

The Korea Infant Physical Growth Examination Survey (KIPGroS): a study protocol

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Growth charts are important tools used to evaluate the growth status of children and estimate the nutritional and health status of the general population. In Korea, the national standardized growth charts were updated in 2017. However, the growth charts developed by the World Health Organization (WHO) are being adopted for children under 3 years of age despite a lack of evidence for their applicability to Koreans. Here we aimed to collect accurate physical measurement data, develop growth charts for infants and toddlers under 3 years of age based on breastfeeding, and evaluate the feasibility of adopting WHO growth standards as a reference in Korea. Beginning April 2020, 6 general and local hospitals were selected nationwide. Mothers and newborns without growth restriction-related factors were enrolled at birth, and they were followed up monthly until 12 months and every 3 months until 36 months. Data were collected on physical measurements; eating habits; childhood morbidity; perinatal factors; and socioeconomic, demographic, and environmental characteristics. All participating hospitals used the same standard equipment. The Korea Infant Physical Growth Examination Survey evaluated the suitability of the WHO growth charts and contributed to the next revision of the Korean growth charts. The results of this study provide a basis for developing health-related strategies for treating children in South Korea.

Key words: Growth charts, World Health Organization, Child

Key message

The suitability of World Health Organization (WHO) growth charts for assessing the growth of children under 3 years of age in all countries remains controversial, and their applicability must be evaluated based on country-specific growth data. The Korea Infant Physical Growth Examination Survey evaluated the suitability of WHO growth charts to contribute to the next revision of growth charts in Korea.

Introduction

Growth charts are important tools used to evaluate the growth status of children, including short stature, underweight, and obesity, and estimate the nutritional status and health level of the general population. In 2006, the World Health Organization (WHO) introduced growth charts for children based on length, height, weight, and age.¹⁾ Many countries have adopted the WHO growth charts for infants and children.²⁾ In 2013, 8 countries (Brazil, China, India, Italy, Kenya, Oman, the United Kingdom, and the United States) participated in establishing international standards for preterm birth and newborn weight, length, and head circumference by gestational age and sex.³⁾ In Korea, the most recent growth charts for children and adolescents were presented in 2017 using surveillance data from childcare facilities, schools, and hospitals nationwide.⁴⁾ However, no data exist for infants

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aged <36 months that could be used as standard values for breastfed infants, especially concerning standardized anthropometric measurements.

The WHO growth charts were introduced following their recommendations and have been used in Korea. According to a study reporting on Korea's National Health Screening Program for infants, height and weight measurements for infants under 1 year of age, especially those who were breastfed, significantly exceeded the WHO growth standards.⁵⁾ Although many reports from academic societies have concluded that the WHO growth standards have their own value,^{2,6-8)} it is unclear whether they can be used in other countries. The international charts used in the European study should be interpreted with caution because they classify children who are small for gestational age as appropriate for gestational age.⁹⁾ In addition, studies in Greenland and Turkey have indicated that WHO growth charts do not properly reflect the growth of children in those countries.^{10,11)} Therefore, the WHO growth charts should be evaluated based on the growth data of each country; however, there are no comparable data before 3 years of age in Korea. Few reports exist concerning the appropriateness of the WHO growth standards for children in East Asian countries.

This study aimed to collect accurate physical measurement data of infants and toddlers under 3 years of age who were raised in appropriate environments without factors that could interfere with their growth. By evaluating the suitability of the WHO growth charts, we aimed to develop growth charts for this target population. These charts served as national standards to ensure that they

accurately reflected the growth characteristics of Korean children.

Overview of study design

The Korea Infant Physical Growth Examination Survey (KIPGroS) is an ongoing prospective birth cohort study. Since April 2020, the Korea Centers for Disease Control and Prevention and Korean Pediatric Society have jointly promoted cohort studies. Six general and local hospitals were selected for the study. The participants underwent physical measurements, and various data were collected during outpatient visits (Fig. 1). A general hospital is a comprehensive medical institution, equivalent to a university hospital, that provides a wide range of specialized medical services. They also have advanced facilities and a large number of medical professionals. A local hospital is a community-based hospital that is typically small and provides essential medical services to the local population. Mothers and newborns were enrolled at birth and followed up beginning on the newborn's date of birth, monthly until 12 months, and every 3 months until 36 months. None of the participants had a history of growth restriction-related factors. Infants with a history of being twin birth, who were born preterm, who were classified as small or large for their gestational age, with poor Apgar scores, with a gestational age of <37 weeks or >42 weeks, with congenital anomalies or chromosomal disorders, with an inability to visit the designated medical institution, whose parents had difficulty speaking Korean, who were not covered by health insurance or did not receive medical aid, who found it challenging to breastfeed for >3 months, or who had difficulty starting complementary feeding within 6 months were excluded. Data were collected on physical measurements; eating habits; childhood morbidity; perinatal factors; and socioeconomic, demographic, and environmental characteristics. All of the participating hospitals used the same standard equipment (Supplementary material).

