Maternal-Fetal Disproportion and Birth Asphyxia
in Rural Sarlahi, Nepal

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Objective: To assess the risk of birth asphyxia associated with maternal and newborn size.

Design: Cohort study.

Setting: Rural community in the Sarlahi district of Nepal.

Participants: Mothers and newborns (n=3189).

Outcome Measure: Birth asphyxia, defined as an infant who failed to cry at birth, and who was unable to breathe or suckle normally after birth or had convulsions.

Results: Birth asphyxia occurred in 78 of 1000 live births, and asphyxia-specific mortality was 11 per 1000 live births. After controlling for confounding factors, mothers with height shorter than 145 cm were more likely to have an infant with birth asphyxia compared with mothers 145 cm or taller (adjusted relative risk [RR], 1.5; 95% confidence interval [CI], 1.1-2.0). Mothers with mid-upper arm circumference smaller than 21.5 cm carried a higher risk of delivering an infant with birth asphyxia compared with those with arm circumference greater than 23 cm (adjusted RR, 1.5; 95% CI, 1.1-2.0). Birth weight was not independently associated with birth asphyxia; however, there was significant interaction between maternal stature and birth weight (P=.01); a 3300-g infant born to a mother shorter than 145 cm carried a 3.8 times higher asphyxia risk (95% CI, 2.2-6.5) than an infant of median weight (2620 g) born to a mother taller than 145 cm.

Conclusions: In rural Nepal, maternal stunting and wasting and large infant head circumference carried higher risk of neonatal asphyxia. Maternal-fetal disproportion resulted in a synergistic elevation in asphyxia risk.

Trial Registration: clinicaltrials.gov Identifier: NCT00115271


W E HAVE PREVIOUSLY reported from rural Sarlahi, Nepal, that multiple-micronutrient supplementation increased mean birth weight by 64 g and reduced the risk of low birth weight by 14% compared with controls receiving vitamin A (retinyl acetate); however, no birth weight or survival advantage was conferred with iron and folic acid, which also resulted in a reduction in low birth weight, of 16%.1,2 Further examination of the data revealed that while iron and folic acid primarily decreased the proportion of low-birth-weight infants, multiple micronutrients also increased the proportion of higher-birth-weight infants.2,3 Importantly, full-term newborn infants of mothers who received multiple micronutrients were at higher risk of early infant mortality (relative risk [RR], 1.74) and were more likely to experience prolonged labor; birth asphyxia, defined as not crying or breathing at birth; or early neonatal death with a birth weight greater than 2000 g (RR, 1.59) than the control group.4 We hypothesized that the elevated risk of birth asphyxia may result from an increase in infant size, particularly among larger infants, beyond a critical point that impeded passage through the pelvis, thereby resulting in intrapartum hypoxia.2,4

For editorial comment see page 671

Maternal-fetal, or cephalopelvic, disproportion is a frequent cause of obstructed labor and consequent maternal and neonatal morbidity and mortality in low-to-middle-income countries where access to skilled care at delivery is limited.5,6 Garner et al7 and Rush8 have raised concern for increasing the risk of maternal-fetal disproportion with interventions aimed at increasing birth size in chronically malnourished women. Short maternal stature is correlated with reduced pelvic size and pelvic deformities due to nutritional deficiencies, such as rickets.5,8,9 Studies in dif-
different ethnic populations\textsuperscript{10,13} and 2 meta-analyses\textsuperscript{14,15} have shown a relationship between maternal stunting and obstructed labor. Higher-birth-weight infants also carry an increased risk of shoulder dystocia\textsuperscript{16} and obstructed labor.\textsuperscript{17}

More than half of childbirths in South Asia occur without a skilled birth attendant.\textsuperscript{18} In these settings, there is limited capacity to intervene for obstructed labor to prevent intrapartum hypoxic insult to the fetus and, furthermore, lack of immediate neonatal resuscitation. In rural Sarlahi, 92% of births occurred in the home, of which the majority occurred without a skilled attendant, and 16% of pregnant mothers were growth stunted (height <145 cm).\textsuperscript{1,19} Our aim was to assess the risk of birth asphyxia associated with maternal and newborn anthropometric measures.

