Original Research Article

Head Circumference and Mid-arm Circumference as Proxy Measures of Gestational Age in Newborns: A Hospital-Based Prospective Observational Study.

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ABSTRACT

Background: Accurate assessment of gestational age (GA) guides neonatal care, but first-trimester ultrasonography is often unavailable, and postnatal maturity scoring requires trained staff. Simple anthropometric measurements may serve as practical proxies. This study evaluated the correlation of head circumference (HC) and mid-arm circumference (MAC) with GA and birth weight in newborns. **Materials and Methods:** This hospital-based prospective observational study enrolled 355 consecutive live-born singleton neonates at a tertiary care hospital in Jaipur, India. GA was assessed using the New Ballard Score (NBS). HC and MAC were measured with a non-stretchable tape at 72 hours of life. Pearson correlation and linear regression were used to assess the relationship of HC and MAC with GA and birth weight. **Results:** The mean GA was 34.49 ± 3.52 weeks (range 28–41), 238 neonates (67.0%) were preterm, and the mean birth weight was 1915 ± 633 g. Mean HC rose from 24.4 cm at 28 weeks to 33.7 cm at 41 weeks, and mean MAC from 7.9 cm to 9.8 cm. HC correlated strongly with GA ($r = 0.865$) and birth weight ($r = 0.789$), whereas MAC showed moderate correlations ($r = 0.540$ and 0.552, respectively; all $p < 0.001$). The regression equation GA (weeks) = 3.74 + 1.063 × HC (cm) had a standard error of estimate (SEE) of 1.76 weeks and a mean absolute error (MAE) of 1.42 weeks. Adding MAC improved accuracy modestly ($R = 0.884$; SEE 1.66 weeks; MAE 1.33 weeks). **Conclusion:** HC is a strong and simple proxy for GA in newborns, and combining it with MAC modestly improves estimation. These measurements may help classify newborns where ultrasonography or skilled maturity scoring is unavailable, but the equations need external validation.

Keywords: Neurologic Examination, Gestational Age, preterm infants

Gestational age (GA) is a key determinant of neonatal management, prognosis and follow-up, particularly in preterm infants. It guides decisions about resuscitation, thermal care, feeding, respiratory support and surveillance for complications, and it underpins the classification of births as preterm, term or post-term for public health surveillance and research [1]. India accounts for the largest number of preterm births of any country [2], so reliable GA assessment is especially important there. Errors in GA assessment misclassify infants, distort growth assessment, and can bias research findings [3]. No single method of GA assessment is ideal. Dating by the last menstrual period (LMP) is simple and inexpensive but depends on maternal recall and a regular 28-day cycle, and it may be inaccurate by one to four weeks [4].

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Ultrasonographic measurement of crown–rump length in the first trimester is the most accurate method, with an error of about five to seven days, but its accuracy declines with advancing gestation, and third-trimester estimates may be inaccurate by up to three weeks [5]. After birth, the New Ballard Score (NBS) is the most widely used method. It combines neuromuscular and physical maturity criteria and estimates GA to within about two weeks, including in extremely preterm infants [6]. However, it requires trained personnel, and its accuracy may be reduced in sick neonates and in those with intrauterine growth restriction, in whom chronic deprivation and redistribution of blood flow alter maturational features [7]. These limitations have prompted interest in simple anthropometric measurements as proxies

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for GA. Head circumference (HC) reflects brain growth, which is relatively preserved in fetal undernutrition because of the brain-sparing effect, so it may be a more stable indicator of maturity than weight or limb measurements. HC at birth is also an important health indicator associated with later neurodevelopmental outcomes [8], and international standards describe its relationship with GA [9]. Mid-arm circumference (MAC) reflects muscle and subcutaneous fat stores, is widely used to assess nutritional status, and has been proposed as a marker of fetal growth and low birth weight [10,11]. Both can be measured quickly with a simple tape by health workers with minimal training.

