ORIGINAL ARTICLE

Determinants of Catch-up Growth in Early Childhood: A Longitudinal Study

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ABSTRACT

Background. Growth failure in the first 1000 days of life can have a major impact on a child's health. Therefore, catching up on growth in early childhood is essential to prevent nutritional problems, especially stunting, as indicated by the height for age z-score (HAZ). Catch-up growth after a period of malnutrition in the first 1000 days of life can be measured as an improvement in linear growth using HAZ parameters.

Objective. This study aimed to determine the factors that influence catch-up growth in early childhood based on the HAZ.

Methods. This three-year cohort study used two waves of secondary data from the Indonesian Family Life Survey (IFLS). Baseline data of the study were taken in 1997 when the children were 0 to 23 months old, then followed up in 2000 (at 3 to 5 years old). The study included 537 children aged 0 to 23 months in 1997. The dependent variable was catch-up growth. The independent variables were: children-related, parent-related, and household factors. We collected secondary data from the IFLS annual report book. Bivariate data analysis was performed using the Chi-squared test, while multivariate analysis was performed using multinomial logistic regression.

Results. There were four groups in this study: not stunted (reference group), stunted catch-up, stunted non-catch-up, and late incident stunted. Bivariate analysis showed that catch-up growth, based on HAZ, was significantly influenced by birth weight (normal birth weight), head circumference (normal head circumference), maternal nutritional status (normal), and maternal height (p <0.05). After controlling for potentially confounding factors, sex (p = 0.003; 95% CI:1.43-5.93) and maternal nutritional status (p = 0.011; 95% CI:0.19-0.81) were the most influential factors on catch-up growth in early childhood.

Conclusion. Children with stunting and catch-up growth are more common among males, and poor maternal nutritional status was associated with stunting and failure to achieve catch-up growth. The determining factors for the late incident and stunted non-catch-up groups include head circumference, breastfeeding status, maternal height, and maternal nutritional status. The stunted non-catch-up group is also influenced by small gestational age (SGA). Therefore, it is important to regularly monitor the growth and development of children in early childhood.

Keywords: catch-up growth, cohort study, early childhood, stunting

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INTRODUCTION

Growth in early childhood affects the health status, productivity, and cognitive abilities of children later in life.[1] Stunting in children under five due to chronic malnutrition can be measured by height-for-age indicators. Stunting conditions often occur in low and middle-income countries, and are known as the biggest bottleneck for child development. Stunted children experience linear growth retardation. Stunting is defined as a condition in which the height-for-age Z-score (HAZ) is less than -2SD.[2] Growth failure at the age of 2 years affects children's height in the next period of growth. Therefore, stunting at the age of 2 years is a risk factor for stunting at school age. To prevent stunting in adulthood, monitoring growth with the height-for-age indicator at an early age is essential so that children can catch up with growth lags. Children aged 0 to 2 years with normal height-for-age should be regularly monitored to ensure that the height-for-age does not decrease when children are older than 2years. Although several studies from a reference population continue to show inconsistent results, 2-year-old children who are stunted can catch up from this poor start and achieve similar adult heights.[3-5]

Most studies on catch-up growth focus on conditions of recovery much later in adolescence. As a result, little is known about recovery among five-year-old children. The severity and duration of the period of malnutrition and the stage of development at which malnutrition begins are influential factors in catch-up growth.[6] According to a 2018 UNICEF report, catch-up growth can still occur until adolescence.[7] However, this condition does not always occur in every child due to several influencing factors, such as puberty and growth hormones that affect nutritional status during adolescence.[1]

Several studies show that catch-up growth can still occur from an early age to adolescence. However, most of these studies did not make clinical observations or measurements on the effect of puberty and growth on children with catch-up growth conditions.[8]

Catch-up growth measurements in this study were carried out on children under five years of age because other growth factors–including puberty– heavily influenced the observation of catch-up growth in adolescence. Puberty will affect growth, so it is not clear whether catch-up growth is caused by growth or the influence of puberty conditions. One study showed that the most important time for catch-up growth is between the ages of 24 months to mid-childhood (48 months) and after mid-childhood to adulthood.[5]

