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Research

Longitudinal Association Between Birth Weight, Birth Length, and Linear Growth in Early Childhood

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ABSTRACT

Background: Linear growth in early childhood is a vital indicator of health and largely determined by birth weight and length. The influence of birth size diminishes with age, yet the timing of this decline remains unclear in Indonesian children. This study aims to examine the influence of birth weight and birth length on linear growth among Indonesian children under five years of age and to determine the age at which these factors no longer play a significant role in body height.
Subjects and Method: A retrospective cohort design was used, including a total of 2,287 children aged 0–60 months in Kayong Regency, West Kalimantan, Indonesia, by the year 2023-2024. Birth weight and length data were collected retrospectively from Child Health Books, and height-for-age z score (HAZ) was measured at the time of the study descriptive statistics were used to summarize the basic characteristics of the cohort.
Results: The linear regression results demonstrated that both birth weight and birth length had a significant association with HAZ in 0-60 months of age. However, this association diminished markedly with age. The effect of birth weight and birth length on linear growth status (HAZ) is more objective statistical interpretation up to 30–36 months of age. These comparisons suggest that while the statistical influence of birth weight and birth length on HAZ diminishes around 30–36 months, the biological effects of early growth constraints may persist beyond this threshold, particularly in environments where nutritional recovery or healthcare access is limited.
Conclusion: The influence of birth anthropometric, particularly birth weight and birth length, on children's linear growth, measured by height-for-age Z-score (HAZ), is strongest during early life and gradually decreases with age.

Keywords: birth length, birth weight, catch-up growth, linear growth

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BACKGROUND

Linear growth in early childhood is a fundamental indicator of nutritional status and overall health, shaped largely by prenatal factors such as birth weight and birth length. Previous research has shown that birth length is a stronger determinant of subsequent height and stunting risk compared to birth weight, emphasizing the importance of intrauterine growth and underscoring its long-term influence on child development (Krebs et al., 2022). According to data from the Indonesian Ministry of Health in 2023, the prevalence of stunting in Indonesia has successfully decreased to 19.8%. This figure indicates a positive downward trend, although the World Health Organization (WHO) sets the ideal standard for stunting prevalence at below 20%. According to the Indonesian Nutritional Status Survey (SSGI), the national prevalence of low birth weight (LBW), defined as a birth weight of less than 2,500 grams, was 6.0%. Infants with low birth weight (LBW) have a 9.3 times higher risk of experiencing stunting compared to infants born with normal birth weight.

Although birth weight and birth length strongly influence linear growth in early life, evidence across diverse cohort studies shows that their effects progressively weaken as children age. Large, pooled analyses and longitudinal cohorts consistently demonstrate that the most substantial linear growth faltering and compensatory catch-up occur during the first two years of life, after which growth trajectories begin to stabilize and increasingly reflect genetic potential rather than prenatal size (Benjamin-Chung et al., 2023; Lourenço et al., 2023). Findings from population studies in Korea and Japan similarly indicate that differences in height by birth size gradually narrow by preschool age, though the degree and timing vary across populations (Yoon et al., 2021; Yamaguchi et al., 2025). An individual growth determined by individuals known and unknown that can be classify as genetic and environmental. These factors are heredity and environment. Environmental factors have significant role in altering growth and development, such as nutrition, illness, injuries, climate, social economic, exercise and secular trends.

It remains unclear at what age birth weight and length cease to have a significant influence on child height, particularly in the Indonesian context. Identifying this critical period is essential for guiding early growth monitoring and timely interventions. Therefore, this study aims to examine the influence of birth weight and birth length on linear growth among Indonesian children aged 0–5 years, and to determine the age at which these birth characteristics no longer significantly affect height.

SUBJECTS AND METHOD

1. Study Design

This study was a retrospective cohort design to evaluate the longitudinal association between birth anthropometry (exposure) and subsequent growth patterns in children aged 0–60 months (outcome). Data were collected at a single point in time, but historical records were utilized to establish the exposure status at birth and track the growth trajectory up to the time of measurement. The study was conducted in Kayong Regency, West Kalimantan, Indonesia, focusing on data collected in 2023-2024. This design is suitable for examining the hypothesis that the influence of prenatal factors (Birth Weight and Birth Length) diminishes over time on Height-for-Age Z-score (HAZ).