Previous Indian and international studies have reported positive correlations between these measurements and GA, but the strength of the reported associations varies widely, and few studies have derived and compared prediction equations for HC and MAC in populations with a high proportion of preterm infants. This study therefore evaluated the correlation of HC and MAC with GA and birth weight in newborns, and assessed whether HC, alone or combined with MAC, can serve as a proxy for GA.

MATERIALS AND METHODS

Study design and setting

This hospital-based, prospective, observational cross-sectional study was conducted in the Department of Pediatrics, Santokba Durlabhji Memorial Hospital, Jaipur, India, a tertiary care center, from Jan 2024 to December 2025. The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from a parent or guardian of each neonate.

Participants

Live-born neonates delivered at the hospital were enrolled consecutively until the required sample size was reached. Neonates were excluded if the mother lacked documented first-trimester ultrasonography or had chronic illness (hypertension, diabetes mellitus, cardiac disease, or severe anemia), or if the pregnancy was multiple. Neonates with gross congenital anomalies, severe perinatal asphyxia, neuromuscular disorders, or congenital infections were also excluded.

Sample size

The sample size was calculated using the formula $n = Z^2 (1 - r^2) / E^2$, with Z = 1.96 for 95% confidence, an expected correlation coefficient (r) of 0.293 between HC and GA based on a previous study, and a margin of error (E) of 0.10. The minimum required sample was 351 neonates, and 355 were enrolled.

Assessment of gestational age and anthropometry

GA was assessed using the NBS, which evaluates six neuromuscular and six physical maturity criteria [6]. Anthropometric measurements were made at 72 hours of life to minimize the effect of head molding and early fluid shifts. Birth weight was recorded naked on a calibrated electronic scale to the nearest 10 g.

HC was measured with a non-stretchable tape around the maximum occipitofrontal circumference, passing over the supraorbital ridges and the most prominent part of the occiput. MAC was measured on the left arm, with the arm relaxed, at the midpoint between the acromion and the olecranon. Both circumferences were recorded to the nearest 0.1 cm; each measurement was taken twice, and the mean was used.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation (SD) and categorical variables as frequency and percentage. The relationships of HC and MAC with GA and birth weight were assessed using Pearson's correlation coefficient. Simple and multiple linear regression were used to derive equations for estimating GA, and their accuracy was described using the standard error of estimate (SEE), mean absolute error (MAE), and mean absolute percentage error (MAPE). A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 355 neonates were included. The mean maternal age was 25.62 ± 4.38 years, and 250 mothers (70.4%) were aged 20–29 years. There were 189 male (53.2%) and 166 female (46.8%) neonates. The mean GA was 34.49 ± 3.52 weeks (range 28–41), and 238 neonates (67.0%) were preterm. The mean birth weight was 1915 ± 633 g, and 252 neonates (71.0%) weighed less than 2500 g (Table 1).

Both measurements increased with advancing GA. Mean HC rose steadily from 24.4 ± 1.1 cm at 28 weeks to 33.7 ± 1.3 cm at 41 weeks (overall mean 28.93 ± 2.86 cm), whereas mean MAC rose less steeply and less consistently, from 7.9 ± 0.5 cm at 28 weeks to 9.8 ± 1.6 cm at 41 weeks (overall mean 8.94 ± 1.13 cm), with greater overlap between adjacent weeks (Table 2).

HC showed a strong positive correlation with GA (r = 0.865) and with birth weight (r = 0.789). MAC showed moderate positive correlations with GA (r = 0.540) and birth weight (r = 0.552). All correlations were statistically significant ($p < 0.001$) (Table 3).

Table 1: Maternal and neonatal characteristics of the study population (n = 355)

Characteristic	N	%
Maternal age (years); mean ± SD 25.62 ± 4.38 (range 18–42)		
< 20	28	7.9
20–24	112	31.5
25–29	138	38.9
30–34	58	16.3
≥ 35	19	5.4
Neonatal sex		
Male	189	53.2
Female	166	46.8
Gestational age (weeks); mean ± SD 34.49 ± 3.52 (range 28–41)		
Preterm (< 37 weeks)	238	67.0
Term (≥ 37 weeks)	117	33.0
Birth weight (g); mean ± SD 1915 ± 633 (range 650–4200)		
< 1000 (extremely low birth weight)	32	9.0
1000–1499 (very low birth weight)	78	22.0
1500–2499 (low birth weight)	142	40.0
2500–3999 (normal)	98	27.6
≥ 4000 (macrosomia)	5	1.4

SD: standard deviation. Gestational age was assessed by the New Ballard Score.