METHODS

STUDY DESIGN, POPULATION, AND INTERVENTION

The data for this study were collected during a cluster-randomized, double-blind trial conducted in the southern rural plains district of Sarlahi, Nepal, from December 1999 through April 2001. The trial evaluated the effect of prenatal and postnatal maternal micronutrient supplementation on birth weight, fetal loss, and early infant mortality.\textsuperscript{1,2} The study procedures are described in detail elsewhere.\textsuperscript{3,4} The study area was divided into 426 sectors, which were each served by a local female worker. Potential childbearing women were visited once every 5 weeks, and pregnancy testing was performed on those reporting amenorrhea in the prior month. Randomization was done by sector for consenting pregnant women to receive supplements and iron and folic acid (cholecalciferol [10 µg], alpha-tocopherol [10 mg], thiamine hydrochloride [1.6 mg], riboflavin [1.8 mg], niacin [20 mg], pyridoxine hydrochloride [2.2 mg], cyanocobalamin [2.6 µg], ascorbic acid [100 mg], phytomenadione [65 µg], copper [2 mg], and magnesium [60 mg]); (3) vitamin A, folic acid, iron, and zinc (30 mg); or (4) vitamin A, folic acid, and iron (60 mg). Study participants were visited twice every 5 weeks, and pregnancy testing was performed on those reporting amenorrhea in the prior month. Randomization was done by sector for consenting pregnant women to receive (1) vitamin A (1000 µg of retinol equivalents); (2) vitamin A and folic acid (400 µg); (3) vitamin A, folic acid, and iron (60 mg); (4) vitamin A, folic acid, iron, and zinc (30 mg); or (5) vitamin A, folic acid, iron, zinc, and multiple micronutrients (cholecalciferol [10 µg], alpha-tocopherol [10 µg], thiamine hydrochloride [1.6 mg], riboflavin [1.8 mg], niacin [20 mg], pyridoxine hydrochloride [2.2 mg], cyanocobalamin [2.6 µg], ascorbic acid [100 mg], phytomenadione [65 µg], copper [2 mg], and magnesium [100 mg]). Study participants were visited twice weekly until 3 months post partum to receive supplements and monitor pregnancy outcomes.

The study was approved by the Johns Hopkins Bloomberg School of Public Health Committee on Human Research (Baltimore, Maryland) and the Nepal Health Research Council (Kathmandu). Verbal consent was obtained from all mothers participating in the trial.

DATA COLLECTION

Baseline interviews regarding socioeconomic status and reproductive history were conducted and maternal weight, height, and mid-upper arm circumference were measured in the home by trained anthropometrists on study enrollment. A birth assessment was conducted after delivery in the home, which included determination of vital status, maternal and infant morbidity during labor and delivery, and infant anthropometry. We used a digital scale to measure infant weight to the nearest 2 g; a length board to measure length to the nearest 0.1 cm; and an insertion tape to measure head and chest circumference to the nearest 0.1 cm. Maternal and infant measurements (excluding weight) were recorded 3 times and the median value was used. Gestational age was calculated using data from both the maternal report of last menstrual period and date of positive pregnancy test result.\textsuperscript{1} Duration of labor was reported by the mother as the number of hours that she had labor pains.

Vital status was monitored until 6 months of age. For infants who died during the study, verbal autopsy interviews were conducted by trained project interviewers using a modified World Health Organization verbal autopsy instrument for infants.\textsuperscript{20,21}

DEFINITION OF BIRTH ASPHYXIA

Based on our prior research evaluating community-based definitions of birth asphyxia,\textsuperscript{24} we defined a case of birth asphyxia as an infant who failed to cry at birth and who was unable to breathe at birth, had convulsions/spasms, or was unable to suckle normally after birth. We included fatal and nonfatal cases to assess the full spectrum of asphyxia-related morbidity and because the number of asphyxia deaths was too small for us to conduct a meaningful analysis. Caretakers retrospectively reported symptoms during the initial infant assessment conducted within 72 hours of delivery or, in the event of death, during a verbal autopsy interview (70% conducted within 2 weeks of death). Verbal autopsy data were extracted from both closed-ended questions and open narratives that were coded for these symptoms. A computer algorithm was used to assign cases of birth asphyxia.