The definition of catch-up growth has been debated and defined in several different ways in the literature.[4,9,10] A 1990 Philippine study defined catch-up growth as the restoration of growth to normal levels and an acceleration of growth rates that may or may not result in growth status up to normal limits according to age and sex.[11] Catch-up growth after a period of malnutrition in the first 1000 days of life can be seen by the improvement of linear growth with height parameters at a later age. In a recent study, catch-up growth was defined in terms of changes in height-for-age z-scores that explained the increased variability in height according to age in children.[3,12,13] Catch-up growth can be measured in absolute and relative terms. In absolute terms, the catch-up growth means the positive change in the difference in height according to age (Height for Age Difference), while the relative parameter sees a positive change in height-for-age z-score (HAZ).[11,14] This study uses the same definition of catch-up growth as the condition of recovery from stunting. The definition used is relative catch-up growth, focusing on the change in height-for-age z-scores over time at an individual level.[6] This study focused on 'recovery from stunting', defined as a positive change in height-for-age z-scores.

Several previous studies have stated that the linear growth of early childhood is persistent and irreversible.[11] In contrast, recent studies have shown that catch-up growth is possible among children under five in studies from LMICs countries.[3,4,10,12,13] These studies differed in how they measured and defined catch-up growth.

Various factors may affect catch-up growth in children (based on changes in HAZ) and child development. The Young Lives (YL) study conducted in Ethiopia, India, Peru, and Vietnam showed that parental education, dietary intake, and maternal height affected children's HAZ. The results show that 50% of stunted children at the age of 1 year will experience improvement and become non-stunted (recovered) at 8 years of age. Although early childhood development and growth vary among children in different countries, the results estimate that 250 million children (43%) under five years of age in low and middle-income countries are at risk of not achieving their development and growth potential based on proxy measures of stunting and poverty.[17] A study of children in the Philippines showed that children with taller mothers managed to recover from stunting at 8.5 to 12 years of age. Low birth weight is also a factor that inhibits catch-up growth in children.[14]

Barriers to growth in height include inadequate intake, suboptimal parenting, and infectious diseases.[2] The importance of linear growth in the first 1000 days of life (1000 HPK) has provided definite research evidence. However, research and debate continue to explore the extent to which children can have catch-up growth after the age of two and which factors greatly influence catch-up growth.[18] It is important to monitor children's growth from an early age by paying attention to other factors that can affect children's growth, for instance, parental factors, socio-economic household, and the community environment.[19] This study aims to analyze longitudinal changes in nutritional status and factors that influence linear growth catch-up in children under five in Indonesia.

METHODS

This study was a retrospective cohort study conducted from April to September 2021 using Indonesian Family Life

Survey (IFLS) secondary data. The IFLS was designed to provide a wealth of information collected at the individual and household level, including many indicators of economic well-being, non-economic, marital, fertility, contraceptive use, health status, and health care use.[20] IFLS has been conducted since 1993 in 13 provinces in Indonesia. IFLS collected interview data related to the children, parents, households, living environment, and existing facilities in the neighborhood. This survey also measured children's health data, anthropometry, and other biochemical measurements. We collected data on children's characteristics and health, parents, and household socio-economics from two data waves in 1997 (IFLS 2) and 2000 (IFLS 3). The questionnaire instrument used by IFLS was included in its annual reports according to the year and survey waves. In addition, this research questionnaire was stated in the household and individual books on IFLS 2 and IFLS 3 data.

Sampling in IFLS data uses multistage random sampling under the provisions of the data owner. Our study subjects were 818 children (with clean data including weight at birth; out of 1215) aged 0 to 23 months in 1997 and followed up to 2000 when children were 3 to 5 years old. Based on the study's inclusion criteria, the number of children who had complete data according to the research objectives was 537. The dependent variable was catch-up growth under the definition of relative catch-up growth, focusing on the change in height-for-age z-scores over time at an individual level.[6] Catch-up growth was observed from changes in height-for-age z-score (HAZ) relative to several definitions used in several studies.[21]

