Measurement of Selected Hip, Knee, and Ankle Joint Motions in Newborns

KELLY GILMORE WAUGH,
JEAN L. MINKEL,
ROCHELLE PARKER,
and VALERIE A. COON

As clinicians become more involved in preventative screening, assessment, and treatment of newborns and infants, an increasing need exists for quantitative, normal joint range-of-motion data for this population. We used a goniometer to assess in 40 healthy, full-term newborns the following passive ranges of motion: hip extension, knee extension, ankle plantar flexion, ankle dorsiflexion, and the popliteal angle. Every infant except one lacked full extension at both the hip and the knee. Plantar flexion was generally limited, but dorsiflexion was unlimited. Popliteal angle measurements showed the greatest amount of variation among the infants. Pearson correlation coefficients indicated that those infants with greater dorsiflexion tended to have less plantar flexion, and those with a greater limitation of knee extension measured with the hip extended tended also to have a smaller popliteal angle. Intrauterine position and newborn flexor tone are discussed as possible contributing factors to the results obtained in this study.

Key Words: Infant, newborn; Joints; Leg; Physical therapy.

Researchers have shown that passive joint range-of-motion measurements in infants and children differ from adult values,1,2 and that specific sequential changes in the range of joint motion occur during the first 15 months of normal development.2,3 Gonio- metric measurements of joint range are used clinically with infants to aid in detecting pathological joint and muscle conditions, to assess and document changes in response to therapeutic regimens, and to provide useful information about muscle tone and motor development. For example, in assessing newborns, the popliteal angle and the amount of passive dorsiflexion are both used as indices of gestational age.4-7 As clinicians become more involved in preventative screening, assessment, and treatment of newborns and infants, an increasing need exists for baseline, goniometric values describing normal joint ranges of this population.

Range of motion characteristics that are unique to newborns are described predominantly in qualitative terms, but quantitative, goniometric guidelines are scarce. Full-term neonates are described qualitatively in the literature, both narratively and pictorially, as lacking full extension at the hip, knee, and ankle, but displaying full ranges of passive dorsiflexion so that the dorsum of the foot contacts the tibia.4-7,9 These limitations in extension and full ranges of dorsiflexion are commonly attributed to the normal position of flexion maintained in utero,5,9-11 and to the increased amount of flexor tone in a full-term newborn.2,3

Reports in the literature on neonatal assessment provide some numerical values for the limitations in extension at the hip, knee, and ankle,10,12 as well as some numerical values for the popliteal angle and the amount of dorsiflexion in full-term newborns.5,13,14 These ranges vary, however, and the way the data were obtained is frequently not reported. In a comprehensive goniometric study of hip motions, Haas and colleagues quantified mean values of hip flexion contracture in 237 healthy newborns.1

Hoffer quantified joint limitations in extension at the hip, knee, and ankle in his study of 50 healthy neonates.5 No specific methodology was included in the latter report.
The purposes of this study were 1) to provide clinically useful mean values and normal ranges of hip extension, knee extension, ankle plantar flexion, ankle dorsiflexion, and the popliteal angle in healthy, full-term newborns and 2) to determine whether any relationships exist between each of these five lower extremity motions.

METHOD

Subjects

Subjects were 40 full-term newborns chosen from infants admitted to the well-baby nursery at Stanford University Hospital during March 1982. Subjects were selected if they met the following criteria: estimated gestational age ≥ 37 weeks (full-term infant), birthweight ≥ 2500 gm (5.5 lb), Apgar score at five minutes ≥ 8, and age between 6 and 72 hours old. Criteria for exclusion were the following: any fixed deformity of the lower extremity, breech presentation, diabetic mother, and general anesthesia given during delivery. Breech infants were determined ineligible because of the increased incidence of pathological findings in the lower extremities in these infants. Selection criteria information was obtained from the infants’ medical records at Stanford University Hospital.

Materials

We used a clear, plastic goniometer with a 360-degree dial and markings in five degree increments for all measurements. The goniometer was modified by shortening the stationary and movable arms, leaving 2 in from the axis to the end of each arm. A hypoallergenic, cosmetic skin pencil was used to mark all anatomical landmarks.

