Foot length—a new and potentially useful measurement in the neonate

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SUMMARY The foot length, occipito-frontal head circumference (OFC), crown-rump, and crown-heel length (CHL) of 123 neonates of gestational ages 26–42 weeks, were measured between 12 hours and 5 days. A gauge, designed and constructed at St Mary's Hospital, Manchester, was used to measure foot length. In term babies (37–42 weeks) who were of weights appropriate for gestational age (AGA) the scatter about the mean of foot length measurements was small (coefficient of variation = 4.5%) compared with birthweight (coefficient of variation = 12.0%). The wide range of foot length measurements in babies of different gestational ages prevented maturity being accurately estimated. The mean birthweight of term light-for-dates (LFD) babies was 30.9% lower than term AGA babies, whereas the mean foot length, OFC, and body length of LFD babies was reduced by only 4.2–8.8%. There was a positive linear correlation between foot length and other indices of body size in LFD and AGA babies of all gestational ages. However, in premature babies (<37 weeks) the correlation between foot length and birthweight ($r = 0.95$) and foot length and CHL ($r = 0.96$) was pronounced. The 95% confidence limits of the regression lines were ± 327 g and ± 2.3 cm respectively. Birthweight and CHL of premature babies can therefore be estimated from a measurement of foot length that is performed simply and rapidly. Measurements of foot length are valuable in premature babies who are too ill at birth for conventional anthropometric measurements to be made, and in whom such measurements cannot be carried out subsequently because of the encumbrance of the incubator and intensive care apparatus. Drug dosages and intravenous fluid requirements based on body weight or surface area can be indirectly calculated from a measurement of foot length.

Certain ill newborn babies, particularly those that are premature, require intensive care from the moment of birth. It is rare for measurements such as birthweight, body length, and occipito-frontal head circumference (OFC) to be made because priority is given to life support. It is virtually impossible to gain access to these babies for anthropometric measurements because they are nursed in incubators and attached to monitoring devices, intravenous infusion lines, and often to mechanical ventilators. Yet the dosages of various drugs and intravenous fluid requirements are based on body weight or surface area.

The foot is usually readily accessible for measure-

ment of its length, even in premature babies, nursed in incubators, and receiving intensive care. There is a positive correlation between foot length and height in adults (Dahlberg and Lander, 1948; Helmut, 1974). Foot length in the fetus is closely correlated with body length (Pospisilova-Zuzakora, 1962) and gestational age (Markowski and Lawler, 1977). We studied foot length measurements in the newborn as a method of estimating other anthropometric indices.

Patients and methods

A neonatal foot length gauge (Fig. 1) was designed by one of us (D.K.J.) and constructed in the hospital workshop (Department of Medical Physics). It is made from Perspex and consists of a platform against which the baby's heel is placed, and a sliding bar which makes contact with the tip of the big toe. The scale beneath the sliding bar has a range from 2 to

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Fig. 1 The neonatal foot length gauge.

15 cm and reads to the nearest 0.5 mm. The instrument is small enough to be introduced through the porthole of an incubator within which it is easily manipulated.

The baby's left foot is held in the examiner's left hand and the gauge is held in his right. The heel is placed against the platform and the head of the first metatarsal and medial aspect of the heel are aligned parallel with the edge of the instrument. The index finger of the examiner's right hand manoeuvres the sliding bar until it just touches the tip of the big toe (Fig. 2). The instrument is withdrawn and the scale is read.

Observer error of the method. The left foot of one baby was measured by one of us (D.K.J.) on 10 occasions within 30 minutes. The result (mean $\pm$ SD) was 7.62 ± 0.08 cm; the coefficient of variation was 1.05%. The same baby's foot was measured once by 10 different examiners (nursing and medical staff of the special care baby unit). The result (mean $\pm$ SD) was 7.56 ± 0.11 ; the coefficient of variation was 1.46%.

Fig. 2 The neonatal foot length gauge.

Measurements were made of foot length (left), OFC, crown-rump, and crown-heel length (CHL) in 123 singleton babies (M:F 59:64), 26–42 weeks' gestation, and of known birthweights. Measurements were made between 12 hours and 5 days. Serial observations previously made suggested that there was no significant change in foot or body length during the first 5 days of life. OFC measurements were made with a glass-fibre tape measure, and body length was measured with the Cardiff neonatometer (Davies and Holding, 1972). Gestational age of each baby was calculated from the first day of the mother's last menstrual period. If this was unknown, clinical examination of the newborn and/or radiological assessment of bone age was used to determine gestational age (Russell, 1969). 66 babies were of weights appropriate for gestational age (AGA) according to the birthweight centile chart of Milner and Richards (1974). 57 babies were <10th centile for gestational age and were termed light-for-dates (LFD).