STATISTICAL ANALYSIS

Infant anthropometric data collected at more than 72 hours after birth were excluded from this analysis. Continuous measurements were categorized into quartiles or predefined categories. Log binomial regression was used to calculate adjusted risk estimates. Twins were included in the analysis, as their inclusion did not substantially alter the estimates; standard errors were adjusted for nonindependence of events.\textsuperscript{22}

We considered confounders based on a priori knowledge of causal relationships with birth asphyxia.\textsuperscript{24-28} The following variables were considered potential confounders: maternal age; parental education and literacy; caste; ethnicity; history of fetal loss; parity; place of delivery; birth attendant; prolonged rupture of membranes; malpresentation; maternal convulsions, swelling, fever, and vaginal bleeding in the 7 days prior to delivery; multiple pregnancies; preterm birth; infant sex; cigarette smoking; use of betel nuts; and multiple-micronutrient treatment allocation group. Confounding variables were included in the final multivariable model if they passed the bivariate screen of \( P < .10 \) and changed the coefficient of interest by more than 8%.\textsuperscript{20}

We explored interaction between maternal stunting and infant size, modeling birth weight and infant head circumference as continuous variables. Lowess plots were generated to guide the choice of scale, and after testing several models, the best fit was found with a restricted quadratic spline with knots at the quartile points.\textsuperscript{20} Wald tests were performed to determine the significance of the interaction. Population-attributable risk percentage was calculated by methods described by Vander Hoorn et al:\textsuperscript{25}

\[
PAF = \frac{\sum_{i=1}^{n} P_i \cdot RR_i - \sum_{i=1}^{n} P'_i \cdot RR'_i}{\sum_{i=1}^{n} P_i \cdot RR_i}
\]

Given the association of prematurity with small infant size and perinatal respiratory depression,\textsuperscript{26} a subanalysis was conducted among full-term infants (≥37 weeks’ gestation). How-
ever, preterm births did not affect estimates at the high birth
weight or head circumference distribution; thus they were re-
tained in the final analysis, which controlled for gestational age.

Stunting is a measure of chronic malnutrition in early child-
hood and was defined as maternal stature shorter than 145 cm
according to the Subcommittee on Nutrition, World Health
Organization.19

Stata statistical software, release 9.0 (Stata Corp, College Sta-
tion, Texas), was used to conduct all analyses. Statistical asso-
ciations and interactions were considered significant at
P < .05.

RESULTS

There were 4926 pregnant women enrolled in the study,
resulting in 4130 live-born infants (Figure 1). The vast
majority of deliveries (approximately 90%) occurred out-
side of a hospital facility; there was poor access to cesar-
ean section (0.4%, n = 17). Among the original birth co-
hort, there were 323 cases of birth asphyxia (45 fatal and
278 nonfatal), yielding an overall asphyxia prevalence of
78 per 1000 live births and an asphyxia-specific mortal-
ity of 11 per 1000. Of the 4130 live births, 3189 (77%)
had both maternal measurements and birth assessments
within 72 hours of birth that were included in the pres-
ent analysis. Among these infants, there were 253 cases of
birth asphyxia (26 fatal and 227 nonfatal), yielding an
asphyxia prevalence of 79 per 1000 live births and as-
phyxia-specific mortality of 8 per 1000. Of the 941 in-
fants with missing anthropometric data, 98 died prior to
birth assessment.