Procedures

Each subject was tested during one session for the following five passive ranges of motion: hip extension, knee extension, ankle dorsiflexion, ankle plantar flexion, and the popliteal angle. This sequence of measurements was repeated three times. All the values attained from the three independent measurements of each motion were within ±5 degrees of each other. Mean values were calculated from the three independent measurements of each motion for analysis. An illustration of the specific angle measured for each of the five motions is included in Figures 1 through 5. Measurements were taken only from the left leg because the results reported by Haas and colleagues showed no significant differences between right and left lower extremity measurements in newborns.

Fig. 1. Method of positioning and clinical determination of hip extension.

Fig. 2. Method of positioning and clinical determination of knee extension. (Note: The position of the hip is this child’s maximum hip extension.)

Fig. 3. Method of positioning and clinical determination of ankle dorsiflexion.
For all measurements, infants were placed in a supine position with their heads maintained in midline to diminish any effects of neonatal neck reflexes, such as the asymmetrical tonic neck reflex (Fig. 1). Placing a finger into the infant's mouth elicited a sucking response and was effective in maintaining the infant in a quiet, relaxed state throughout the session. With the exception of the popliteal angle, all ranges were assessed in a position that placed the biarticular muscles on slack and allowed the maximum motion available at that joint. Before measuring, we palpated traditional anatomical landmarks and marked the landmarks with a skin pencil to ensure standardization in measurement technique.

**Hip extension.** To stabilize the pelvis while measuring hip extension, we flexed the right leg until the thigh rested in contact with the abdomen or until the buttocks began to rise up from the table (Thomas test position) (Fig. 1). The knee of the measured leg was held in maximum extension. Landmarks used for aligning the goniometer were the greater trochanter, palpated and marked with the hip in extension; the lateral femoral condyle; and the lateral midline of the subject's trunk. Once the infant was positioned, the left hip was passively extended in neutral rotation until the investigator felt the anterior superior iliac spine rock forward; this rocking motion signaled the end of extension range. The right leg was maintained in contact with the abdomen for all remaining measurements.

**Knee extension.** To measure knee extension, the investigator passively extended the knee while maintaining the ipsilateral hip in maximum extension and neutral rotation (Fig. 2). We used the lateral femoral condyle, the greater trochanter proximally, and the lateral malleolus distally as landmarks.

**Dorsiflexion and plantar flexion.** We measured ankle motions with the hip and the knee of the measured leg held in maximum flexion and neutral rotation. Positioning of the goniometer was the same for measurement of both dorsiflexion and plantar flexion. The axis of the goniometer was shifted distally from the lateral malleolus to allow for alignment of the movable arm of the goniometer along the lateral aspect of the fifth metatarsal. The head of the fibula was used as a reference point for positioning the stationary arm. We measured dorsiflexion without an inversion or eversion component by exerting pressure on the upper third of the sole of the foot (Fig. 3). To assess plantar flexion, the investigator exerted pressure on the most proximal aspect of the dorsum of the foot while preventing inversion or eversion of the ankle (Fig. 4).

**Popliteal angle.** To assess the popliteal angle, the investigator flexed the measured leg so the thigh contacted the abdomen in a knee-to-chest position without allowing the buttocks to rise up from the table (Fig. 5). From this position, the knee of the measured leg was extended slowly to allow for adaptation to the change in muscle length, until strong resistance was felt. Reference landmarks were the greater trochanter, palpated and marked with the hip in the knee-to-chest position; the lateral femoral condyle; and the lateral malleolus.

The two primary investigators conducted all of the measurement sessions. One investigator performed all measurements, and the other investigator recorded the measurements and stabilized the child in each of the test positions.

We calculated mean, standard deviation, and range for each of the lower extremity motions assessed in this study. Pearson correlation coefficients were computed to examine potential relationships between each of the five motions. Results were not judged to be significant unless the p value was ≤ .05.
RESULTS

The 40 newborns assessed in this study (18 boys and 22 girls) were between 37 and 42 weeks estimated gestational age (X = 39.8 weeks, s = 1.2 weeks) and were between 6 and 65 hours old at the time of measurement (X = 24.9 hours, s = 13.9 hours). Birth-weights ranged from 2,720 to 5,130 gm (6 lb to 11.3 lb) with a mean birthweight of 3,549.5 gm (7.8 lb) (s = 489.6 gm; or ± 1.1 lb). Infants were white (27), black (6), Mexican-American (4), and Asian (3).