2. Population and Sample

The study cohort comprised 2,287 children aged 0 to 60 months and these data represent the total population.

3. Study Variables

The dependent variable studied was height-for-age Z-score (HAZ), and the independent variables were birth weight and birth length.

4. Operational Definition of Variables

Z-scores were measured at the time of the study: height-for-age Z-score (HAZ) as the primary outcome used to assess linear growth and test the main hypothesis.

The weight measured at birth were categorized as follows: Birth Weight was categorized as low birth weight (LBW, <2500 g), normal birth weight (NBW, reference), and high birth weight (HBW, >3,700 g).

Birth Length was categorized as short birth length (SB, <45 cm), Normal Birth Length (NBL, reference), and high Birth length (TB, >51 cm).

Child's Age was defined in months.

Gender was categorized as boy or girl.

5. Study Instruments

The required data were obtained by accessing historical documents: birth weight and birth length were collected retrospectively from the children's medical records or the Maternal and Child Health Book. The anthropometric measurements (weight and length/height) were obtained during the study period, alongside recorded age and gender. Anthropometric measurements were carried out by health workers (midwives, nurses, or doctors) assisted by community health workers.

6. Data Analysis

Descriptive statistics were used to summarize the basic characteristics of the cohort. "Lowess" command in Stata 14.0 was used to show the patterns of HAZ based on birth weight and birth length. The analysis involved multivariate linear regression where separate models were constructed for HAZ as the dependent variable. To rigorously test the hypothesis of a diminishing effect, the regression analysis was used to show the point when the birth weight or birth length significantly or insignificantly associated with height-for-age.

RESULTS

1. Sample Characteristics

Table 1 showed the basic characteristics of subjects, whenever boys showed characteristics similar to those of girls except in the proportion of short birth and the height-for-age z-score. The proportion of low birth length boys was larger than girls (10.0% vs 7.7%).

Table 1. Sample characteristics

Variables	Total (n=2,287)	Boys (n=1,168)	Girls (n=1,119)
Age in month (mean, SD)	26.4 (17.0)	25.8 (16.8)	21.7 (17.2)
Birth weight in kg (mean, SD)	3.0 (0.38)	3.04 (0.38)	2.96 (0.37)
Low birth weight (n, %)	96 (4.2)	41 (3.5)	55 (4.9)
High birth weight (n, %)	112 (4.9)	67 (5.7)	45 (4.0)
Birth length in cm (mean, SD)	48.4 (2.0)	48.6 (1.7)	48.2 (2.2)
Short stature at birth (n, %)	203 (8.9)	117 (10.0)	86 (7.7)

2. Multivariate analysis

Table 2 (2a and 2b) showed that birth weight (LBW/HBW) and birth length were significantly associated with their HAZ in 0-60 months of age (see Table 2a, 2b).

Table 2a. Multiple linear regression of HAZ based on birth weight

HAZ	b	95% CI		p
Child's age (month)	-0.01	-0.02	-0.01	0.012
Male	-0.14	-0.22	0.01	0.060
Birth weight (normal as ref.)	Ref.			
Low birth weight	-0.50	-0.70	-0.01	0.304
High birth weight	0.29	0.10	0.01	0.471
Adj. R^2	0.07 (7%)			

Table 2b. Multiple linear regression of HAZ based on birth length

HAZ	b	95% CI		p
Age (month)	-0.01	-0.02	-0.01	<0.001
Male	-0.13	-0.21	-0.05	0.002
Birth length (normal)	Ref.			
Short at birth	-0.31	-0.53	-0.08	0.009
Tall at birth	0.57	0.30	0.85	<0.00
Adj. R^2= 0.065 (6.5%)				

Low birth weight and high birth weight (or short at birth and tall at birth) showed catch-up or catch down phenomenon to reach the HAZ of normal birth weight/length subjects (see Figure 1).