Baseline data were taken in IFLS 2, and nutritional status was calculated using the WHO Anthro software for children under five. Calculation of nutritional status based on body height/length relative to age was used to categorize children's groups based on nutritional status. The group of children aged 0-23 months in this study was divided into two groups: stunted and not stunted. At 3-5 years old, they were grouped again into not stunted, late incident, stunted catch-up, and stunted non-catch-up. The independent variables are factors related to children's growth: children, parents, and household income. We included gender, birth weight, head circumference, history of infectious disease, anemia status, breastfeeding, child's first feeding, and immunization in the child factors. Parental factors included the covariates of maternal height, gestational age category, father's nutritional status, maternal nutritional status, fathers' smoking habits, and household income. Parents' nutritional status was divided into normal BMI and BMI at risk (being underweight or overweight). Gestational age was divided into two categories: term (≥37 weeks) and preterm (<37 weeks).

Univariate analysis was used to assess the subject's characteristics (average and percentage). Bivariate analysis was used to determine the relationship of the dependent variable according to related factors in each study group using the chi-square test. In addition, the Multinomial logistic regression test was conducted for multivariate analysis. This study was approved by the Research Ethics and Community Service Commission, Faculty of Public Health, University of Indonesia No: Ket- 459/UN2. F10.D11/PPM.00.02/2021, on August 27th, 2021. The questionnaire book used in this secondary data collection has received an ethical license granted by the RAND Human Subject Protection Committee (IRB RAND) to IFLS5 No. s0064-06-01-CR01.

RESULTS

Out of 537 included children, 536 were assessed on their nutritional status using the HAZ (Table 1). One child was not assessed due to incomplete data in the final wave of the IFLS 2014. A little above half of the children were girls (51.3%), but more than half in the stunted catch-up group were boys (59.5%). Most children from all groups had normal birth weight (78.4%) and head circumference (84.1%). The majority had no history of infectious disease (72.4%) and anemia (54.7%) for both catch-up and non-catch-up groups. Most children were breastfed for≥6 months (70.2%), but were given complementary foods for the first time at the age of <6 months (62.7%). Most children did not receive basic immunization below two years of age (69.4%). Most had mothers with normal maternal height at delivery (82.09%) and term gestational age (92.2%), i.e., giving birth at a gestational age greater than 36 weeks for all groups. In each group, both parents had mostly normal BMI category h (fathers, 67.7%; mothers, 86.1%). More than half of fathers had a smoking habit (64.4%), and household income was evenly distributed in each quartile.

Bivariate analysis showed that birth weight, head circumference, maternal height, and maternal nutritional status were associated with stunted catch-up growth. After being controlled by other factors and using multinomial logistic analysis, the most influential factors on stunted catch-up growth were gender (0.003) and maternal nutritional status (0.011). Boys had a higher chance of experiencing a stunted catch-up (aOR = 2.92; 95% CI1.43, 5.93) than girls. Normal maternal nutritional status is a stunted catch-up protection factor (aOR =. Children with BMI at-risk mothers had more stunted catch-up (aOR=0.40; 95% CI 0.19, 0.81).

Table 2 shows that the variables that affect the stunted catch-up group of children are sex and maternal nutritional status ($p<0.05$). There is a difference with the stunted catch-up group. Table 3 shows the variables that affect the late incident stunted group and the bivariate analysis results. Head circumference, infection, duration of breastfeeding, child immunization, maternal height, and maternal nutritional status were associated with late incident stunted conditions ($p<0.05$). Multivariate analysis showed that children with small head circumference were at risk of late-incident stunting (aOR=4.74; 95% CI: 1.90-11.81). Children with breastfeeding duration <6 months (aOR=2.82; 95% CI: 1.35-5.87) and short mothers (aOR=3.00; 95% CI: 1.26-

Table 1. Distribution of Children Based on Demographic and Clinical Characteristics

