot is held in varying degrees of forefoot adductus with the heel in varus and equinus. The flexibility of the foot varies with the more flexible foot amenable to serial casting alone. Kite[21] advocates correction of one deformity at a time, starting with the forefoot adductus, then the varus and finally the equinus, allowing the cast to dry in-between. He notes to test for adequate correction by observation of the foot hanging in an abducted position. Kite believes in judgement for correction clinically and believes that it is more important than radiographic assessment. Hensinger and Jones[15,20,22] advocate radiographic evaluation for assessment of correction. Radiographic evaluation on the lateral view will have a talocalcaneal angle of greater than 35° if the deformity is corrected. On anteroposterior view, the talocalcaneal angle normally is 20° to 40°. In the deformed foot, this angle is less than 20°. Surgical correction may involve staged soft tissue releases and osseous procedures. All authors agree that conservative casting should be performed before surgery is attempted.

SUMMARY

One hundred normal newborns were evaluated. Normal ranges of joint motion were established for the newborn foot. There was no statistical significance between sex, or right and left limbs. It is important to remember that measurements may vary between individual examiners, but should be consistent within each examiner. When examining the newborn patient, the baby should be relaxed and the measurement taken when all reflexive stimulus is removed. Neonatal deformities should be well-documented, noting the severity of the problem and the flexibility.

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