CHARACTERISTICS OF BIRTH ASPHYXIA CASES

Table 1 presents characteristics associated with birth
asphyxia. Mothers of infants experiencing birth as-
phyxia were more likely to be younger, primiparous, have
a history of fetal loss, and be Madheshi (“people from
the plains”) vs Pahadi (“people from the hills”). Asphyxi-
ated infants were more likely to have been attended by a
physician or midwife. Intrapartum complications were

![Table 1. Antepartum and Intrapartum Factors Associated
With Birth Asphyxia in Sarlahi, Nepal](image)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>With Birth Asphyxia (n=253)</th>
<th>Without Birth Asphyxia (n=2936)</th>
<th>Missing Values, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antepartum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>75 (30)</td>
<td>1004 (34)</td>
<td>11</td>
</tr>
<tr>
<td>20-24</td>
<td>91 (36)</td>
<td>782 (27)</td>
<td></td>
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<tr>
<td>25-30</td>
<td>60 (24)</td>
<td>664 (23)</td>
<td></td>
</tr>
<tr>
<td>≥30</td>
<td>27 (11)</td>
<td>475 (16)</td>
<td></td>
</tr>
<tr>
<td>Pahadi ethnicity</td>
<td>68 (27)</td>
<td>918 (31)</td>
<td>4</td>
</tr>
<tr>
<td>Maternal literacy</td>
<td>46 (18)</td>
<td>585 (20)</td>
<td>0</td>
</tr>
<tr>
<td>Primiparous mother</td>
<td>91 (36)</td>
<td>664 (23)</td>
<td>0</td>
</tr>
<tr>
<td>Maternal history of fetal loss</td>
<td>41 (16)</td>
<td>383 (13)</td>
<td>0</td>
</tr>
<tr>
<td>Maternal multiple-micronutrient supplementation</td>
<td>66 (26)</td>
<td>617 (21)</td>
<td></td>
</tr>
<tr>
<td>Intrapartum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital delivery</td>
<td>13 (5)</td>
<td>108 (4)</td>
<td>68</td>
</tr>
<tr>
<td>Birth attendant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family/friend/no one</td>
<td>80 (32)</td>
<td>1669 (57)</td>
<td></td>
</tr>
<tr>
<td>Traditional birth attendant, traditional healer, or community health worker</td>
<td>72 (28)</td>
<td>795 (27)</td>
<td></td>
</tr>
<tr>
<td>Physician or auxiliary nurse/midwife</td>
<td>101 (40)</td>
<td>471 (16)</td>
<td>1</td>
</tr>
<tr>
<td>Fever in 7 d before delivery</td>
<td>13 (5)</td>
<td>88 (3)</td>
<td>5</td>
</tr>
<tr>
<td>Vaginal bleeding within 30 d before delivery</td>
<td>6 (2)</td>
<td>53 (2)</td>
<td>6</td>
</tr>
<tr>
<td>Vaginal discharge within 30 d before delivery</td>
<td>153 (6)</td>
<td>20 (10)</td>
<td>477</td>
</tr>
<tr>
<td>Prolonged rupture of membranes</td>
<td>17 (7)</td>
<td>98 (3)</td>
<td>49</td>
</tr>
<tr>
<td>Nonvertex presentation</td>
<td>20 (8)</td>
<td>42 (1)</td>
<td>9</td>
</tr>
<tr>
<td>Multiple pregnancy, twin</td>
<td>11 (4)</td>
<td>40 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Prolonged labor</td>
<td>128 (51)</td>
<td>1088 (37)</td>
<td>37</td>
</tr>
<tr>
<td>Infant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age, wk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;34</td>
<td>19 (8)</td>
<td>179 (6)</td>
<td></td>
</tr>
<tr>
<td>34-37</td>
<td>35 (14)</td>
<td>418 (14)</td>
<td>4</td>
</tr>
<tr>
<td>37-41</td>
<td>131 (52)</td>
<td>1637 (56)</td>
<td></td>
</tr>
<tr>
<td>≥41</td>
<td>67 (27)</td>
<td>699 (24)</td>
<td></td>
</tr>
<tr>
<td>Female sex</td>
<td>97 (38)</td>
<td>1476 (50)</td>
<td>1</td>
</tr>
</tbody>
</table>

*Longer than 24 hours in a primiparous or longer than 12 hours in a
multiparous mother.