No.	Characteristic		Change in height for age								N	%
			None				Changed					
			Not stunted*		Stunted non-catch-up		Stunted catch-up		Late incident stunted			
			n	%	n	%	N	%	n	%		
	Total		**206**	**38.43**	**143**	**16.68**	**79**	**14.74**	**108**	**20.15**	**536**	**100**
1	***Sex (N=536)***	Male	97	47.09	64	44.76	47	59.49	53	49.07	261	48.69
		Female	109	52.91	79	55.24	32	40.51	55	50.93	275	51.31
2	***Birth weight (N=536)***	Normal	174	84.47	105	73.43	56	70.89	85	78.70	420	78.36
		Low	32	15.53	38	26.57	23	29.11	23	21.30	116	21.64
3	***Head circumference (N=536)***	Normal	189	91.75	117	81.82	66	83.54	79	73.15	451	84.14
		Small	17	8.25	26	18.18	13	16.46	29	26.85	85	15.86
4	***Infection 0-2 years (N=536)***	No	156	75.73	106	74.13	56	70.89	70	64.81	388	72.39
		Yes	50	24.27	37	25.87	23	29.11	38	35.19	148	27.61
5	***Anemia status (N=466)***	No	102	59.65	63	50.40	39	56.52	51	50.50	255	54.72
		Yes	69	40.35	62	49.60	30	43.48	50	49.50	211	45.28
6	***Duration of breastfeeding (N=536)***	≥6 months	141	68.45	123	86.01	63	79.75	49	45.37	376	70.15
		<6 months	65	31.55	20	13.99	16	20.25	59	54.63	160	29.85
7	***Complementary food (N=536)***	≥6 months	80	38.83	44	30.77	25	31.65	51	47.22	200	37.31
		<6 months	126	61.17	99	69.23	54	68.35	57	52.78	336	62.69
8	***Basic immunization 0-2 years (N=536)***	Yes	72	34.95	45	31.47	26	32.91	21	19.44	164	30.60
		No	134	65.05	98	68.53	53	67.09	87	80.56	372	69.40
9	***Mother's height (N=536)***	Normal	192	93.20	103	72.03	65	82.28	80	74.07	440	82.09
		Short	14	6.80	40	27.97	14	17.72	28	25.93	96	17.91
10	***Gestational age (N=536)***	Term	184	89.32	139	97.20	68	86.08	103	95.37	494	92.16
		Preterm	22	10.68	4	2.80	11	13.92	5	4.63	42	7.84
11	***Father's nutritional status (N=536)***	Normal BMI	131	63.59	104	72.73	57	72.15	71	65.74	363	67.72
		Abnormal BMI	75	36.41	39	27.27	22	27.85	37	34.26	173	32.28
12	***Mother's nutritional status (N=536)***	Normal BMI	168	81.55	122	85.31	75	94.94	102	94.44	467	87.13
		Abnormal BMI	38	18.45	21	14.69	4	5.06	6	5.56	69	12.87
13	***Father's smoking habits (N=483)***	No	67	36.61	46	34.33	26	36.11	33	35.11	172	35.61
		Yes	116	63.39	88	65.67	46	63.89	61	64.89	311	64.39
14	***Household income (N=536)***	Quartile 4	66	32.04	25	17.48	21	26.58	22	20.37	134	25.00
		Quartile 3	45	46.39	37	57.81	25	53.19	23	43.40	130	24.25
		Quartile 2	51	46.79	47	59.49	14	43.75	26	47.27	138	25.75
		Quartile 1	44	25.29	34	32.38	19	33.93	37	43.53	134	25.00

*Note: *Reference group*

7.12) are risk factors for late incident stunting in children under five. BMI of risk mothers was protective against late-incident stunting (aOR= 0.35; 95% CI: 0.17-0.73).

Based on the bivariate analysis results, the factors that significantly affected the stunted non-catch-up condition were birth weight, head circumference, breastfeeding duration, maternal height, and gestational age (p <0.05) (Table 4). After being controlled for other factors by conducting multinomial logistic analysis, it was shown that the determinants of the stunted non-catch-up group were birth weight, head circumference, duration of breastfeeding, and maternal height (p <0.05). Children with low birth weight (aOR = 2.31; 95% CI 1.11,4.79) and small head circumference (aOR = 2.82; 95% CI 1.09, 7.28) have a risk of experiencing stunted non-catch-up or persistent stunting compared to children with normal birth weight and head circumference. Breastfeeding ≥6 months was a protective factor for the occurrence of stunted non-catch-up (aOR = 0.29; 95% CI 0.13, 0.66). Children with short mothers were at risk of experiencing stunted non-catch-up (OR = 2.97; 95% CI 1.34, 6.56).