Table 2: Head circumference and mid-arm circumference by gestational age (n = 355)

GA (weeks)	n	HC (cm), mean ± SD	HC (cm), P10–P90	MAC (cm), mean ± SD	MAC (cm), P10–P90
28	18	24.4 ± 1.1	23.0–25.7	7.9 ± 0.5	7.2–8.5
29	20	24.8 ± 1.2	23.4–26.3	8.0 ± 0.9	7.2–9.5
30	22	25.8 ± 1.1	24.2–27.1	8.2 ± 0.8	6.9–9.2
31	24	26.6 ± 1.4	25.0–28.5	8.5 ± 1.0	7.0–9.7
32	26	27.1 ± 1.0	26.1–28.2	8.3 ± 0.7	7.5–9.0
33	28	27.9 ± 1.6	26.1–30.0	8.7 ± 1.0	7.4–10.1
34	30	28.8 ± 1.4	26.7–30.3	8.7 ± 0.8	7.9–9.6
35	32	29.2 ± 1.3	27.6–30.5	8.8 ± 0.9	7.6–9.8
36	38	30.2 ± 1.7	28.1–31.7	9.2 ± 1.0	8.1–10.4
37	35	30.5 ± 1.9	28.4–32.9	9.7 ± 1.0	8.5–10.9
38	32	31.4 ± 1.4	29.9–32.7	9.5 ± 1.1	8.1–11.1
39	25	32.6 ± 1.4	30.7–34.1	9.6 ± 1.1	8.4–11.1
40	18	32.1 ± 1.1	30.8–33.2	10.0 ± 0.7	9.1–11.0
41	7	33.7 ± 1.3	32.6–35.4	9.8 ± 1.6	8.3–12.0
All	355	28.93 ± 2.86	–	8.94 ± 1.13	–

GA: gestational age; HC: head circumference; MAC: mid-arm circumference; SD: standard deviation; P10–P90: 10th to 90th percentile.

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Table 3: Correlation of head circumference and mid-arm circumference with gestational age and birth weight (n = 355)

Parameter	GA, r	p-value	Birth weight, r	p-value
Head circumference	0.865	< 0.001	0.789	< 0.001
Mid-arm circumference	0.540	< 0.001	0.552	< 0.001

r: Pearson correlation coefficient; GA: gestational age. Correlations with GA are the square roots of the coefficients of determination from the regression analysis (Table 4), which agree with the week-by-week data in Table 2.

On linear regression, HC alone explained 74.8% of the variation in GA, with an SEE of 1.76 weeks and an MAE of 1.42 weeks. MAC alone explained 29.2% of the variation, with an SEE of 2.98 weeks. The combined HC and MAC model had the highest predictive accuracy, explaining 78.2% of the variation in GA, with an SEE of 1.66 weeks, an MAE of 1.33 weeks and an MAPE of 3.88% (Table 4).

Table 4: Linear regression models for estimating gestational age and their predictive accuracy (n = 355)

Predictor(s)	Regression equation, GA (weeks)	R	R^2	SEE (wk)	MAE (wk)	MAPE (%)
Head circumference	3.74 + 1.063 × HC	0.865	0.748	1.76	1.42	4.13
Mid-arm circumference	19.80 + 1.644 × MAC	0.540	0.292	2.98	2.41	7.16
HC + MAC	1.44 + 0.962 × HC + 0.584 × MAC	0.884	0.782	1.66	1.33	3.88

All models were statistically significant ($p < 0.001$). HC and MAC in cm. GA: gestational age; HC: head circumference; MAC: mid-arm circumference; R: multiple correlation coefficient; R^2: coefficient of determination; SEE: standard error of estimate; MAE: mean absolute error; MAPE: mean absolute percentage error. Accuracy was assessed in the same sample used to derive the equations.

