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# Radiological evaluation of bone growth in neonates born at gestational ages between 26 and 41 weeks: Cross-sectional study

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**Abstract** The length of the ossified part of the long bones of the upper (humerus) and lower limb (femur) as well as the axial length (that is, height) of the vertebral body of L1 were measured on a plain supine radiograph in 347 newborn babies (228 males, 119 females) with the gestational age (GA) from 26 to 41 weeks. All were admitted to the neonatal intensive care unit. Reasons for admission included hyaline membrane disease, meconium aspiration syndrome, neonatal asphyxia or transient tachypnea of the newborn. Patients with abnormal growth, gross anomalies, or who were the products of multiple births were excluded.

The average weekly increment in the height of L1 for male infants born at GA varying from 26 to 41 weeks was 0.23 mm, for the humerus 1.82 mm and for the femur 2.35 mm. The corresponding data for females was 0.20 mm, 1.54 mm and 2.30 mm.

The ratio of the height of L1 to body length progressively increased between 26 to 41 weeks. A growth spurt in L1 was noted for both sexes at 34 weeks of GA. Long bone growth was similar in male and female infants born before 36 weeks. However, the ratio of femur to body length in males increased after 36 weeks. The ratio of humerus to body length remained constant over the entire range of GA.


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## 1. Introduction

Measurement of the thoracic and lumbar spine lengths has been used to determine intrauterine fetal size and gestational age (GA) [1–3]. Femur length and abdominal circumference have been included for intrauterine growth measurement for a long time, its evaluation is subject to bias [4]. Femur length measurements by prenatal ultrasound are not good for gestational assessment past 20 weeks [5,6]. However, there is little information on the growth of long bones in early life. We assessed the height of the first lumbar vertebra and the lengths of the humerus and femur in infants born at varying gestational ages in order to investigate the relationship between bone length and GA in the newborn infant.

## 2. Materials and methods

We analyzed plain supine chest radiographs of all neonates admitted to the neonatal intensive care unit (NICU) over the course of 1 year. In order to avoid confounding by conditions with abnormal growth, patients who were small or large for GA, had gross anomalies, or were the products of multiple births were excluded. The study population was ethnically homogeneous Chinese newborns. The GA was determined by the Dubowitz scoring system [7].

GA scoring, measurement of body length, and radiographs were all performed within 24 h after birth. The upper limbs were put close to the trunk and lower limbs on neutral position when taking a film. The X-ray beam would be focused on L1. Gonadal protection was routinely performed. A metallic ruler, precise to 0.01 mm, was placed beside the baby when the film was taken and was used to measure the axial length (height) of vertebral body L1 and the lengths of the humerus and femur. Three radiologists measured each parameter in all films in order to reduce observer error. The parents gave the informed consents for the study.

### 2.1. Statistical analysis

SSPS, version 10.1.3C (SSPS Inc.), was used to perform all the analyses. Linear regression analysis was used to test the relationship between growth of bones and GA as well as body length and weight. Multiple regression analysis was used to explore explanatory variables and develop a prediction equation [8]. A $p<0.05$ was considered statistically significant.

**Table 1** Birth body weight, birth body length, humerus length, L1 height, and femur length by gestational age between 26 and 41 weeks

| GA (weeks) | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *n* | 6 | 7 | 7 | 14 | 13 | 20 | 17 | 36 | 26 | 33 | 23 | 28 | 28 | 26 | 39 | 24 |
| BBW (g) | 853 ± 169 | 934 ± 183 | 1053 ± 124 | 1170 ± 164 | 1486 ± 270 | 1567 ± 250 | 1615 ± 321 | 1865 ± 312 | 2050 ± 304 | 2241 ± 368 | 2536 ± 452 | 2669 ± 343 | 2958 ± 289 | 3163 ± 365 | 3135 ± 366 | 3193 ± 366 |
| *n* | 6 | 7 | 7 | 13 | 13 | 20 | 16 | 36 | 25 | 32 | 23 | 27 | 27 | 26 | 38 | 24 |
| BBL (cm) | 34.5 ± 3.1 | 35.1 ± 1.8 | 35.9 ± 1.7 | 37.7 ± 2.6 | 39.5 ± 3.0 | 40.5 ± 2.7 | 40.9 ± 2.5 | 42.9 ± 2.5 | 43.8 ± 2.1 | 45.8 ± 2.3 | 46.1 ± 2.6 | 47.9 ± 1.8 | 48.7 ± 1.9 | 50.6 ± 2.5 | 50.2 ± 1.9 | 50.2 ± 2.4 |
| *n* | 6 | 6 | 6 | 13 | 13 | 19 | 17 | 36 | 26 | 32 | 22 | 28 | 27 | 25 | 38 | 24 |
| Humerus (mm) | 41.7 ± 3.3 | 42.6 ± 3.3 | 44.8 ± 2.7 | 45.9 ± 3.8 | 48.2 ± 3.4 | 50.5 ± 4.3 | 51.2 ± 4.1 | 53.2 ± 4.0 | 55.0 ± 3.4 | 56.3 ± 3.8 | 57.7 ± 3.9 | 61.3 ± 4.9 | 62.1 ± 3.9 | 64.0 ± 5.1 | 64.5 ± 4.4 | 66.9 ± 2.8 |
| *n* | 6 | 7 | 7 | 12 | 13 | 20 | 17 | 36 | 26 | 33 | 23 | 28 | 27 | 25 | 39 | 24 |
| L1 (mm) | 3.8 ± 0.3 | 4.2 ± 0.3 | 4.3 ± 0.3 | 4.6 ± 0.3 | 5.1 ± 0.5 | 5.2 ± 0.4 | 5.3 ± 0.6 | 5.6 ± 0.5 | 6.0 ± 0.5 | 6.1 ± 0.5 | 6.3 ± 0.4 | 6.7 ± 0.4 | 6.8 ± 0.4 | 7.1 ± 0.4 | 7.1 ± 0.4 | 7.1 ± 0.4 |
| *n* | 4 | 6 | 6 | 12 | 12 | 19 | 16 | 30 | 20 | 27 | 16 | 18 | 14 | 16 | 20 | 10 |
| Femur (mm) | 44.7 ± 2.1 | 49.9 ± 3.9 | 51.7 ± 3.6 | 53.7 ± 3.0 | 58.4 ± 5.2 | 59.6 ± 3.9 | 61.1 ± 2.9 | 63.9 ± 3.6 | 64.8 ± 4.5 | 67.5 ± 6.2 | 71.3 ± 5.6 | 73.6 ± 6.8 | 77.0 ± 5.4 | 78.5 ± 4.6 | 78.0 ± 6.0 | 83.7 ± 3.8 |

BBL—birth body length, BBW—birth body weight, GA—gestational age, *n*—number of cases.