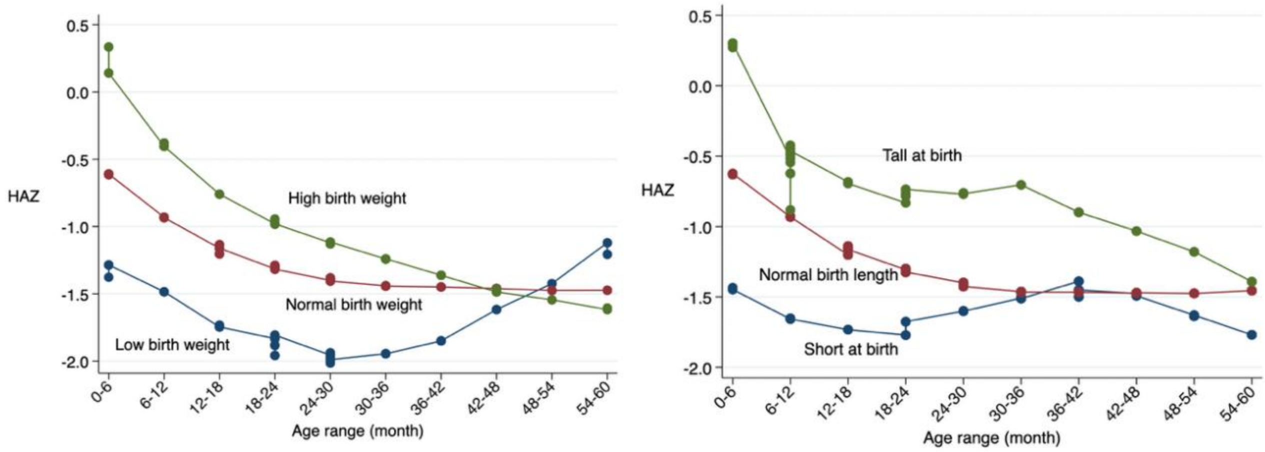

Figure 1. Growth trajectory of subjects based on birth weight and birth length groups

The linear regression results demonstrated that both BW and BL had a significant association with HAZ in early infancy. However, this association diminished markedly with age. The association of BW with HAZ became statistically non-significant after 36 months of age (see Table 3a, 3b).

Tabel 3a. Multiple linear regression of HAZ based on birth weight (<36 months of age)

HAZ	b	CI (95%)		p
Age (month)	-0.027	-0.032	-0.022	0.001
Sex (male)	-0.175	-0.274	-0.075	0.001
Birth weight (normal)	Ref.			
Low birth weight	-0.562	-0.794	-0.329	0.001
High birth weight	0.441	0.214	0.668	0.001
Adj. R^2 = 0.092 (9.2%)				

Tabel 3b. Multiple linear regression of HAZ based on birth weight (≥36 months of age)

HAZ	b	95% CI		p
Age (month)	0.01	-0.01	0.01	0.837
Sex (male)	-0.05	-0.18	0.09	0.495
Birth weight (normal)	Ref.			
Low birth weight	-0.20	-0.59	0.18	0.301
High birth weight	0.04	-0.27	0.35	0.821
Adj. R^2= 0.003 (0.3%)				

Similarly, the association of BL with HAZ became statistically non-significant after 30 months of age (see Table 4a, 4b). Beyond these cut-off ages, birth anthropometry emerged as the non-significant predictors of HAZ, supporting the hypothesis of deceleration or acceleration to target height.

Tabel 4a. Multiple linear regression of HAZ based on birth length (<30 months of age)

HAZ	b	95% CI		p
Age (month)	-0.04	-0.04	-0.03	0.001
Sex (male)	-0.14	-0.25	-0.03	0.010
Birth length (normal)	Ref.			
Short at birth	-0.60	-0.93	-0.26	0.001
Tall at birth	0.53	0.21	0.86	0.001
Adj. R^2= 0.107 (10.7%)				

Tabel 4b. Multiple linear regression of HAZ based on birth length (≥30 months of age)

HAZ	b	95% CI		p
Age (month)	-0.01	-0.01	0.01	0.246
Sex (male)	-0.09	-0.21	0.03	0.134
Birth length (normal)	Ref.			
Short at birth	-0.03	-0.33	0.27	0.839
Tall at birth	0.40	-0.10	0.89	0.115
Adj. R^2= 0.002 (0.02%)				

The coefficient regression of low birth weight was larger than short at birth to HAZ in 0-60 months of age subjects (-0.504 vs -0.305), otherwise both were almost similar in early infancy subjects (<30-36 months of age) (-0.562 vs -0.596). These results were identical in the regression of the coefficients of birth weight, height, and birth height against HAZ.

