

Supplementary material

Study design

This study was conducted in collaboration with 6 general hospitals in South Korea: Seoul National University Hospital (Seoul), Seoul National University Bundang Hospital (Gyeonggi-do), Korea University Ansan Hospital (Gyeonggi-do), Jeju National University Hospital (Jeju), Eulji University Hospital (Daejeon, Chungcheongnam-do), and Pusan National University Yangsan Hospital (Gyeongsangnam-do). Newborns fitting the study criteria were scheduled for outpatient visits according to specific postnatal days for physical measurements and survey administration. Additionally, newborns born at non-participating hospitals but residing near the study sites and meeting the selection criteria (including breastfeeding requirements, dietary control, and the ability to regularly attend outpatient follow-ups) were also included in the study if they were healthy and under 2 months old.

Participant characteristics

Newborns under 2 months old, whose mothers adhered to World Health Organization breastfeeding guidelines and met the selection criteria, were recruited. A baseline environmental survey was conducted to assess parental education and income levels, ensuring the inclusion of a group whose growth was not environmentally constrained by socioeconomic factors. The detailed recruitment criteria are outlined below.

Inclusion criteria

1. Singleton, full-term infants delivered under normal circumstances:
 - Gestational age of 37 to 42 weeks.
 - Appropriate for gestational age: Birth weight between the 3rd and 97th percentiles for gestational age.
 - No major perinatal diseases.
 - Not requiring admission to the neonatal intensive care unit (NICU) for more than 24 hours.
2. Newborns delivered by mothers with no smoking history before or after delivery.
3. Infants with no health, environmental, or economic limitations affecting growth:
 - Actual residence is within an accessible distance to the participating hospitals.
 - Parents are proficient in Korean (reading and writing).
 - The family is covered by health insurance or eligible for medical assistance.
4. Parents who are willing to comply with breastfeeding recommendations:
 - Exclusive or predominant breastfeeding for at least 3 months (90 days).
 - Introduction of complementary foods at 6 months (180 days).
 - Continued partial breastfeeding for a minimum of 12 months (365 days).
 - Breastfeeding with occasional formula supplementation (one bottle per day) is permitted during the first 1 to 2 weeks of life.

Exclusion criteria

1. Newborns older than 8 weeks (± 7 days) whose parents do not consent to participate.
2. Infants not screened or physically measured within 24 hours of birth.
3. Infants with health, environmental, or economic limitations affecting growth.*
4. Maternal restrictions:
 - Mothers with a smoking history before or after delivery.
 - Mothers with pregnancy-induced hypertension, preeclampsia, or eclampsia.
 - Mothers with gestational diabetes requiring medication.
5. Infants requiring NICU admission for more than 24 hours after birth or diagnosed with the following conditions:
 - Neonatal neurological diseases.
 - Neonatal respiratory distress.
 - Congenital malformations (excluding atrial septal defect or patent ductus arteriosus in the heart).
 - Chromosomal disorders (e.g., Down syndrome, Turner syndrome).
 - Evidence of intrauterine infections.
 - Large for gestational age: Birth weight exceeding the 97th percentile for gestational age.
 - Small for gestational age: Birth weight below the 3rd percentile for gestational age.

Recruitment

We actively promoted the study using promotional materials such as tri-fold brochures, postcard-sized flyers, and posters. These materials were distributed directly, and study awareness was raised through regular neonatal ward rounds by participating medical staff. Posters were also placed in obstetrics outpatient waiting rooms, along with the distribution of promotional materials. For online promotion, consent was obtained from mothers of healthy, full-term singleton newborns prior to discharge, asking if they would agree to participate in a text message survey. Once consent was obtained, a bulk notification message was sent. To expand participant recruitment, a promotional video highlighting the infant growth measurement study was produced and distributed.

To prevent dropout, we provided breastfeeding telephone consultations 6 times: once after each outpatient visit and before the next visit, from birth until 6 months of age. Parents of participating infants, regardless of breastfeeding frequency, received breastfeeding status assessments, education, encouragement for continued breastfeeding, and a “question and answer” session at birth or during the most recent visit. Additionally, a social network service was set up to provide real-time responses to participants’ questions regarding complementary feeding and medical consultations. Participants were compensated with travel expenses for each visit and received commemorative gifts upon their first study visit, at 6 months, and at 12 months. Moreover, online live childcare education and counseling sessions, conducted by university hospital medical professionals, were provided monthly.

We conducted intensive breastfeeding education for infants from birth to 6 months of age. A nutritionist provided monthly breastfeeding consultations, which included assessing breastfeeding status, offering education on breastfeeding techniques, encouraging continued breastfeeding, and discussing precautions for breast pumping if needed. Guidance on introducing solid foods was also provided, along with a “question and answer” session. In addition, age-appropriate educational materials were directly distributed to parents. During each measurement and consultation, healthcare providers consistently

Quality control of the study

We conducted regular online meetings with the research staff to review and monitor the progress of the study. In addition, regular quality control of input data was conducted. Monthly checks of electronic case report form data registration ensured the identification and correction of missing or erroneous data. The status of breastfeeding and nutritional counseling was also reviewed. To ensure the accurate and consistent use of measurement devices, theoretical and practical training workshops were held quarterly for all study personnel, focusing on measurement and calibration procedures. Institution-specific workshops were conducted every 2 months. To ensure the accuracy of the physical measurement devices, we conducted daily, weekly, and monthly calibrations.