DISCUSSION

In this study of 355 newborns, most of whom were preterm, HC showed a strong linear relationship with GA assessed by the NBS, explaining about three-quarters of its variation. MAC was a weaker predictor, and adding it to HC improved estimation only modestly. HC was also strongly correlated with birth weight. These findings support HC as a simple proxy for GA, particularly where early ultrasonography and skilled maturity scoring are unavailable.

The strength of the HC–GA correlation in this study (r = 0.865) closely matches that reported by Das et al., who studied 530 neonates of 28–41 weeks' gestation in a tertiary care hospital in India and reported r = 0.863, with measurements also taken after three days of life [12]. Other studies have reported weaker correlations, including r = 0.60 in 1000 neonates in Delhi [13], r = 0.566 in Central India [14], r = 0.526 in 300 neonates [15], and r = 0.483 in Ethiopia [16]. The differences are probably explained by the GA range of the study populations. Our cohort and that of Das et al. spanned 28 to 41 weeks, with many preterm neonates, whereas cohorts dominated by term infants have a narrow GA range, which mathematically weakens correlation coefficients. Differences in the reference standard also matter: the Ethiopian study used LMP dating, which is less precise than the NBS [16]. Despite these differences, all these studies found a significant positive association between HC and GA, and most identified HC as one of the measurements most closely related to GA, in keeping with the relative preservation of brain growth in the fetus [7].

The prediction equation derived in this study, GA = 3.74 + 1.063 × HC, had an SEE of 1.76 weeks and an MAE of 1.42 weeks, which is comparable to the precision of the NBS itself (about ±2 weeks) [6]. The slope implies that each 1 cm increase in HC corresponds to roughly one additional week of gestation across the preterm range. Das et al. found that combining HC with crown–heel length improved prediction [12], and Thawani et al. derived a model combining birth weight, HC, and MAC that estimated GA to within two weeks in 75.5% of neonates [13]. In our data, adding MAC to HC reduced the SEE only from 1.76 to 1.66 weeks, suggesting that in practice HC alone provides most of the available information.

MAC correlated less strongly with GA than HC. MAC reflects subcutaneous fat and muscle, which accumulate

mainly in late gestation and are strongly influenced by fetal nutrition, so it varies more among infants of the same GA. This was evident in the wide and overlapping MAC ranges between adjacent gestational weeks. Our correlation (r = 0.540) is like that reported in Ethiopia (r = 0.481) [16], although a study from Central India reported a much stronger correlation (r = 0.903) [17]. The sensitivity of MAC to nutritional status makes it more useful for identifying low birth weight and small-for-gestational-age (SGA) infants than for estimating maturity: MAC and chest circumference identified SGA newborns with good accuracy in India and Tanzania [18,19], and MAC has also been proposed as a screening tool for low birth weight [11,20].

This study has limitations. GA was assessed using the NBS, which has an inherent error of about two weeks, rather than first-trimester ultrasonography, although the latter was available as an inclusion criterion. The single-center design and the high proportion of preterm and low-birth-weight neonates may limit generalizability to community settings and term populations. Neonates were not classified as SGA or appropriate for GA, so the effect of growth restriction on the equations could not be assessed. The accuracy measures were calculated in the same sample used to derive the equations and may therefore be optimistic. Inter-observer variability was not assessed. External validation in independent and community-based populations is needed before the equations are used in practice.

CONCLUSION

This study showed that HC correlated strongly with GA and birth weight in newborns, whereas MAC showed only a moderate correlation. A simple equation based on HC estimated GA with an accuracy comparable to that of the NBS, and adding MAC improved estimation only modestly. Since HC measurement is simple, inexpensive, and requires minimal training, it may serve as a practical proxy for GA where early ultrasonography or skilled maturity assessment is unavailable.

Additional Information

Disclosures

Human subjects: Consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee, Santokba Durlabhji Memorial Hospital, Jaipur issued approval.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following:

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