The mean, standard deviation, and range of each of the five motions assessed in this study are displayed in the table.

All subjects lacked complete hip extension, with limitations ranging from 21.7 to 68.3 degrees (X = 46.3°, s = 8.2°). Although one infant had full knee extension, all other subjects in this study displayed some degree of knee extension limitation (X = 15.3°, s = 9.9°).

The mean for dorsiflexion was 58.9 degrees (s = 7.9°), and plantar flexion averaged 25.7 degrees (s = 6.3°). Except for one infant who had equal amounts of plantar flexion and dorsiflexion (38° each), all subjects displayed a greater range of dorsiflexion than of plantar flexion. In 75 percent of the subjects, dorsiflexion was twice as great as plantar flexion.

The popliteal angle showed the greatest amount of variation (s = 13.4°) with measurements ranging from 113.4 to 173.3 degrees.

Pearson correlation calculations were used to investigate any relationships between each of the five lower extremity motions. The results indicated that those infants with greater dorsiflexion range tended to have less plantar flexion (r = −.48, p ≤ .01), and those with a greater limitation of knee extension measured with the hip extended tended to have smaller popliteal angles (r = −.68, p ≤ .001). No other correlations were significant.

DISCUSSION

We chose the positioning and measuring techniques used in this study for consistency and accuracy and for clinical reproducibility. We acknowledge that other more complicated procedures may be more precise; however, the goal of this report was to provide normal baseline values of selected lower extremity joint motions in newborns that could be reproduced and used clinically.

Joint range limitations at the hip and knee in newborns have often been referred to as “contractures” or “deformities,” but the characteristic lower extremity joint limitations observed in newborns do not necessarily reflect pathological conditions as these terms imply. The term “extension limitation” rather than “flexion contracture” was therefore used in this report to describe the lack of full passive extension at the hip and knee in healthy neonates. Values reported as “hip flexion contracture” in the studies by Haas and colleagues and by Hoffer represent the same angle as the values reported as “hip extension limitation” in this study.

Haas and colleagues reported that the mean hip flexion contracture in 237 newborns was 27.9 degrees, with a range of 10 to 75 degrees. Hoffer reported hip flexion contractures ranging from 50 to 80 degrees, but he did not include mean values in his study. The mean of 46.3 degrees of extension limitation reported in our study is considerably larger than the 27.9 degree mean reported by Haas and colleagues, and it falls below the range reported by Hoffer. This discrepancy in normal values of hip extension limitation may reflect variations both in positioning techniques and in interpretations of end of range. Although a Thomas test position was used both in this study and in the study by Haas and colleagues, variations in the degree of flexion maintained at the contralateral hip during this procedure will affect the position of the pelvis and subsequently affect the value obtained for hip extension limitation.

Results of this study are consistent with other reports describing knee extension limitations at birth of 0 to 35 degrees. One infant in this study showed a knee extension limitation of greater than 35 degrees, and only one infant displayed a full range of knee extension (0° of limitation).

We encountered very little resistance to passive ankle dorsiflexion. In most infants, the dorsum of the foot was brought into contact with the anterior surface of the lower leg. The values for dorsiflexion range presented in this report (36.7 to 71.7°) support Hoffer’s finding of 40 to 80 degrees.
The observation that some degree of plantar flexion limitation is normal in full-term newborns is supported by the results of this study ($\bar{X} = 25.7^\circ$ of plantar flexion). Hoffer reported that a few subjects in his investigation lacked plantar flexion to neutral, whereas all infants in our study achieved at least 10 degrees of plantar flexion. The results of this study support the view expressed by Griffin and by Bernbeck and Sinios that maximum plantar flexion in a full-term newborn of less than neutral may indicate an abnormality.

