Risk Factors for Rapid Growth in Undernourished Children: Analysis of Indonesian Family Life Survey

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ABSTRACT

Background. Children who suffer from undernutrition would grow rapidly to catch-up-growth after improvement in nutrition intake. However, this rapid growth during early life might have harmful effects on children's long-term health. Rapid growth, which is too fast, increases the risk of cardiovascular disease and obesity.

Objective. To determine the prevalence and analyze the risk of rapid growth in children, particularly who experienced undernutrition in 1000 first days of life, compared to well-nourished children.

Methods. This cohort study used data from the second and third waves of the Indonesia Family Life Survey (1997 and 2000). A total of 671 children aged 0 to 23 months in 1997 and 3 to 5 years in 2000 were included in this study. Rapid growth was determined as a change in length- or height-per-age and weight-per-age z-score greater than 0.67, based on WHO Child Growth Standard between years of follow-up. The anthropometric measurements were conducted by trained health workers. Children with history of low birth weight, stunting, underweight, and/or wasting were categorized as undernourished children. We used a logistic regression model to identify the risk of rapid growth in children among undernourished and well-nourished children, adjusted by characteristics of children, parents, and the household socioeconomic status.

Results. The prevalence of rapid growth in length/height and weight in undernourished children was 44.56% and 35.2%, respectively. The odds of undernourished children to grow rapidly in length/height compared to well-nourished children was 6.36 (95% CI 3.94,10.26; $p = 0.000$) after being controlled by socio-demographic characteristics. There was a higher odd 5.7 (95% CI 3.4, 9.5; $p = 0.000$) of rapid growth in weight in undernourished children. The odds of rapid growth in height increased significantly in children aged 12 to 23 months and children with mothers who had lower education levels. Furthermore, the odds of rapid growth in weight-for-age increased significantly in all children whose fathers had lower education levels.

Conclusion. This study adds to the evidence that there is an increased risk for rapid growth in length/height and weight in undernourished children and the risk was higher among older children aged 12 to 23 months. The study also found that maternal education was related to the risk of rapid growth in height and paternal education was strongly related to the risk for rapid growth in weight.

Keywords: rapid growth, undernourished children, early life, cohort study

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INTRODUCTION

Growth is defined as increasing body size determined by genetic, hormonal, and environmental factors. Growth is an excellent indicator of a child's health and living conditions that should be monitored to ensure that the child has optimum growth.[1,2] Poor child growth or undernutrition in early life has been correlated with adverse health effects in later life. Therefore, recovery from undernutrition and prevention of growth faltering has been set as priorities. However, some evidence show that too fast growth or rapid growth in early life has detrimental effects on health in later life, increasing the risk of obesity and cardiovascular disease (CVD), high blood pressure, and cancer.[1–4]

The first concept of rapid growth was defined as acceleration in growth in response to recovery from a period of growth restriction, illness, or starvation. This growth pattern appears to reduce morbidity and mortality for undernourished children, improve cognitive function and neurodevelopment.[1,3,5] To achieve the normal size, children who experienced undernutrition in early life grew rapidly because of their retarded growth. Several studies have shown the prevalence of rapid growth in children with low birth weight, small for gestational age (SGA), and stunting. However, rapid growth has also happened in children with normal birth weight or at term appropriate for gestational age (AGA).[3,6–8]

Several studies have shown that rapid growth in weight or length in early life is a risk factor for obesity and cardiometabolic syndrome. A study from the Hong Kong Birth cohort showed that the higher weight gain, body mass index, and length z-score from birth to 8 years were associated with higher blood pressure and body fat at 17.5 years. A cohort study in Singapore suggested that children with fetal growth deceleration followed by rapid postnatal weight gain from birth to 2 years were associated with elevated blood pressure and insulin resistance in childhood. In children with AGA, rapid growth in infancy and early childhood increased the Body Mass Index (BMI), percentage of body fat and risk of overweight at age seven years. [2,3,9]

Rapid growth has a positive outcome on cognitive function in the short term but might increase the risk of overnutrition and chronic disease in later life. It occurs in children with undernutrition–low birth weight, SGA, stunting, and underweight–and in children born at term and have normal birth weight. Therefore, to prevent the adverse effect of rapid growth in later life, it is important to know the risk factors for rapid growth in weight and length in children during early life. Although a study that analyzed the predictive factors of rapid growth in early life was limited, this study examined the significant risk factors of rapid growth related to children's characteristics, including parents and household socioeconomic conditions particularly comparing undernourished children and normal group.