Table 2. Child, Parents, Household Characteristic, and Stunted Catch-Up Growth

No.	Variables		N	%	Stunted Catch-up			
					COR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
1	***Sex***	Female	276	51.4	1		1	
		Male	261	48.6	1.26 (1.00-1.59)	0.061	2.92 (1.43-5.93)	0.003*
2	***Birth weight***	Normal	421	78.4	1		1	
		Low	116	21.6	1.87 (1.17-2.99)	0.009	2.23 (0.96-5.15)	0.061
3	***Head circumference***	Normal	452	84.17	1		1	
		Small	85	15.38	1.99 (1.01-3.91)	0.043	2.21 (0.72-6.77)	0.165
4	***Infection 0-2 years***	No	389	72.44	1		1	
		Yes	148	27.56	0.93 (0.79-1.09)	0.402	0.53 (0.24-1.13)	0.102
5	***Anemia status***	No	255	54.72	1		1	
		Yes	211	45.28	1.07 (0.77-1.49)	0.656	0.88 (0.44-1.75)	0.724
6	***Duration of breastfeeding***	≥6 months	377	70.2	1		1	
		<6 months	160	29.8	0.64 (0.39-1.03)	0.058	0.43 (0.18-1.06)	0.068
7	***Complementary food***	≥6 months	201	37.43	1		1	
		<6 months	336	62.57	1.11 (0.92-1.34)	0.260	0.89 (0.44-1.79)	0.747
8	***Basic immunization 0-2 years***	Yes	165	30.73	1		1	
		No	372	69.27	1.03 (0.85-1.23)	0.764	1.32 (0.63-2.76)	0.462
9	***Mother's height***	Normal	440	81.94	1		1	
		Short	97	18.06	2.60 (1.30-5.22)	0.006	1.57 (0.57-4.30)	0.374
10	***Gestational age***	Term	495	92.18	1		1	
		Preterm	42	7.82	1.30 (0.66-2.65)	0.444	1.70 (0.55- 5.18)	0.351
11	***Father's nutritional status***	Normal BMI	364	67.78	1		1	
		Abnormal BMI	173	32.22	0.76 (0.52-1.14)	0.172	0.76 (0.38-1.50)	0.430
12	***Mother's nutritional status***	Normal BMI	468	87.15	1		1	
		Abnormal BMI	69	12.85	0.27 (0.10-0.74)	0.004	0.40 (0.19-0.81)	0.011*
13	***Father's smoking habit***	No	172	35.54	1		1	
		Yes	312	64.46	1.01 (0.82-1.23)	0.940	1.17 (0.57-2.40)	0.665
14	***Household income***	Quartile 4	134	24.95	1.08 (0.92-1.27)	0.239	0.96 (0.71-1.32)	0.836
		Quartile 3	130	24.21				
		Quartile 2	138	25.7				
		Quartile 1	135	25.14				

Note: Significant p <0.05; COR: Crude Odds Ratio, AOR: Adjusted Odds Ratio

DISCUSSION

HAZ has been used to assess catch-up growth in children.[4] Recovering from stunting or experiencing catch-up growth can help reduce the negative effects of early growth retardation and successfully catch up with growth and developmental delays later in life. Our study used a strict definition according to a recent 2020 study, which includes a relative measurement using the HAZ to assess catch-up growth.[21]

The prevalence of stunting among children was 41.53% for those aged 0 to 23 months, and 46.83% for those aged 3 to 5 years.[22] The present study results show that children who are stunted at their younger ages may regain their growth in their later development stages, specifically during early adolescence. Bivariate analysis showed that children who have low birth weight and small head circumference had higher odds of experiencing stunting at 0 to 23 months and have the opportunity to experience catch-up growth. Birth weight (cOR=1.87;95%CI: 1.17-2.99) and head circumference (cOR=1.99: 95% CI: 1.01-3.91) were risk factors for stunted catch-up. Thus, birth weight is a fairly dominant factor affecting the postnatal nutritional status and later life. Research in Tanjung Sari shows that birth weight and maternal height are associated with child stunting.[23] For the same reason, finding that the incidence of catch-up growth is associated with maternal height.[12.] Based on a 2020 study, several maternal characteristics result in stunting reduction and trigger catch-up growth, including parity, number of parity, maternal nutritional status, and maternal height.[24]

