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The Consecutive 3-month Length Increment to Predict Early Linear Growth Failure

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Abstract

AIM: This study aimed to assess the consecutive 3-month length increment thresholds, by the first 6 months, to predict stunted at the age of 6 months.

METHODS: We analyzed data from the Bogor Longitudinal Study on Child Growth and Development in West Java, Indonesia. A total of 635 free of stunting at birth children were analyzed in this study. Early linear growth faltering, as the dependent variable, was the stunted at 6 months of age. The four thresholds of the consecutive 3-month length increment were considered in predicting stunted at the age of 6 months. The thresholds were a consecutive 3-month length increment below 25th percentile, 15th percentile, and 5th percentile of the WHO Child Growth Velocity Standard. The 4th threshold was generated from the Bogor Longitudinal Study sample and determined using receiver operating characteristic analysis. The sensitivity, specificity, PPV, and NPV of the thresholds were calculated.

RESULTS: Among the thresholds, the 25th percentile of the WHO Child Growth Velocity Standard generates the highest sensitivity. The ability of the 25th percentile threshold to correctly identify children who had stunting at 6 months of age is 56.7%. However, the children whose experience a consecutive 3-month length increment below 15th percentile had highest risk to become stunted at the age of 6 months, adjusted by sex, birthweight, and birth length.

CONCLUSION: A consecutive 3-month length increment could be beneficial as a tool in identifying infants at high risk of early linear growth failure in stunted prevalent population.

Introduction

In 2020, globally, 22% or 149.2 million children under 5 were stunting and fail to achieve their linear growth potential [1]. Stunted has been shown to have long-term and intergenerational consequences [2], [3], [4], [5]. However, the consequence of stunting, such as deterioration in motor and cognitive development, could also be suffered before the growth failure falling below a specific cutoff [6]. Nutrient deficiency in early childhood could lead to linear growth failure simultaneously with deficits in brain development [7].

Linear growth failure was generally identified by measuring the attained length by age and plotted on the growth chart and compare the points with the z-scores lines [8], or comparing the child’s height for age z-scores (HAZs) with linear growth standard. However, the linear growth dynamic is complex, therefore, it requires sensitive indicators to identify early linear growth faltering before it falling into stunted [9]. Few studies proposed that growth velocity can recognize growth faltering earlier than the attained growth. The studies pointed out that the growth influencing factor directly affected growth velocity, whereas its impact on attained growth can only be identified after the growth faltering has manifested [9], [10]. The study suggested that the use of a reference table of length increment was a sensitive method recommended for evaluating the growth progress of infants suspected at high risk to have linear growth failure [10].

Few studies have estimated the ability of anthropometric measurement or longitudinal growth in early life to detect linear growth faltering or to predict stunting. A study in Guatemala showed that length indicators were superior to weight indicators in predicting stunting at 3 years of age in stunted population; nonetheless, the velocities were worse than attained growth [11]. A cohort study in Nepal showed that growth velocity z-scores significantly predicted stunting at age 2 years, even though attained growth showed a superior prediction. However, the study pointed out that the growth velocities provide a significant benefit over attained growth that it is better predicts short-term outcomes or consequences since it represents the present risk profile [12]. Length velocity depicts current growth, whereas the attained growth depicts what has happened in the past or is a result of the growth velocity [13].

Attained lengths in a consecutive measurement are highly correlated. A child who is stunted in a visit is likely to remain stunted in the next visit. Unlike attained length, in healthy and normally growing children, the correlation between two consecutive length increments or velocities is generally low. Therefore, a single low value of length increment or velocity is uninformative. Only when the velocities are repeatedly low, may they be considered alarming [14]. A study proposed the use of two consecutive increments thresholds as an approach to screen for linear growth faltering [15]. The study selected 2 consecutive monthly increments below the 15^{th} percentile as the screening criterion of linear growth faltering. Few studies proposed 25^{th} percentiles as cutoff in predicting the risk of growth faltering [16], [17]. Other authors pointed out that grow velocity below the 5^{th} percentile is defined as growth deceleration [18].

Studying velocity is important, especially in the 1^{st} year of life, to identify the critical period for prevention or early intervention of early growth faltering. Very few studies have proposed the approach of using successive 3-month length increment to predict the early linear growth failure. We, therefore, aimed to assess the 3-month length increment thresholds, by the first 6 months, to predict stunted at the age of 6 months.

Methods

Study design and participants

The Bogor Longitudinal Study on Child Growth and Development (BLSCGD) was a prospective cohort study. Pregnant women from five villages in Bogor Tengah subdistrict, Bogor City, West Java, Indonesia, were enrolled since 2012 and it is still ongoing. They were followed up during pregnancy and all the eligible infants were followed up after delivery and are planned until 18 years of age. This study analyzed a total of 635 children born in 2012–2017. Premature children, twins, stunting at birth children, and children with incomplete length measurements at the age of 3 and 6 month were excluded from the study.