METHODS

This study used longitudinal data from the Indonesia Family Life Survey (IFLS) that collected samples in 13 out of 27 provinces in Indonesia. Families were selected from 4 provinces in Sumatra, 5 in Java, and the rest, 4 from Bali, Nusa Tenggara Barat, South Kalimantan and Sulawesi, using stratified random sampling based on the residential area. We used data from the second wave of IFLS in 1997 and the third wave in 2000. IFLS provides data on individual and household levels, including health and socioeconomics; one focus of IFLS is infant and children health.

The study design was an observational cohort from 1997 to 2000. The study population was households or families with children under two years or aged 0 to 23 months in 1997, and followed until the age of 3 to 5 years in 2000. The singleton children with complete anthropometric measurements data were included as samples. On the other hand, children who were premature or born with SGA condition and children with the extreme value of standard deviation score in anthropometric indicators were excluded from the study. From a total of 1215 households with children under2-years of age available in 1997,671 children were included in this study. The questionnaires of IFLS consist of individual, household and community books followed by anthropometric and health measurements. Data were collected using direct interviews for adults and proxy interviews for children and infants. In addition, data were merged from several questionnaires. The study protocol was approved by the Institutional Review Board, Universitas Indonesia No.: Ket_464/UN2.F10.D11/ PPM.00.02/2021.

We followed the children aged 0 to 23 months from baseline in 1997 until 3 to 5 years of age in 2000. Children's data included in this study were birth dates, survey dates, age group, sex, birth weight, length or height, weight, and exclusive breastfeeding experience. For parents' data, we collected the mother's height, weight, and parents' education level. Additionally, household data included total assets, household income, and housing area. All parents' and household characteristics were taken at baseline in 1997. As a result, the IFLS had a high response rate in every wave; 91% at the individual level and 94% at the household level.

We defined children age based on birth date and survey date. The age group was categorized as follows; 0 to 5 months, 6 to 11 months and 12 to 23 months. In the multivariate model, we divided the age group into two categories; below 12 months and 12 to 23 months. Birth weight was categorized as normal birth weight (>3 kg) and low birth weight (≤3 kg). Children with birth weights lower than 3 kg had an increased risk of the cardiometabolic syndrome in later life.[10] The trained nurse performed anthropometric and health measurements, and the same methods were applied in every survey wave. Length or height was measured using Shorr measuring boards, and children's weight was measured using Seca Floor Model Scales.

Anthropometric data was converted into age-gender-specific z-score using WHO Anthro software, based on WHO Child Growth Standard. Children's length/height measurements were converted into height- or length-per-age z-score (HAZ) and weight measurements into weight-per-age z-score (WAZ). Moreover, children's weight-per-height/length was converted into a weight-per-height z-score (WHZ). Furthermore, stunting was defined as HAZ score < -2SD, underweight as WAZ score < -2SD and wasting as WHZ score < -2SD. Rapid growth was defined as an increase or change of HAZ and WAZ from 1997 (children aged 0 to 23 months) to 2000 (children aged 3 to 5 years) by more than 0.67 units; equal to one unit major centile band in SD Score. This cut-off point has been used in some studies of rapid growth in weight, body mass index (BMI) and length/height incorporating the Asian population as study samples.[8,9,11] Finally, we grouped children in 1997 into normal and undernourished children. The latter was defined as children with history of low birth weight, stunting, underweight, and wasting; whether just one or a combination.

The mother's and father's education levels were grouped into two categories: attended school less than nine years and attended school at least nine years or above. We classified total assets based on the median value, divided into a group of below and above median value. Household income was divided into groups with lower than minimum regional wages and the others with more than minimum wages. Residential area was grouped as urban and rural areas.

Sample characteristics were tabulated to describe the distribution, by frequency and percentages of the total sample for categorical variables, and by mean with standard deviation or median and range after normality test for numeric variables. We performed bivariate analysis using the chi-square test, the t-test for bivariate analysis, and multiple logistic regression for multivariate analysis to find the most correlated risk factor for rapid growth in height and weight. Rapid growth is presented with an odds Ratio and 95% CI with a p-value <0.05 considered significant. We analyzed the data using STATA software version 15.