Multivariate analysis showed that determinant factors in stunted catch-up were sex and maternal nutritional status. A previous study showed a negative relationship between females and catch-up growth, where males were more likely to experience catch-up growth than females. The results show that mothers with BMI at risk are a protective factor in the stunted catch-up growth group. Maternal nutritional status is one of the predictors of child stunting. This finding is important because it shows that children can recover from early nutritional disorders and identifies predictors of catch-up growth for children under five. A study in Peruvian children stated that additional factors associated with catch-up growth included the child's sex, age at second assessment, and maternal height.[25]

Almost half of the children in this study were stunted when they were under two years old and under five. The children in this study not only experienced catch-up but also experienced late incident stunted and stunted non-catch-up conditions. Bivariate analysis in the late incident group showed that head circumference, infection, breastfeeding, child immunization, height, and maternal nutritional status were significantly related to the late incident stunted group. Only childhood immunization was not a determining factor based on multinomial logistic analysis of the significantly related variables. The bivariate analysis results showed that children who did not receive complete basic immunization were at risk of experiencing a late incident stunted condition (OR = 1.23; 95% CI 1.08,1.42). A systematic review showed that complete childhood vaccination is an indicator of a functional health system.[24] Complete vaccination is predicted to increase the change in HAZ rates in Nepalese children by 4 to6% and 3% in Paraguay.[24]

Table 3. Child, Parents, Household Characteristic, and Late Incident Stunted Group

No.	Variables		N	%	Late-incident Stunted			
					COR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
1	***Sex***	Female	276	51.40	1		1	
		Male	261	48.60	1.04 (0.82-1.32)	0.738	1.52 (0.78-2.93)	0.213
2	***Birth weight***	Normal	421	78.40	1		1	
		Low	116	21.60	1.37 (0.85 - 2.22)	0.202	1.50 (0.64-3.48)	0.343
3	***Head circumference***	Normal	452	84.17	1		1	
		Small	85	15.38	3.25 (1.87 -5.65)	0.000	4.74 (1.90-11.81)	0.001*
4	***Infection 0-2 years***	No	389	72.44	1		1	
		Yes	148	27.56	0.855 (0.73-1.03)	0.041	0.94 (0.45-1.96)	0.883
5	***Anemia status***	No	255	54.72	1		1	
		Yes	211	45.28	1.22 (0.93-1.60)	0.141	1.24 (0.65-2.36)	0.512
6	***Duration of breastfeeding***	≥6 months	377	70.20	1		1	
		<6 months	160	29.80	1.73 (1.32-2.25)	0.006	2.82 (1.35-5.87)	0.005*
7	***Complementary food***	≥6 months	201	37.43	1		1	
		<6 months	336	62.57	0.86 (0.70-1.06)	0.152	1.23 (0.62-2.44)	0.543
8	***Basic immunization 0-2 years***	Yes	165	30.73	1		1	
		No	372	69.27	1.23 (1.08-1.42)	0.004	1.36 (0.62-3.01)	0.438
9	***Mother's height***	Normal	440	81.94	1		1	
		Short	97	18.06	3.81 (2.09-6.93)	0.000	3.00 (1.26-7.12)	0.013*
10	***Gestational age***	Aterm	495	92.18	1		1	
		Preterm	42	7.82	0.43 (0.16-1.12)	0.069	0.33 (0.068-1.64)	0.178
11	***Father's nutritional status***	Normal BMI	364	67.78	1		1	
		Risk BMI	173	32.22	0.94 (0.68-1.29)	0.706	0.97 (0.52-1.84)	0.944
12	***Mother's nutritional status***	Normal BMI	468	87.15	1		1	
		Risk BMI	69	12.85	0.30 (0.13-0.69)	0.002	0.35 (0.17-0.73)	0.005*
13	***Father's smoking habit***	No	172	35.54	1		1	
		Yes	312	64.46	1.02 (0.85-1.23)	0.805	1.02 (0.52-2.02)	0.936
14	***Household income***	Quartile 4	134	24.95	1.17 (1.02-1.34)	0.045	1.28 (0.96-1.73)	0.092
		Quartile 3	130	24.21				
		Quartile 2	138	25.70				
		Quartile 1	135	25.14				