Study variables

Child length was measured monthly and mothers were interviewed for food intake, immunization, morbidity, child growth monitoring, breastfeeding practice, health care and feeding practices, and health-seeking behavior. The trained field assistants measured child recumbent height to the nearest 0.1 cm using a multifunction length board. The information about immunization, morbidity, child growth monitoring, breastfeeding practice, health care, and feeding practices, and health-seeking behavior were collected using a structured questionnaire. Birthweight and length were obtained from the records of health workers who assist the delivery and measured within 24 h after delivery.

Early linear growth failure, as the dependent variable, was stunted at age 6 months. Stunted was defined as length-for-age Z-score (LAZs) <−2 SD. The LAZs were calculated using the WHO Anthro software. Length increments, as the independent variable, were described as a 3-month length increment (cm), conditional on age and sex. The 3-month age intervals were 0–3 months and 3–6 months.

Statistical analysis

The monthly follow-up of the eligible children was planned for the same date of each month. However, in practice, the actual ages at which the measurements were taken are sometimes ahead of or below the target ages. The target ages in this analysis were 0, 30, and 60 days. Therefore, in the purposes of the 3-month length increment analysis, the actual measurement age was corrected to the target age using the maximum tolerable difference according to the correction procedures in the construction of the WHO child growth velocity standard, that is, ± 3 days for children aged 0−6 months, ± 5 days for children aged 6−12 months, and ± 7 days for children aged 12−24 months [14]. We estimated the length measurements corresponding to target age by conducted the linear interpolation if the absolute difference between the actual measurement age and the target age was bigger, but not more than 15 days, than the tolerable difference.

The approach in predicting stunted at 6 months of age was using the consecutive 3-month length increment, by the first 6 months, in four specified thresholds. The thresholds were consecutive 3-month length increment below 25^{th} percentile, 15^{th} percentile, and 5^{th} percentile of the WHO child growth velocity standard. The 4^{th} threshold was generated from the Bogor Longitudinal Study Sample and determined using the receiver operating characteristic (ROC) analysis. The area under curve (AUC) was also measured to summarize the overall diagnostic accuracy of the test [19]. The sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV) of the thresholds were also calculated.

A variable indicates that the child experienced a consecutive 3-month length increment below the threshold was created (categorized as “occurred” and “not occurred”), to examine the association of experienced the length increments below specified threshold at 0–6 months to stunted at the age of 6 months. The relative risk and 95% confidence interval were calculated using Cox regression. The general characteristics of the participants were presented in percentages. All data analyses were performed using IBM SPSS V21.0.

Ethical consideration

The study protocol was approved by the Ethics Committee of the National Institutes of Health Research and Development, Ministry of Health, Indonesia (No.LB.02.01/2/KE.221/2020). Written informed consent was obtained from all participants of the Bogor Longitudinal Study on Child Growth and Development. Informed consent was confirmed by the Ethics Committee of the National Institutes of Health Research and Development.

Results

The characteristics of the 635 participants are summarized in Table 1. The number of boys was slightly fewer than girls. The education of the parents was mostly high school and above. Most of the boys and girls had birthweight 3000 g and above, and birth length 48 cm and above. The prevalence of stunted increased from 10.7% at the age of 3 months to 20.4% at 6 months of age.

Table 1: Characteristics of the participants

Variables	n	%
Gender (boy)	388	48.2
Birthweight		
<−1 SD	97	15.3
≥−1 SD	538	84.7
Birth length		
<−1 SD	52	8.2
≥−1 SD	583	91.8
Prevalence of stunted at 3 months	65	10.7
Prevalence of stunted at 6 months	138	20.4

ROC curve analysis of the threshold found in this cohort (4th threshold) is summarized in Table 2 and Figure 1. The results of the AUC analysis in boys and girls in all age intervals were significantly different from what was expected by chance ($p < 0.001$).

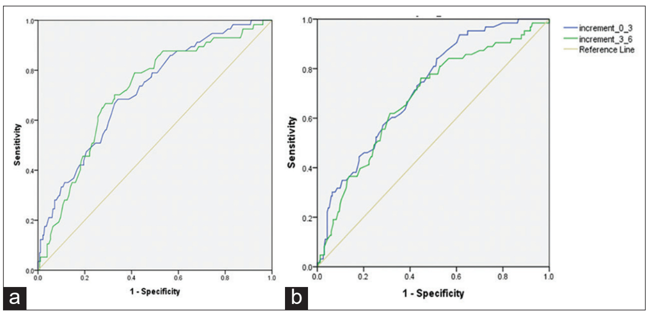

Figure 1: The ROC curve of 3-month length increment (4th threshold) in predicting stunted at the age of 6 months. (a) Girls, (b) Boys

Most of the AUC values were acceptable. The cutoff points of the 3-month length increment found in this longitudinal study were determined as the intersection

Table 2: The area under curve (AUC) of the 3-month increment to predict stunted at the age of 6 months (generated from the BLSCGD sample)

Age interval	Boys			Girls		
(month)	AUC	95% CI	p	AUC	95% CI	p
0–3	0.721	(0.655–0.787)	<0.001	0.715	(0.645–0.786)	<0.001
3–6	0.679	(0.605–0.754)	<0.001	0.713	(0.641–0.784)	<0.001

of the curve for sensitivity and specificity. Between 0 and 3 months, the cutoff points of length velocity in predicting the incidence of stunted were 10.3 cm for boys and 8.8 cm for girls. Between 3 and 6 months, the cutoff points were 4.7 cm for boys and 4.3 cm for girls (Table 3).