Griffin stated that the amount of passive plantar flexion and dorsiflexion motion at the ankle varies among infants depending on their in utero position. As the fetus grows and adapts to an increasingly limited intrauterine space, the foot is mechanically compressed into varying degrees of dorsiflexion and accompanying inversion and eversion. The lack of resistance to passive dorsiflexion characteristic of full-term newborns has been reported to reflect an apparent "relaxation of the passive tone of the posterior muscles of the leg." The statistically significant, although relatively low, correlation found in this study between dorsiflexion and plantar flexion measurements ($r = -0.48, p < 0.01$) suggests that those infants with greater dorsiflexion range tended to show less plantar flexion. This correlation may be a reflection of this intrauterine foot position. In the full-term newborn, the predominant lower extremity flexor pattern with its dorsiflexion component may also be a contributing factor to the full ranges of dorsiflexion and to the correlation between dorsiflexion and plantar flexion reported in this study.

Measurement of the popliteal angle is often used in neonatal exams as an indication of the amount of passive flexor tone present at birth. Popliteal angle measurements in this study ($\bar{X} = 150.9^\circ$) were considerably larger than values reported by Dubowitz and Dubowitz, Saint-Anne Dargassies, and Amiel-Tison. Dubowitz and Dubowitz stated that the popliteal angle is "often" 110 degrees or less in normal newborns, and Saint-Anne Dargassies described angles to be between 90 and 130 degrees. According to Amiel-Tison, the average popliteal angle in a newborn of 40 weeks estimated gestational age is 80 degrees. Illingworth, however, estimated the popliteal angle to be 160 degrees in the full-term infant. In the present assessment of the popliteal angle, initial resistance was usually encountered early in the range. The investigators allowed the hamstrings to adapt to the change in muscle length by performing the movement slowly, however, and achieved a greater amplitude of the popliteal angle. Variability in the position of the pelvis on the table during the measurement and differences in the degree of relaxation achieved in the posterior musculature may account for the apparent discrepancy in reported values for the popliteal angle in full-term newborns.

This study documented limitations in knee extension in two positions: with the hip extended and with the hip flexed (popliteal angle). The investigators' subjective assessment of the end-feel of the ranges suggested that the resistance encountered at the knee with the hip extended reflected a tightening of joint structures, and muscle length appeared to be the limiting factor when the hip was positioned in flexion. A significant correlation was found in this study between knee extension limitation and the popliteal angle ($r = -0.68, p < 0.001$). This correlation indicated that infants with a greater limitation in knee extension measured with the hip extended also tended to display a smaller popliteal angle. Compression and limited mobility in utero, in conjunction with predominant flexor tone, could effect adaptations in both joint and muscle structures. These factors may contribute to an understanding of the relationship between a larger knee extension limitation and a smaller popliteal angle.

Every infant in this study except one showed a lack of full extension at the hip and the knee in combination with a lack of full plantar flexion. No significant correlations were found, however, between the degree of extension limitation present at each of these three lower extremity joints in the newborn. For example, those infants with a greater limitation of hip extension did not necessarily show a greater limitation in knee extension range. As an infant matures, developmental changes occur in the degree of passive range of motion in the lower extremity. Saint-Anne Dargassies reported a gradual decrease from the normal full range of dorsiflexion occurring within the first few days of life. Furthermore, increases in available hip extension range from neonatal values have been documented at six weeks of age. Following infants longitudinally beyond the neonatal stage to document changes in the range of passive motion at the hip, knee, and ankle joints would be an interesting extension of this study. A longitudinal assessment of this kind would elucidate trends in normal growth and development and also provide guidelines for joint range of motion assessment throughout infancy and childhood.

**CONCLUSION**

We clinically assessed, in 40 healthy, full-term newborns, the following passive ranges of motion: hip extension, knee extension, ankle plantar flexion, ankle dorsiflexion, and the popliteal angle. Results revealed mean limitations in hip and knee extension of 46.3 and 15.3 degrees, respectively. Ankle plantar flexion was generally limited ($\bar{X} = 25.7^\circ$), whereas dorsiflexion was characteristically unlimited ($\bar{X} =$
58.9°). Popliteal angle measurements ranged from 113.3 to 173.3 degrees, with a mean of 150.9 degrees. Results of correlation calculations indicated that those infants with greater dorsiflexion range tended to have less plantar flexion \((r = -0.48, p \leq 0.01)\), and those infants with a greater limitation in knee extension tended to display a smaller popliteal angle \((r = -0.68, p \leq 0.001)\). Although these correlations were statistically significant, their sizes indicated that the associations between the factors were not strong.

REFERENCES