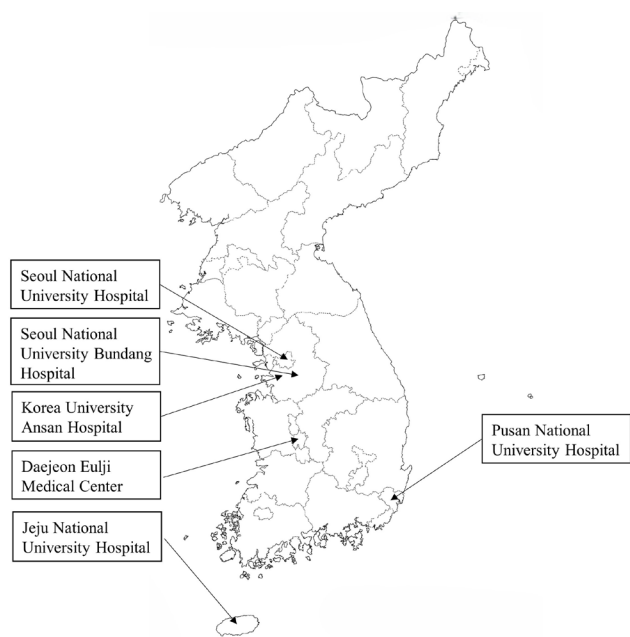


Fig. 1. Geographical distribution of KIPGroS in South Korea. KIPGroS, Korea Infant Physical Growth Examination Survey.

Eligibility criteria of study participants

The KIPGroS participants were infants born in Korea, followed up to age 3 years, and those whose parents agreed to participate based on the established methods of the WHO study.¹⁾

The inclusion criteria were as follows:

1. Singleton normal full-term delivery
 - Gestational weeks, 37–42
 - Appropriate for gestational age

- Absence of severe perinatal disease
2. No maternal smoking history during pregnancy
 3. No health, environmental, or economic constraints affecting infant growth
 4. Parental willingness to follow lactation recommendations

The exclusion criteria were as follows:

1. Refusal to consent to study within 8 weeks of age
2. No screening or anthropometric measurements performed within 24 hours after birth
3. Maternal history of gestational hypertension, preeclampsia, or gestational diabetes
4. Neonatal intensive care unit stay > 24 hours
 - Neonatal brain disease
 - Neonatal respiratory distress syndrome
 - Congenital malformation
 - Chromosomal disease (Down syndrome, Turner syndrome)
 - Evidence of intrauterine infection

Recruitment strategies

The KIPGroS was conducted in 5 metropolitan regions and 6 medical institutions. Recruitment began in April 2020 and continued until July 2022. Healthy infants born at the participating institutions to mothers who could breastfeed, control their diet, and regularly visit the outpatient clinic were recruited. Healthy infants born at external institutions were selected to expand the recruitment scope.

The participants were recruited using various methods. First, the participating doctors, who regularly visited the nursery rooms, promoted the study to the mothers. Second, promotional posters were displayed at obstetrics and gynecology outpatient clinics, and promotional materials were distributed. Third, a text message containing information about the cohort study was sent to all of the mothers of healthy newborns. Fourth, a promotional video for the KIPGroS was posted on YouTube and the infant physical growth measurement survey site. Fifth, the study information was posted in an online parenting community, commonly referred to as a “mom’s café,” where expecting mothers and mothers raising infants under 2 months of age share parenting information. Finally, study information brochures were sent to 39 public health centers to inform pregnant women about the KIPGroS.

Study population

An adequate number of participants must be obtained

to create new reference growth charts based on growth data of breastfeeding infants in South Korea. In the cohort data of the 2006 WHO growth charts, there were 1,746 participants across 6 countries (mean, 290 participants each).¹²⁾ The United States had the smallest number of participants among the 6 countries (n=208).¹³⁾ The percentage of children who completed the 24-month follow-up was 88.5% (mean, 257 children per country). Therefore, at least 250 participants completed the 24-month measurement period. Considering the general attrition rate of the infant cohort, at least 300 children were recruited for this study. The goal was to recruit at least 300 newborns for whom complete information was collected over 36 months.