Height measuring device

- Place the measuring device on a flat surface.
- Use an 80-cm calibration rod to measure the distance between the headboard and footplate, and record the data on the calibration form.
- The difference between the measured values should not exceed 3 mm.
- Perform a comprehensive equipment inspection to ensure there are no malfunctions or safety issues.

Weighing scale

- Ensure the device has sufficient battery power or is connected to an adapter. Low power may cause issues during calibration.
- Prepare test weights for calibration (recommendation: 15 kg total, consisting of one 10 kg and one 5-kg weight). Calibration cannot proceed with too light a weight. (The measuring range is up to 20 kg, with 5-g increments for weights under 10 kg and 10-g increments for weights between 10–20 kg.)
- Calibration procedure:
 1. With the device powered off, hold the hold button while turning it on.
 2. When numbers appear, release the hold button and press it again until the "CAL" indicator blinks. Press and hold the button.
 3. Place the 15-kg test weight on the scale and record the measurement on the calibration form.
 4. The scale will display the current measurement of the test weight.
 5. Adjust the displayed value to match the actual test weight.
 - A short press of the hold button decreases the value.
 - A long press shows the "inc" indicator briefly, after which pressing the kg button increases the value.
 6. After setting the correct value, press and hold the hold button until "sto" is displayed, then release it immediately.
 7. Once the settings are complete, the screen will turn off, indicating calibration is finished.
 8. Remove the test weight, power on the scale again, and verify the measurement with the test weight.

Tape measure

Perform a comprehensive equipment inspection.

- Check if the tape measure's markings are clear.
- Check the stretching of the tape measure: Align the 0 mark on the left of the measuring tape with the 0 mark on a 60-cm calibration ruler, and verify that the 45 cm mark on the tape aligns with the 45-cm mark on the ruler.
- Check for any bending or deformation.

Guidelines for anthropometric measurements

1. Height measurement

For children under 24 months, height is measured while lying down. Before measurement, remove the child's clothing and diaper. Lay the child straight on the measuring board, ensuring their body is parallel to the measurement line, with their face facing forward. An assistant should hold the child's head, making sure the head is in the midline position and the Frankfort horizontal plane is perpendicular to the ground. The primary measurer holds the child's feet with one hand and gently extends the knees using the elbow with minimal pressure. The feet should be fully vertical and aligned with the footplate. The measurer moves the footplate to touch the child's heels and records the measurement to the nearest 0.1 cm. Measure twice and take the average, ensuring that the difference between the 2 measurements is less than 0.7 cm. If the difference exceeds 0.7 cm, repeat the measurement and discard the outlier. For children over 24 months, height is measured standing. The child stands straight on a flat surface with their heels, buttocks, back, and the back of the head touching the vertical measuring board. The head should face forward in the Frankfort horizontal plane. Arms should hang naturally at the sides with palms facing the legs. The elbows should be close to the body, with feet slightly apart (approximately 60°), and knees not overlapping. After asking the child to take a deep breath, place the headboard on the top of the head with enough pressure to flatten the hair. The measurer should ensure correct posture from both the front and side views before taking the reading.¹⁾

2. Weight measurement

For children under 24 months, weight is measured lying down. The scale must be placed on a flat, solid surface. Remove the child's clothes if possible, and lay the child still in the center of the scale. Read the weight displayed on the screen. If the child weighs less than 10 kg, record the weight to the nearest 5 g; if over 10 kg, record it to the nearest 10 g. Measure twice and use the average, ensuring the difference between the 2 measurements is less than 100 g. If the difference exceeds 100 g, repeat the measurement and discard the outlier. If the diaper is not removed, weigh the child with the diaper and then subtract the diaper's weight to record the actual body weight. For children over 24 months, weight is measured standing.¹⁾

3. Head circumference measurement

Use a flexible, noncorrosive measuring tape that does not irritate the child's skin. The child should face forward during the measurement. Wrap the tape horizontally around the head, passing just above the eyebrows and ears, and lightly press it against the hair. Ensure the tape forms a level plane around the head. An assistant can help hold the tape. Avoid pressing into the skin and measure to the nearest 0.1 cm. The largest part of the head should be used for the measurement. Hold both ends of the tape, and read the measurement where the zero mark meets the opposite end. Measure twice and use the average, ensuring the difference between the 2 measurements is less than 5 mm. If the difference exceeds 5 mm, repeat the measurement and discard the outlier.¹⁾

4. Waist circumference measurement

For children under 24 months, measure waist circumference while the child is lying down, facing forward. Measure before feeding. The measurement should be taken at the level of the navel, ensuring the tape is vertical to the ground. Avoid pressing the skin and measure to the nearest 0.1 cm. Hold the zero mark of the tape with the left hand and the other end with the right hand, then read the measurement at the point where the zero mark meets the other end. Measure twice and use the average, ensuring the difference between the 2 measurements is less than 5 mm. If the difference exceeds 5 mm, repeat the measurement and discard the outlier. For children over 24 months, measure waist circumference while standing. The child should stand straight, facing forward, with feet shoulder-width apart. Measure at the midpoint between the lowest rib and the top of the iliac crest (hip bone). Ensure the tape forms a horizontal plane around the waist.¹⁾

Reference

1. Korea Disease Control and Prevention Agency. Cheongju (Korea): Korea National Health & Nutrition Examination Survey, 2016.