Figure 1. Flowchart of study participants.
more common among asphyxia cases and included maternal self-report of fever (≤7 days before delivery), vaginal bleeding (≤30 days before delivery), vaginal discharge (≤30 days before delivery), prolonged rupture of membranes (>24 hours), nonvertex presentation (breach, foot, or hand presentation), and prolonged labor (>24 hours in a primiparous or >12 hours in a multiparous mother). The entire duration of labor for a newborn experiencing asphyxia was significantly longer, by 4.3 hours (P<.001), and the second stage of labor was longer by 15 minutes (P=.01). Birth asphyxia cases were more frequently male and from a multiple pregnancy.

MATERNAL NUTRITIONAL STATUS AND RISK OF BIRTH ASPHYXIA

Mothers shorter than 145 cm more often had an infant with birth asphyxia compared with otherwise similar women who were taller than 145 cm (adjusted RR, 1.5; 95% confidence interval [CI], 1.1-2.0) (Table 2). Similarly, newborns of women with a mid-upper arm circumference smaller than 21.5 cm carried higher risk of asphyxia compared with newborns of those with an arm circumference larger than 23 cm (adjusted RR, 1.5; 95% CI, 1.1-2.0). Low body mass index (<18.5) (calculated as weight in kilograms divided by height in meters squared) was not significantly associated with birth asphyxia (adjusted RR, 1.3; 95% CI, 0.9-1.7). When all maternal anthropometric measures were included in the same model (Table 2), maternal stunting (height <145 cm) was the only significant predictor of birth asphyxia (adjusted RR, 1.4; 95% CI, 1.0-1.9).

INFANT BIRTH SIZE AND RISK OF BIRTH ASPHYXIA

Large head circumference (>33.5 cm) carried a 1.6 times increased adjusted risk of birth asphyxia compared with a head circumference of 32.6 to 33.5 cm (95% CI, 1.1-2.2) (Table 3). The risk of birth asphyxia for infants with birth weight less than 2000 g (adjusted RR, 1.2; 95% CI, 0.8-1.8) and birth weight greater than 3000 g (adjusted RR, 1.3; 95% CI, 0.9-1.8) was greater than that of infants who weighed 2000 to 2999 g, though it was not statistically significant after controlling for confounders. Similarly, the risk of birth asphyxia for infants of low (<29.4 cm, adjusted RR, 1.3; 95% CI, 0.9-1.9) and high (>31.9 cm, adjusted RR, 1.4; 95% CI, 0.9-2.0) chest circumference was elevated compared with those with a chest circumference of 29.4 to 20.5 cm, though not to a level of statistical significance. In a model including all of the infant measures (Table 3), both head circumference larger than 33.5 cm (adjusted RR, 1.6; 95% CI, 1.1-2.3) and chest circumference smaller than 29.4 cm (adjusted RR, 1.5; 95% CI, 1.0-2.1) were significant predictors of birth asphyxia.

INTERACTION OF MATERNAL STUNTING AND INFANT SIZE

The risk of birth asphyxia associated with maternal stunting significantly increased as birth weight rose beyond approximately 3000 g (Figure 2). Compared with an infant of median birth weight (2620 g) born to a nonstunted mother (>145 cm), a newborn of similar weight born to a stunted mother was at 1.8 times higher risk (95% CI, 1.2-2.6), whereas a 3300-g infant of a stunted mother was at 3.8 times greater risk (95% CI, 2.2-6.5) (Table 4); the interaction between maternal stunting and birth weight was significant (P=.01).

Birth asphyxia risk associated with maternal stunting appeared to peak at median head circumference then plateau at higher head circumference (Figure 3). However, this trend was not statistically significant. Compared with an infant of median head circumference (32.6 cm) born to a nonstunted mother, a similar newborn of a stunted mother carried a 2.0-fold higher risk (95% CI, 1.4-2.9) and an infant with a head circumference of 34.5