Data collection and measurement protocols

The primary outcome of this study was the collection of anthropometric measurements from newborns. In the KIPGroS, demographic data (parents’ height, weight, address, educational status, birthplace, nationality, multicultural family status, current residence, household size, monthly income, and primary caregiver status), study participant information (sex, gestational week, Apgar score, birthdate, and birthplace), maternal pregnancy information (birthdate, pre-pregnancy weight, gravidity, parity, and medical history), anthropometric measurements (height, weight, head circumference, and waist circumference), and nutritional assessment (breastfeeding type and amount). Anthropometric measurements were performed on the date of birth and once every 1–2 weeks thereafter, every month until 12 months, and every 3 months until 36 months of age.⁴⁾ Body measurements were performed using standardized measurement equipment,¹⁴⁾ and values were entered into a case report form (<http://kipgros.pediatrics.or.kr>). When the actual age for measurement was later or earlier than the target age, the maximum number of tolerable days between the planned and actual measurements was determined (Table 1).

At each outpatient clinic visit, we assessed and recorded the feeding types from the available options (Table 2). Infants who were exclusively breastfed or primarily breastfed with an allowance for formula feeding (1–2 times) at night were classified into the exclusive breastfeeding group. Participants included in the breastfeeding performance analysis were those who were exclusively breastfed

Table 1. Maximum allowable days between measurement plan data and actual measurement date

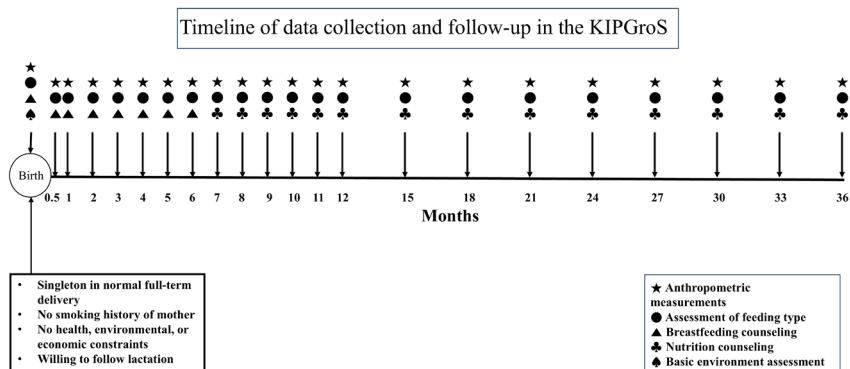
Age of subject	Maximum tolerable difference (day)
Before 1 month	±3
After 1 month	±7

Table 2. Breastfeeding types by age range

Age range	Breastfeeding types
Birth – less than 7 mo	Exclusive breastfeeding Predominant breastfeeding with nighttime formula feeding (1–2 times) Mixed feeding (formula ratio 30%–50%) Mixed feeding (formula ratio more than 50%) Formula feeding
7 Mo – 12 mo	Exclusive breastfeeding Mixed feeding (breastfeeding + formula feeding) Formula feeding
12 Mo – 36 mo	Exclusive breastfeeding Mixed feeding (breastfeeding + formula feeding) Formula feeding Weaned

Table 3. Timeline of data collection and participants' details by age

Age (mo)	0	0.5	1	2	3	4	5	6	7	8	9	10	11	12	15	18	21	24	27	30	33	36
Anthropometric measurements	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Assessment of feeding type	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Breastfeeding counseling	○	○	○	○	○	○	○	○														
Nutrition counseling									○	○	○	○	○	○	○	○	○	○	○	○	○	○
Basic environmental assessment	○																					

**Fig. 2.** Timeline of data collection and follow-up in the KIPGroS. KIPGroS, Korea Infant Physical Growth Examination Survey.

or primarily breastfed with nighttime formula feeding at 3 and 6 months and those who were breastfeeding at 12 months. Between birth and 6 months of age, breastfeeding counseling was provided; after 6 months, nutritional counseling was provided. Table 3 and Fig. 2 show the data collection timeline and survey details for the participants by age.

Ensuring data quality and reliability

The participants' data were entered into the case report form by the researcher and monitored periodically by the website administrators. Various quality assurance activities were conducted to ensure the consistency and reliability of the collected information. A measurement

and calibration workshop for all researchers is held once a year, while a measurement and calibration workshop for each institution is held once a quarter. The measured values were recorded and documented for each participant during the workshop. Additionally, a physical measurement checklist was distributed during the workshops at each hospital.¹⁵ The measurement equipment used for the data collection was the same at each institution.