RESULTS

Half of the children aged 12 to23 months were female, but the sex ratio was nearly equal (Table 1). More than 20% of the children had birth weights lower than 3 kg, and the most prevalent cause of undernutrition was stunting, occurring in 39% of the children. More than half of them had experienced undernutrition during the first 1000 days of life. Most children were not exclusively breastfed. Mother's height was normally distributed, with the mean mother's height of 150 cm, which was above the cut-off point for short maternal stature. The lowest height of the mothers was 134.7 cm, which was considered short. Mother's weight was not normally distributed, (median, 47.8 kg; range, 24 to 89.2). Mothers commonly had lower education levels (attended

Table 1. Characteristics of Study Participants

Variables	N	%
Child Characteristics		
Age Group (671) (in months)		
0–5	181	26.97
6–11	152	22.65
12–23	338	50.37
Gender		
Female	353	52.61
Male	318	47.39
Birth Weight		
Normal	530	78.99
Low Birth Weight	141	21.01
Height for Age Z Score at Baseline		
Normal	409	60.95
Stunting	262	39.05
Weight for Age Z score at Baseline		
Normal	537	80.03
Underweight	134	19.97
Weight for Height Z score at Baseline		
Normal	591	88.08
Wasting	80	11.92
Undernourished Condition		
Normal	285	42.47
Undernourished	386	57.53
Rapid Growth in HAZ		
Non-rapid Growth	473	70.50
Rapid Growth	198	29.50
Rapid Growth in WAZ		
Non-rapid Growth	514	76.60
Rapid Growth	157	23.40
Exclusive Breastfeeding		
Exclusive	327	48.73
Non-exclusive	344	51.27
Parents Characteristics		
Mother's Height (cm)	Mean: 150.1 (SD 5.1)	Range: 134.7 to 168.2
Mother's Weight (kilogram)	Median: 47.8 (IQR 9)	Range: 24 to 89.2
Mother's Education Level		
≥9 years of Schooling	280	41.73
<9 years of Schooling	391	58.27
Father's Education Level (N = 626)		
≥9 years of Schooling	369	59.04
<9 years of Schooling	256	40.96
Household Socio-economic Condition		
Household total asset		
Above median value	335	49.93
Lower median value	336	50.07
Household income last month		
≥ Regional minimum wage	410	61.10
< Regional minimum wage	261	38.90
Area of Residence		
Urban	285	42.47
Rural	386	57.53

school less than nine years), but most fathers attended school more than nine years. Half of the samples had total household assets lower than the median value, but 61.1% had monthly income more than Indonesia Regional Minimum Wage in 1997 (135,353 rupiahs). Most of the study participants lived in the rural area.

The factors associated with rapid growth in length or height were age group, undernutrition status before two years, mother's height and weight, parents' education level, and total household assets (Tables 2 and 3). Similar to the result on rapid growth in height, factors associated with rapid weight growth were age group, undernutrition history, mother's body size, and fathers' education level.

Undernourished children in early life had a higher odd of having a rapid growth in height (AOR 6.36; 95% CI 3.94,10.26) and weight (AOR 5.7; 95% CI 3.4, 9.5) compared with normal children. Children aged 12 to 23 months (AOR 2.01; 95% CI 1.34, 3.02) were likely to grow rapidly in height, and if the mothers had lower education level, the odds of rapid growth in height were higher (AOR 1.88; 95% CI 1.07, 3.27). Children whose fathers had lower education levels were more likely to have rapid growth in weight (AOR 2.11; 95% CI 0.2,3.7). The odds of rapid growth in height and weight in a model without undernutrition history was higher among children aged 12 to 23 months. The odds of rapid growth in height among this age group was higher in children whose mothers had low education levels. In addition, lower maternal weight contributes to higher risk of rapid growth in height and weight. While on the other hand, if the father attends school less than nine years, the children are more likely to grow rapidly in weight.