Table 3 shows sensitivities, specificities, positive predictive value (PPV), and negative predictive value (NPV) of the thresholds. Among the thresholds, the 25th percentile generates the highest sensitivity. The ability of 25th percentile threshold to correctly identify children who had stunting at 6 months of age is 56.7%. However, the children whose experience a consecutive 3-month length increment below 15th percentile had highest risk to become stunted at the age of 6 months, adjusted by sex, birthweight, and birth length. Children experienced a consecutive 3-month length increment below 15th percentile had risk 5 times higher to become stunted at the age of 6 months, adjusted by sex, birthweight, and birth length (Table 4).

Discussion

The unrecognized slow rate of gain in a child's length or height often goes to stunted. The ROC

Table 3: The sensitivities, specificities, positive predictive value, and negative predictive value of the thresholds* in predicting stunted at 6 months of age

Thresholds	Length increment cut-off (cm)	Sensitivity (%)	Specificity (%)	Positive PV (%)	Negative PV (%)
25th percentile WHO					
Boys					
0–3	10.6	56.7	84.3	45.6	89.3
3–6	5.5				
Girls					
0–3	9.8				
3–6	5.2				
15th percentile WHO					
Boys					
0–3	10.1	44.2	91.4	54.6	87.5
3–6	5.1				
Girls					
0–3	9.3				
3–6	4.9				
5th percentile WHO					
Boys					
0–3	9.3	19.2	98.3	71.9	83.9
3–6	4.4				
Girls					
0–3	8.6				
3–6	4.2				
BLSCGD**					
Boys					
0–3	10.3	32.5	95.4	61.9	85.8
3–6	4.7				
Girls					
0–3	8.8				
3–6	4.3				

*The 3-month consecutive length increment, **The Bogor Longitudinal Study on Child Growth and Development.

curve analysis showed that 4th threshold generated from the Bogor Longitudinal Study had a good discriminating ability to predict stunted at the age of 6 months ($p < 0.0001$). Not in line with our finding, a study in Guatemala showed that the length velocity performed a poor discriminating ability in predicting stunting at 3 years of age [11]. This may be due to the ability of length velocity better predict the short-term consequences [12], while the study in Guatemala estimated the ability of length velocity at 3−6 months on distinguished the stunting status at the age of 3 years. The growth velocity represents the picture of current growth or represents what is happening currently [20], [21]. The longer the growth velocity period, the less related it was for the targeted nutritional status or attained growth.

Table 4: Association between the occurrence of a consecutive 3-month length increment below the thresholds and stunted at 6 months of age

The occurrence of a consecutive 3-month length increments below the thresholds	RR (95% CI)*	p value
The 25th percentile		
Occurred	4.6 (3.2−6.7)	<0.001
The 15th percentile		
Occurred	5.0 (3.4−7.2)	<0.001
The 5th percentile		
Occurred	4.8 (3.1−7.7)	<0.001
The BLSCGD		
Occurred	4.6 (3.1−6.7)	<0.001

*Adjusted by sex, birthweight, and birth length.

Analysis showed that the sensitivity of the 4th threshold generated from the Bogor Longitudinal Study was lower than the 25th percentile threshold. Nevertheless, the percentage of children experienced a consecutive 3-month length increment below the 4th threshold, who actually become stunted (PPV) at 6 months of age is 61,9%, higher than 25th percentile and 15th percentile threshold but lower than the 5th percentile. However, the thresholds were used in a population with a high prevalence of stunting. The prevalence of stunted in children under 2 years of age in Indonesia in 2018 was 29,9% [22]. It is likely that the PPV or NPV found using the thresholds would be different in other population. The PPV and NPV were associated with the prevalence of stunting in the population. Assuming all factors remain constant, the increase of the stunting prevalence will increase the PPV and decrease the NPV [23].

The commitment in stunting reduction highlights the importance of early identification of children at risk on linear growth faltering. This study showed that a consecutive 3-month length increment could be beneficial to predict infants who are at risk of early linear growth failure in stunted population. Detecting changes in length velocity can be used as an approach in identifying critical timing for stunting prevention program. The length velocity is beneficial in determining appropriate time to start the intervention. However, length velocity must also be interpreted together with attained length to examine the effectiveness of the intervention [18].

Length velocity assessment, however, requires the availability of an accurate length board in the health center. It needs repeated measurement by a competent staff, and it is more complex to be implemented than the use of attained growth. Further investigation was needed to investigate a feasible approach to predict long-term linear growth failure in the community using length increment or length velocity approach. Despite the unpracticality of the length velocity measurement, it is important to monitor infant linear growth at least 3 monthly, especially in the first 6 months of life when the postnatal most rapid velocity of growth occurred. Infancy is still a vital phase for avoiding major growth deficits later in life. We also suggested that infants should be enrolled in the growth monitoring program soon after birth or no later than 1 month. Infant's length, as well as infant's weight, should be monitored periodically.

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