DISCUSSION

The primary objective of this study was to determine the age at which the influence of birth anthropometry—specifically birth weight (BW) and birth length (BL)—on height-for-age Z-score (HAZ) becomes statistically non-significant in children aged 0–60 months. Our multivariate linear regression models revealed a critical transition period: the association between BW and HAZ was not significant after 36 months, while the influence of BL diminished earlier (non-significant after 30 months). These findings indicate that the effects of intrauterine growth, reflected by BW and BL, are strongest during infancy, before gradually attenuating with age. This pattern aligns with large-scale evidence from the K1 Child Growth Consortium, which reported that the onset and most rapid progression of linear growth faltering occur between birth and 24 months, underscoring the dominant role of prenatal and early-life factors during this period (Benjamin-Chung et al., 2023). Similarly, the Women First trial demonstrated that birth length is the strongest predictor of height and stunting status up to approximately 24 months of age, after which its influence markedly weakens (Krebs et al., 2022). Together, these findings support the notion that birth size exerts its appears to exert during the first two years of life, corresponding to the critical window for growth monitoring. Government intervention to reduce the number of stunted growth in children due to chronic malnutrition, which focuses on the First 1,000 Days of Life (HPK)—from pregnancy to the age of 2, with the main program of providing supplementary food and contraception programs. The Indonesian government also organizes integrated health service posts (*Posyandu*) activities for regular growth measurement.

However, data from longer follow-up studies suggest that the effects of birth size, although reduced, may persist into later childhood. The MINA-Brazil Study found a consistent tracking pattern between birth size and child height up to age five, indicating that early growth deficits can have residual effects (Lourenço et al., 2023). Likewise, the nationwide Korean cohort observed partial catch-up growth among low-birth-weight infants, but differences in height compared to normal-birth-weight peers often remained detectable until 60 months (Yoon et al., 2021). In the context of our findings, these comparisons suggest that while the statistical influence of BW and BL on HAZ diminishes around 30–36 months, the enviromental effects of early growth constraints may persist beyond this threshold, particularly in environments where nutritional recovery or healthcare access is limited. Our study showed that although not-significant of HAZ among LBW, NBW, and HBW, the means of HAZ among those groups were -1.68, -1.48, and -1.45 SDs. also in SB, NBL, and TB, we found similar results (-1.46 vs -1.46vs -1.07).

The observed cessation of a significant influence of BW and BL on HAZ by 30–36 months is biologically meaningful and can be explained through two interconnected mechanisms: catch-up growth (CUG) and canalization or deceleration toward target height. The early and significant association between extreme birth sizes and HAZ reflects the initial deviation in growth potential caused by intrauterine growth restriction or macrosomia. The subsequent attenuation of this association suggests that most infants, particularly those born small-for-gestational-age (SGA) and receiving adequate postnatal care and nutrition, successfully undergo CUG and shift their growth trajectory toward their genetic potential (Leroy et al., 2020; Sinha et al., 2022). The cut-off age of 30–36 months observed in this study aligns with pediatric endocrinology principles indicating that the majority of CUG is typically completed between two and four years of age. Following this phase, children generally enter a period of canalization, during which growth velocity slows and stabilizes along genetically determined percentiles, representing a biological adjustment toward their inherent growth channel (Eymann et al., 2023).

Our findings also align with broader population-level evidence showing that the most substantial deviation in linear growth occurs within the first two years of life, after which growth trajectories tend to stabilize (Benjamin-Chung et al., 2023; Putri et al., 2023). Furthermore, these results support the classical concept of regression to the mean, whereby extreme anthropometric measures in early life tend to shift toward the population or genetic average over time. Once the rapid, energy- and hormone-driven CUG phase concludes—around 30–36 months—height becomes predominantly influenced by genetic and environmental factors, such as parental stature and nutrition, rather than prenatal anthropometry. This developmental transition explains why the effects of BW and BL, although initially strong, become statistically and biologically less relevant as the child progresses into later preschool years.