Results

In the 94 term (37–42 weeks) AGA and LFD babies birthweight was the index of body size that had the greatest scatter of the results about the mean (coefficient of variation = 12.0 and 11.9% respectively), whereas the coefficients of variation of foot length, OFC, and body length were smaller (3.5–8.5%) (Table 1). Nevertheless, in babies of different maturity there was a wide range of foot lengths at each gestational age and there was a considerable overlap between foot lengths at different gestational ages (Fig. 3).

For each index of body size the mean result in LFD term babies was compared with the corresponding result in AGA term babies and the percentage reduction was calculated. LFD babies

Table 1 Mean $\pm$ SD, coefficient of variation of different indices of body size in 94 term babies who were of weights appropriate for gestational age or light-for-dates. The percentage reduction of mean values in LFD babies compared with AGA babies is also shown.

Indices	Babies				
	Weight appropriate for gestational age (n = 51)		Light-for-dates (n = 43)		Reduction of mean values (%)
	Mean $\pm$ SD	Coefficient of variation (%)	Mean $\pm$ SD	Coefficient of variation (%)	
Foot length (cm)	7.92 $\pm$ 0.36	4.5	7.24 $\pm$ 0.4	5.5	8.6
Birthweight (g)	3402 $\pm$ 408	12.0	2350 $\pm$ 280	11.9	30.9
Occipito-frontal circumference (cm)	34.03 $\pm$ 2.88	8.5	32.60 $\pm$ 1.32	4.0	4.2
Crown-rump length (cm)	34.13 $\pm$ 1.52	4.5	31.12 $\pm$ 1.39	4.5	8.8
Crown-heel length (cm)	51.08 $\pm$ 2.05	4.0	46.58 $\pm$ 1.61	3.5	8.8

Fig. 3 Foot lengths of babies of different gestational ages. Weight appropriate for gestational age ●; light-for-dates*.

were 30.9% lighter than AGA babies. However, there was only a modest reduction (4.2–8.8%) of the mean foot length, body length, and OFC in LFD babies compared with AGA babies (Table 1).

A positive linear correlation between foot length and the other indices of body size was observed in AGA and LFD babies of all gestational ages (Table 2). However, the foot lengths of the 23 premature babies (< 37 weeks) showed an especially high degree of correlation with birthweight ($r = 0.95$) and crown-heel length ($r = 0.96$), and the 95% confidence limits of the regression lines were ± 327 g and ± 2.3 cm respectively (Figs 4 and 5).

Table 2 Correlation coefficient (r) between foot length and other indices of body size in 123 babies, 26–42 weeks' gestation, who were of weights appropriate for gestational age or light-for-dates

Foot length v. other indices	Correlation coefficient (r)	
	Weight appropriate for gestational age	Light-for-dates
Foot length		
birthweight	0.89	0.91
occipito-frontal circumference	0.90	0.82
crown-rump length	0.88	0.89
crown-heel length	0.91	0.88

Fig. 4 Birthweight (kg) and foot length (cm) of 23 premature babies. On either side of the regression line (solid) are the 95% confidence limits, ± 327 g (broken line).

Fig. 5 Crown-heel length (cm) and foot length (cm) of 23 premature babies. On either side of the regression line (solid) are the 95% confidence limits, ± 2.3 cm (broken line).

usually premature and, as well as requiring intravenous fluids, are potential recipients of a variety of drugs including antibiotics, digoxin, and alkalis agents, the dosages of which are calculated according to bodyweights or surface areas. We have shown that birthweights and CHL of premature babies can be estimated from measuring the foot lengths and such measurements can be made simply, rapidly, and safely in spite of the encumbrance of the incubator and intensive care equipment. In those babies who are so ill at birth that measurements of weights and body lengths are not possible, the measurement of foot length allows fluid requirements and drug dosages to be calculated.

In term babies foot lengths, like body lengths, and OFC had relatively small scatter of results about the mean compared with birthweights. Markowski and Lawler (1977) suggested that foot length could be used to predict the gestational age of very premature aborted fetuses. However, in this study the range of foot lengths at different gestational ages was so wide as to preclude the accurate estimation of maturity.

It is conventional teaching that LFD babies tend to be long and to have large heads in relation to their birthweights. Our findings reinforce this and suggest that in most cases of intrauterine growth retardation foot length is also spared at the expense of bodyweight. Jrai *et al.* (1977) drew attention to the heterogeneity of LFD babies and demonstrated that those who suffer from hypoglycaemia tend to have a greater reduction in birthweight relative to CHL compared with normoglycaemic LFD babies. The measurement of foot length may prove to be a valuable adjunct to other anthropometric measurements in the classification of LFD babies; it may be the only measurement that can be conveniently made in ill babies nursed in incubators.

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Discussion

Ill newborn babies nursed in incubators and receiving intensive care are generally inaccessible for measurements of bodyweight and CHL. Such babies are

- Markowski, B., and Lawler, S. D. (1977). Use of early fetal tissues obtained from suction termination of pregnancy. *Lancet*, **1**, 186–188.
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