DISCUSSION

Rapid growth in children who experienced undernutrition in early life occurs due to catching up with growth after restricted conditions to reach the normal body size. However, growth is also determined by genetics

Table 2. Characteristics of Study Participants and Rapid Growth in Height

Variable	Total	Rapid Growth	COR (95% CI)	*P* value	AOR[a] (95% CI)	*P* value[a]	AOR[b] (95% CI)	*P* value[b]
Child Age (in months)								
<12	333	67 (20.12)	1	**0.000**	1	**0.000**	**1**	**0.001**
12-23	338	131 (38.76)	1.93 (1.5-2.5)		2.63 (1.8-3.83)		**2.01 (1.34-3.02)**	
Child Sex								
Female	353	100 (28.33)	1	0.480	1	0.368	1	0.548
Male	318	98 (30.82)	1.09 (0.86-1.37)		1.18 (0.82-1.7)		1.13 (0.76-1.66)	
Undernutrition								
No	285	26 (9.12)	1	**0.000**	-	-	**1**	**0.000**
Yes	386	172 (44.56)	4.88 (3.3-7.16)		-		**6.36 (3.94-10.26)**	
Exclusive Breastfeeding								
Yes	327	88 (26.91)	1	0.150	1	0.55	1	0.795
No	344	110 (31.98)	1.19 (0.94-1.5)		1.12 (0.77-1.62)		1.05 (0.7-1.6)	
Mother's Height	671		0.95 (0.92-0.98)	**0.001**	0.98 (0.94-1.02)	0.34	0.98 (0.94-1.02)	0.388
Mother's Weight	671		0.96 (0.94-0.98)	**0.001**	0.97 (0.94-0.99)	**0.019**	0.98 (0.95-1)	0.177
Mother's Education Level								
≥9 years of Schooling	280	61 (21.79)	1	**0.0002**	1	**0.008**	**1**	**0.027**
<9 years of Schooling	391	137 (35.04)	1.6 (1.24-2.08)		2.05 (1.2-3.47)		**1.88 (1.07-3.27)**	
Father's Education Level (N = 626)								
≥9 years of Schooling	369	88 (23.85)	1	**0.001**	1	0.213	1	0.162
<9 years of Schooling	256	93 (36.33)	1.52 (1.19-1.94)		1.35 (0.8-2.16)		1.43 (0.86-2.37)	
Household total asset								
Above median value	335	87 (25.97)	1		1	0.996	1	0.608
Lower median value	336	111 (33.04)	1.27 (1-1.61)	**0.045**	1.00 (0.67-1.5)		1.12 (0.72-1.7)	
Household income								
≥ Regional minimum wage	410	121 (29.5)	1	0.998	1	**0.049**	1	0.055
< Regional minimum wage	261	77 (29.5)	0.99 (0.79-1.27)		0.65 (0.43-0.99)		0.64 (0.41-1)	
Area of Residence								
Urban	285	77 (27.02)	1	0.224	1	0.440	1	0.595
Rural	386	121 (31.35)	1.16 (0.91-1.48)		1.17 (0.78-1.75)		1.12 (0.73-1.73)	

COR – Crude Odds Ratio, AOR[a] – Adjusted Odds Ratio without Undernutrition group, P Value[a] – P value without Undernutrition category, AOR[b] – adjusted Odd Ratio with Undernutrition group, P Value[b] – P Value with undernutrition group, CI – Confidence Interval. Adjusted by child age, sex, exclusive breastfeeding, mother's height and weight, parents' education level, total asset, household income and residence area.

and environmental factors. Therefore, children who did not have a history of undernutrition in utero or postnatal might grow rapidly in weight and length due to environmental and lifestyle factors that promote faster growth. From the growing body of research, rapid growth in early life, whether in undernourished or normal children, is considered as a risk factor of chronic disease in later life.

The risk factors are associated with obesity, higher blood pressure, insulin resistance and higher lipid profile.[3,7,9,11,12] We analyzed longitudinal data showing the risk factors of rapid growth in length or height and weight in children from 0 to 23 months and then followed until the age of 3 to 5 years. Although the study that analyzes determinants factors of rapid growth using Indonesia population was limited, to our knowledge, this study is the first that analyze the determinants factors of rapid growth in early life. We developed two multivariate analyses to compare the risk factors of rapid growth for children with and without differentiation by a history of undernutrition.