**Table 2. Association of Birth Asphyxia With Maternal Anthropometric Measures**

<table>
<thead>
<tr>
<th>Maternal Measure</th>
<th>Newborns With Asphyxia/Newborns per Category, No.</th>
<th>Relative Risk (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude</td>
<td>Adjusted*a</td>
</tr>
<tr>
<td>Height, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥145</td>
<td>201/2706</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>&lt;145</td>
<td>52/483</td>
<td>1.5 [1.1-1.9]</td>
</tr>
<tr>
<td>Body mass indexc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>101/1226</td>
<td>1.1 [0.8-1.6]</td>
</tr>
<tr>
<td>18.5-20</td>
<td>79/984</td>
<td>1.1 [0.8-1.5]</td>
</tr>
<tr>
<td>22.5</td>
<td>14/190</td>
<td>1.0 [0.5-1.8]</td>
</tr>
<tr>
<td>Mid-upper arm circumference, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;21.5</td>
<td>127/1367</td>
<td>1.3 [1.0-1.8]</td>
</tr>
<tr>
<td>21.5-22.4</td>
<td>45/664</td>
<td>0.9 [0.7-1.4]</td>
</tr>
<tr>
<td>22.5-22.9</td>
<td>21/286</td>
<td>1.1 [0.7-1.7]</td>
</tr>
<tr>
<td>≥23.0</td>
<td>59/944</td>
<td>1 [Reference]</td>
</tr>
</tbody>
</table>

*a Adjusted for maternal age, ethnicity, parity, multiple pregnancy, malpresentation, infant sex, and preterm birth. Individual anthropometric measures are not adjusted for each other.

*b Adjusted for maternal age, ethnicity, parity, multiple pregnancy, malpresentation, infant sex, and preterm birth. Each anthropometric measure is adjusted for the other anthropometric variables.

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cm carried a 2.8 times increased risk (95% CI, 1.8-4.4); there was not a significant interaction (P = .11).

**POPULATION-ATTRIBUTABLE RISK**

Based on calculation of population-attributable risk percentage, we estimated that 7% of birth asphyxia in this study population would not have occurred if all mothers were taller than 145 cm (data not shown). Fourteen percent of birth asphyxia in the population was attributed to large infant head circumference (>33.5 cm), while 5% of asphyxia cases were attributed to birth weight greater than 3000 g (data not shown).

This study reports on the association of indicators of maternal and infant size and nutritional status with birth asphyxia in a rural South Asian community with a high prevalence of home birth and poor access to emergency obstetrical care. In Sarlahi, mothers with a history of chronic malnutrition, evidenced by growth stunting, carried a 50% higher risk of delivering a newborn with symptoms of birth asphyxia. Acute malnutrition, measured by mid-upper arm circumference, was also associated with a 50% higher risk. Infants with large head circumference were 60% more likely to experience birth asphyxia. Furthermore, there was significant interaction between maternal stunting and infant birth weight, supporting the hypothesis that maternal-fetal disproportion placed newborns at higher risk of birth asphyxia in this resource-limited setting.

In a meta-analysis by Dujardin et al,14 who used hospital and community data from developed and developing countries, short maternal stature (lowest 30% of population) was consistently associated with elevated risk of cesarean section across different ethnic populations. A meta-analysis by Kelly et al15 that pooled data from 25 countries estimated that short maternal height (lowest quartile of population) was associated with a 60% increased risk of assisted delivery. In a Kathmandu hospital, neonatal encephalopathy, a neurological outcome of birth asphyxia, was 3-fold higher in mothers with a height shorter than 145 cm.32 In the Zaria birth survey in Nigeria, infants weighing more than 3500 g born to mothers shorter than 1.5 m had a 9.5 times increased risk of operative delivery compared with infants of average size born to tall mothers.33 In Guatemala, deliveries complicated by cephalopelvic disproportion had a 4-fold elevated risk of cesarean section.34 We did not analyze operative delivery or assisted delivery in our study owing to the low proportion of women with access to these procedures (approximately 0.4%).