Statistical analyses

The data were analyzed using IBM SPSS Statistics ver. 25.0 (IBM Co., Armonk, NY, USA). Normally distributed continuous variables (height-for-age, weight-for-age, head circumference-for-age, and body mass index) are expres-

sed as mean and standard deviation, while categorical variables are presented as number and percentage. Independent *t*-tests and Mann-Whitney tests were used to compare continuous variables, while the chi-square or Fisher exact test was used to examine categorical variables. Associations between variables were investigated using linear and logistic regression analyses. A Bland-Altman plot was used to evaluate the intra- and interobserver technical error measurements. In all analyses, statistical significance was assessed using a 95% confidence interval and 2-sided *P* values of <0.05.

Ethics and dissemination

The study protocol was approved by the Institutional Review Board (No. 2010-120-1166) of Seoul National University Hospital, Korea. Informed consent was obtained from the participants' parents during their first visit. The participants and their guardians were guaranteed the right to withdraw from the study at any time. Upon the withdrawal of consent, all data collected up to that point were destroyed. Only the researchers involved in this study had access to the data. The data were pseudonymized, and all analyses were performed under complete anonymization.

Critical importance of early childhood growth and nutrition

Infancy and early childhood are vital periods characterized by rapid growth and development that lay the foundation for an individual's lifelong health and well-being.^{16,17)} Proper nutrition is crucial during this period since it directly influences vital organ development, cognitive abilities, and overall physical growth.¹⁸⁾ Nutrition, which is important for brain development from conception to 3 years of age, is among the most important modifiable factors during the first 1,000 days of life.¹⁹⁻²¹⁾

Undernutrition during infancy independently affects cognitive and developmental abilities during childhood and adolescence. A prospective cohort study revealed that stunting by two or 3 years is significantly associated with cognitive deficits, poor academic performance, and increased school dropout rates, even after the adjustment for socioeconomic factors.²²⁾ This highlights the need to address nutritional requirements during this critical window to support optimal growth and development.

WHO growth standards and their global relevance

Established in 2006, the WHO Health Organization growth standards for children provide a global framework for monitoring growth and promoting prolonged breastfeeding.^{1,23)} These standards emphasize exclusive or predominant breastfeeding for at least 4 months, the introduction of complementary foods by 6 months, and continued breastfeeding until at least 12 months. Although these standards have been widely adopted, their applicability to diverse populations remains controversial. Studies in various countries have raised concerns that the WHO growth charts may not accurately reflect the growth of children in each country.^{10,11)} Consequently, it is essential to assess the suitability of these standards within the context of specific populations, such as breastfed infants in Korea.

Need for updated growth charts in Korea

In Korea, growth charts for children aged 3 years and older were revised in 2017, but the WHO growth standards continue to be used for children under 3 years because of a lack of country-specific data. This reliance highlights the urgent need for comprehensive growth data to develop national standards tailored to the Korean population for this particular demographic.

The KIPGroS addresses this gap by collecting detailed physical measurement data from infants and toddlers under 3 years of age who have been raised in appropriate environments. By evaluating the suitability of the WHO growth charts for Korean children, we aimed to provide evidence for the next revision of Korea's growth charts and contribute to public health policy formulation.

Addressing methodological challenges of KIPGroS

Cohort studies often face challenges such as participant withdrawal, which can affect data quality and reliability.²⁴⁾ To mitigate this, the KIPGroS study incorporated strategies to maintain engagement, including 6 breastfeeding consultations during the first 6 months, nutrition counseling from 7 months onward, transportation support, and incentives such as souvenirs for participants.

Selection bias is another potential limitation, as the participants were primarily recruited from 6 designated hospitals through the voluntary registration of pregnant women.²⁵⁾ To address this, we enrolled participants from diverse backgrounds and locations, including public health center promoters, local communities, and online

parenting forums.

Conclusion

The KIPGroS provides critical data on the growth patterns of Korean infants and toddlers under 3 years of age. By evaluating the suitability of the WHO growth charts, this study plays a pivotal role in informing the next revision of Korea's growth charts and ensuring that they accurately reflect the growth characteristics of Korean children.

In addition to revising growth standards, the findings of this study offer valuable insights for shaping public health policies, particularly those promoting breastfeeding and early nutritional interventions, to support healthy growth and prevent chronic diseases. By addressing these foundational aspects of child health, the KIPGroS contributes to the development of evidence-based strategies to enhance the well-being of future generations in South Korea.

Footnotes







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