Of the children who grew rapidly in length or height and weight, most were aged 12 to 23 months at baseline and had undernutrition experience before two years old. The children whose mothers had lower height and weight were more likely to grow rapidly. Socioeconomic factors that contributed to rapid growth in height were the lower education level of parents and lower household asset ownership. A similar result was obtained for rapid growth in weight for which the father's education level was the strongest determinant. There is no association of exclusive breastfeeding status to rapid growth, although the proportion of rapid growth was higher in children who were not exclusively breastfed. More male children had rapid growth in height but did not significantly differ from females.

After adjusting for characteristics of children, parents, and household, without differentiating undernutrition status, factors that contributed to rapid growth in height were children aged 12 -23 months at baseline, lower mother's education level, and lower household income. In the model

Table 3. Characteristics of Study Participants and Rapid Growth in Weight

Variable	Total	Rapid Growth	COR (95% CI)	*P* value	AOR[a] (95% CI)	*P* value[a]	AOR[b] (95% CI)	*P* value[b]
Child Age (in months)								
<12	333	57 (17.12)	1	**0.0001**	1	**0.02**	1	0.110
12-23	338	100 (29.59)	1.73 (1.3-2.31)		1.89 (1.28-2.82)		1.41 (0.93-2.14))	
Child Sex								
Female	353	79 (22.38)	1	0.512	1	0.512	1	0.678
Male	318	78 (24.53)	1.096 (0.83-1.44)		1.14 (0.77-1.68)		1.09 (0.73-1.6)	
Undernutrition								
No	285	21 (7.37))	1	**0.000**	-	-	**1**	**0.000**
Yes	386	136 (35.23)	4.78 (3.1-7.37)		-		**5.7 (3.4-9.5)**	
Exclusive Breastfeeding								
Yes	327	72 (22.02)	1	0.150	1	0.919	1	0.873
No	344	85 (24.71)	1.12 (0.85-1.48)		1.02 (0.69-1.51)		0.97 (0.64-1.46)	
Mother's Height	671		0.95 (0.92-0.98)	**0.004**	0.96 (0.92-1)	0.054	0.96 (0.92-1.)	0.052
Mother's Weight	671		0.96 (0.93-0.98)	**0.001**	0.97 (0.94-0.99)	**0.042**	0.98 (0.96-1.01)	0.251
Mother's Education Level								
≥9 years of Schooling	280	57 (20.36)	1	**0.115**	1	0.404	1	
<9 years of Schooling	391	100 (25.58)	1.26 (0.94-1.67)		0.78 (0.44-1.39)		0.66 (0.36-1.2)	0.182
Father's Education Level (N = 626)								
≥9 years of Schooling	369	70 (10.97)	1	**0.003**	1	**0.012**	**1**	**0.008**
<9 years of Schooling	256	75 (29.33)	1.54 (1.16-2.05)		1.98 (1.16-3.38)		**2.11 (1.2-3.7)**	
Household total asset								
Above median value	335	69 (20.6)	1		1	0.511	1	0.244
Lower median value	336	88 (26.19)	1.27 (0.96- 1.68)	0.087	1.16 (0.75-1.78)		1.31 (0.83-2.07)	
Household income								
≥ Regional minimum wage	410	92 (22.4)	1	0.462	1	**0.353**	1	0.412
< Regional minimum wage	261	65 (24.9)	1.1 (0845-1.46)		0.81 (0.52-1.26)		0.82 (0.521-1.31)	
Area of Residence								
Urban	285	58 (20.35)	1	0.109	1	0213	1	0.299
Rural	386	99 (25.63)	1.26 (0.95-1.68)		1.31 (0.85-2.02)		1.27 (0.81-1.99)	

COR – Crude Odds Ratio, AOR[a] – Adjusted Odds Ratio without Undernutrition group, P Value[a] – P value without Undernutrition category, AOR[b] – adjusted Odd Ratio with Undernutrition group, P Value[b] – P Value with undernutrition group, CI – Confidence Interval. Adjusted by child age, sex, exclusive breastfeeding, mother's height and weight, parents' education level, total asset, household income and residence area.

with undernutrition status, the most contributing factor of rapid growth in height was undernutrition history; the association of age group and mother's education level were attenuated but not significant.

In a model without undernutrition status, factors that contributed to rapid growth in weight were age group 12 to 23 months, lower mother's weight, and lower father's education level. However, after including undernutrition status, only the father's low education level was associated with rapid growth in weight besides undernutrition status.