While maternal-fetal disproportion and consequent obstructed labor are important causes of birth asphyxia, other risk factors, including maternal infections, pregnancy-related hypertensive disorders, maternal anemia, ante-

**Table 3. Association of Birth Asphyxia With Newborn Anthropometric Measures**

<table>
<thead>
<tr>
<th>Birth Anthropometry</th>
<th>Newborns With Asphyxia/Newborns per Category, No.</th>
<th>Relative Risk (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Crude</td>
</tr>
<tr>
<td>Head circumference, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;31.8</td>
<td>57/821</td>
<td>1.0 (0.7-1.5)</td>
</tr>
<tr>
<td>31.8-32.5</td>
<td>54/797</td>
<td>1.0 (0.7-1.5)</td>
</tr>
<tr>
<td>≥33.5</td>
<td>48/712</td>
<td>1.6 (1.2-2.7)</td>
</tr>
<tr>
<td>Birth weight, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2000</td>
<td>27/231</td>
<td>1.6 (1.1-2.3)</td>
</tr>
<tr>
<td>≥3000</td>
<td>50/579</td>
<td>1.2 (0.9-1.6)</td>
</tr>
<tr>
<td>Chest circumference, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;29.4</td>
<td>83/836</td>
<td>1.5 (1.1-2.2)</td>
</tr>
<tr>
<td>29.4-30.5</td>
<td>44/682</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>30.5-31.9</td>
<td>67/907</td>
<td>1.1 (0.8-1.7)</td>
</tr>
<tr>
<td>≥31.9</td>
<td>59/764</td>
<td>1.2 (0.8-1.7)</td>
</tr>
</tbody>
</table>

\(^a\) Adjusted for maternal age, ethnicity, parity, multiple pregnancy, malpresentation, infant sex, and preterm birth. Individual anthropometric measures are not adjusted for each other.

\(^b\) Adjusted for maternal age, ethnicity, parity, multiple pregnancy, malpresentation, infant sex, and preterm birth. Each anthropometric measure is adjusted for the other anthropometric variables.
Thus, for infants with heads smaller than this critical point, as head circumference increased, the risk of maternal stunting resulted in an increasing risk of cephalopelvic disproportion. However, for infants with heads larger than this circumference, maternal stunting may not contribute to a further increase in the risk of cephalopelvic disproportion, given that large head circumference alone may already place the infant at a higher risk of difficulty in passing through the pelvis. Additionally, the study may not have been sufficiently powered to detect an interaction.

There is no gold standard definition of birth asphyxia for use at the community level. We have previously conducted methodological research\(^{25,26}\) and based our case definition on symptoms from verbal autopsy-validation studies.\(^{20,26}\) The incidence of birth asphyxia and asphyxia-specific mortality were similar to community-based studies in Uttar Pradesh and Maharashtra, In-
symptoms were collected within 72 hours for nonfatal birth asphyxia and most verbal autopsies were performed within a week after the death, minimizing recall bias.

In a rural community-based study in Nepal that examined the effects of micronutrient supplementation on birth weight,1 we used available anthropometric data to explore the relationship between maternal and infant size at birth and the risk of birth asphyxia. We found that maternal stunting and wasting, large infant head circumference, and maternal-fetal disproportion in size pose increased risk of neonatal morbidity and mortality due to birth asphyxia in a setting where most births occur in the home without access to obstetrical and neonatal care. This mechanism may potentially explain the increased risk of mortality observed in infants of mothers who received multiple-micronutrient supplementation previously reported in our cohort.3 These findings need further examination in different settings, as they may not be generalizable to populations that may vary with respect to the prevalence of stunting, anatomic shape of the pelvis, and access to prenatal and obstetrical care.40,41

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REFERENCES


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**Announcement**

2010 Certifying Examination in Adolescent Medicine

**Examination date:** March 22, 2010.

**Registration dates:** August 4, 2009, through November 3, 2009.

**Registration for reregistrants:** September 15, 2009, through December 15, 2009.

The final month of registration requires payment of a late fee.

All applicants must complete applications online during the registration periods. The requirements for online applications are found on the American Board of Pediatrics Web site: http://www.abp.org. Additional information including eligibility requirements is found on the American Board of Pediatrics Web site. Each application will be considered individually and must be acceptable to the American Board of Pediatrics.

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