Across all birth-size categories, children exhibit differing rates of HAZ deceleration—slower in those born LBW or short, and faster in those born HBW or tall—yet the overall pattern reflects a universal process of canalization in which growth trajectories gradually converge toward genetically determined potential. Evidence from large cohort studies reinforces this mechanism: the Women First trial showed that the influence of birth length on linear growth is strongest in the first two years before diminishing, and the Hokkaido Birth Cohort found that children born with low birth weight continue adaptive catch-up until school age, supporting progressive regression to the mean (Krebs et al., 2022; Poudel et al., 2024). The identified ages of 30–36 months mark a clinically important transition, as birth weight and length still exert substantial influence during this window, particularly in high-stunting settings, while children who do not achieve sufficient catch-up—such as those born SGA—remain at elevated risk. Consistent with this, the MAL-ED study demonstrated that further gains in linear growth remain possible between 24 and 60 months even as the influence of birth size wanes (Richard et al., 2021). After approximately 36 months, however, established height deficits become increasingly resistant to reversal, and the predictive power of birth anthropometry declines, shifting clinical and public health focus toward postnatal determinants including infection burden, dietary quality, and assessment of genetic growth potential.

The 30–36-month period represents the stage at which the influence of birth weight and length has largely waned and genetically driven growth predominates, making deviations in HAZ trajectories after this period increasingly interpretable as pathological rather than physiological. Because infants born very small or very large often display atypical yet normal growth dynamics, reliance on standard WHO charts may misclassify healthy catch-up or deceleration as growth faltering, particularly when short-at-birth infants maintain appropriate velocity despite remaining below conventional centile channels. This supports the need for growth references tailored to LBW/HBW and short/tall-at-birth cohorts during the active catch-up and canalization phase up to 30–36 months, a strategy reinforced by recent work such as the Japanese birth-weight–stratified standards that allow more precise identification of true catch-up failure (Yamaguchi et al., 2025). Beyond roughly 36–48 months, when prenatal effects have dissipated and growth stabilizes under genetic and environmental regulation, standard WHO charts can again serve as an appropriate reference with thoughtful clinical interpretation.

A significant strength of this study is its retrospective cohort design, which allowed for the establishment of a clear temporal relationship between the exposure (birth size) and the outcome (HAZ) across the critical 0–6-month period, more improves temporal inference than standard cross-sectional studies. Furthermore, the large sample size enhances the generalizability of the findings within the local Indonesian context.

However, studying is not without limitations. The retrospective collection of birth data from maternal and child health books *"Buku KIA"* may introduce recall bias or minor measurement errors for birth size. Crucially, the absence of parental height data (genetic potential) prevented us from directly quantifying the degree of regression to the mean against the true target height, which is a major determinant of final adult height. Future studies should incorporate parental height to solidify the finding that genetic factors take over as the dominant growth driver after 30-36 months. Wider and spreader subjects are needed for further study as Indonesia has more diverse population and archipelago.

The effect of birth weight and birth length on linear growth status (HAZ) in the Kayong cohort is profoundly strong up to 30–36 months of age. After this period, the prenatal influence fades, suggesting successful catch-down/catch-up growth in the majority of the population and the subsequent dominance of genetic factors. The age of 30-36 months represents a critical window for managing children with growth failure, as prenatal anthropometry loses its predictive power thereafter. These findings have important public health implications, supporting the implementation of early screening and preventive interventions to promote optimal child growth and development at the population level. From a clinical perspective, the findings highlight the importance of regular growth surveillance and developmental monitoring to facilitate early identification and management of at-risk children.

AUTHOR CONTRIBUTION

Author 1 collected data, conceived and designed the study, developed the methodology, analyzed the data, and prepared the first draft of the manuscript. Author 2 conducted experiments, curated the data, and contributed to manuscript revisions. Author 3 developed the software and generated visualizations. Author 4 supervised the project and critically reviewed and edited the manuscript. All authors read and approved of the final manuscript.

CONFLICT OF INTEREST

There is no conflict of interest.

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