Based on a study using the Indonesian Basic Health Survey data in 2010, children aged 12 to 23 months had the highest prevalence of stunting (40.4%). In this study, the prevalence of stunting of the samples was 39%; it was the most prevalent undernutrition. A study from Asiki in Uganda showed that out of 39.2% of stunted children, 31.5% recovered from stunting. Additionally, another study in India showed that more than half of stunted children regained their growth at the age of 7 years, which is in line with the results of this study, showing that among children with undernutrition, 44.5% had rapid growth in height and 35.6% had rapid growth in weight.[13–15] A study in Dortmund, Germany, showed that among children with normal birth weight and had appropriate gestational age (AGA), children who grew rapidly were more likely to have low body weight, shorter length at birth, and had earlier gestational age. Consequently, during childhood, those children tend to be heavier, taller and have more chance to develop overweight.[3] In line with the study in Germany, based on a systematic literature review, it is suggested that rapid growth among children with SGA and IUGR, compared to AGA children, had a positive association with neurocognitive outcomes, adiposity, insulin resistance and blood pressure.[16]

A systematic literature review about factors associated with catch up growth in stunted children showed that mothers who had appropriate stature were more likely to have children who experienced faster growth. In contrast, this study found that in the rapid growth of height and weight group, the mother who had lower height and weight was significantly different from the non-rapid growth group.[17] Furthermore, a study in Amsterdam showed that faster linear growth was associated with taller maternal status. In this study, in a group with rapid growth in height and weight, they had shorter mothers than the non-rapid growth group.[18]

The mother's education level was significantly associated with rapid growth in height but not in rapid growth in weight. In contrast, the father's education level was associated with rapid growth in weight. In summary, parents with low education levels were more likely to have children who grow rapidly in height and weight. Similar to a study in Rotterdam, children whose mothers had the lowest education level were shorter at baseline and grew faster in length from 2 to 18 months.[12] A study in Indonesia showed that maternal education was related to child growth and development.[19] Studies in India showed that educated women had a lower prevalence of stunting; rapid growth occurred mostly in stunted children. Children from low socioeconomic status that showed accelerated linear growth tend to have mothers with lower education levels, younger age, shorter and more likely to smoke during pregnancy. Consequently, those children tended to have low birth weight and were less likely to be breastfed. In line with this study, a cohort study in Amsterdam also showed that faster weight gain and linear growth were more common in mothers with lower educational levels.[12,18] A study in China showed contrary results; they reported no influence of socioeconomic factors on rapid growth in childhood between 2 to 5 years old.[11] Another study in Hong Kong also showed no association between parental education and height growth.[19] A literature review showed that children with better economic status tend to achieve better nutrition and are more likely to grow rapidly, but this study showed the opposite results.[17]

The different socioeconomic backgrounds might have varied feeding practices; hence, this leads to distinct linear growth patterns. Nutrition plays a pivotal role in an infant's growth rate; formula-fed children grew faster than those who breastfed and tend to be heavier and taller. Undernourished children are more sensitive to environmental factors; if they had formula food during childhood, they would have faster growth and contribute to chronic disease later in life.[11,12,20] A study from Hong Kong showed a contrary result; exclusively breastfed children had faster height growth in childhood.[20] Although the proportion of non-exclusively breastfed children was higher in the rapid growth group based on height and weight, the difference was not significant in this study. A limitation of this study is that we did not analyze dietary intake data of the children and maternal health during pregnancy that might determine rapid growth in children due to unavailable data.

CONCLUSION

Children who experienced undernutrition in early life included low birth weight, stunting, underweight and wasting, were more likely to have rapid growth in length or height and weight. Children aged 12 to 23 months at baseline had a higher odds of rapid growth in height and weight as the prevalence of undernutrition was higher among those groups. Parents' educational level contribute to rapid growth; lower education level of mother led to rapid growth in height, and lower education level of father contribute to rapid growth in weight. Children with undernutrition tend to have compensatory growth; they are more sensitive to changes in living conditions and environmental factors that might promote faster growth. Further research is needed to confirm the other risk factors associated with rapid growth, direct or indirect, to complete the result of this study. Therefore, a better intervention program could be developed to prevent the long-term adverse effect of rapid growth in later life, optimize health, and control children's

growth, particularly those who experienced undernutrition in early life.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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