Note: Significant p <0.05 (95% CI); COR: Crude Odds Ratio, AOR: Adjusted Odds Ratio

This study's potential determinant factors for late incident stunting were infection (diarrhea and respiratory tract infections), breastfeeding status, maternal height, and maternal nutritional status. Infection in the form of prolonged diarrhea in children will reduce the nutritional status and inhibit child growth.[15,16] A study in Peru showed a significant reduction in linear growth in each age-related panel with diarrhea during the first six months of life and prolonged diarrhea up to 2 to 6 months before the age at which height was measured. Diarrhea occurring after six months of age is associated with a transient height deficit followed by a subsequent period of growth.[11] Breastfeeding for less than six months is at risk for late-onset stunting conditions. However, a study stated that breastfeeding in the 2nd and 3rd years of life, regardless of the child's food intake from the main meal, had a significant relationship with stunting and severe stunting. Mothers need to be educated about the risks of prolonged breastfeeding to reduce the burden of this undernutrition.[26] Thus, it is important for children to be exclusively breastfed for six months with controlled breast-feeding duration and complementary feeding after that age.

Developing countries often experience multiple insults with limited recovery time, leading to persistent height deficits.[27] Gestational age was the only determining factor in the stunted non-catch-up group. Children born at preterm or premature gestational age are a protective factor for the occurrence of stunted non-catch-up (cOR= 0.26; 95% CI: 009-0.74). A leading systematic review shows that global risk factors in the total number of attributable stunting cases were identified: fetal growth restriction (defined as being born at term and small for gestational age), premature, unimproved sanitation, childhood diarrhea, and short maternal stature.

Table 4. Distribution of Children according to Characteristics of the Child, Parents, Household, and Stunted Non-catch-up

No.	Variables		N	%	Stunted non-catch-up			
					COR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
1	***Sex***	Female	276	51.40	1		1	
		Male	261	48.60	0.95 (0.75 -1.19)	0.667	1.03 (0.57-1.87)	0.906
2	***Birth weight***	Normal	421	78.40	1		1	
		Low	116	21.60	1.71 (1.12-2.60)	0.011	2.31 (1.11-4.79)	0.025*
3	***Head circumference***	Normal	452	84.17	1		1	
		Small	85	15.38	2.20 (1.24-3.90)	0.006	2.82 (1.09-7.28)	0.031*
4	***Infection 0-2 years***	No	389	72.44	1		1	
		Yes	148	27.56	0.97 (0.86-1.11)	0.734	1.08 (0.55-2.14)	0.807
5	***Anemia status***	No	255	54.72	1		1	
		Yes	211	45.28	1.23 (0.95-1.58)	0.114	1.22 (0.68-2.19)	0.484
6	***Duration of breastfeeding***	≥6 months	377	70.20	1		1	
		<6 months	160	29.80	0.44 (0.21-0.69)	0.000	0.29 (0.13-0.66)	0.003*
7	***Complementary food***	≥6 months	201	37.43	1		1	
		<6 months	336	6.57	1.13 (0.97-1.32)	0.122	1.23(0.67-2.28)	0.493
8	***Basic immunization 0-2 years***	Yes	165	30.73	1		1	
		No	372	69.27	1.05 (0.91-1.23)	0.498	1.49 (0.79-2.81)	0.213
9	***Mother's height***	Normal	440	81.94	1		1	
		short	97	18.06	4.11 (2.32-7.27)	0.000	2.97 (1.34-6.56)	0.007*
10	***Gestational age***	Term	495	9.18	1		1	
		Preterm	42	7.82	0.26 (0.09-0.74)	0.006	0.36 (0.08-1.51)	0.165
11	***Father's nutritional status***	Normal BMI	364	67.78	1		1	
		Risk BMI	173	32.22	0.74 (0.54-1.03)	0.074	0.753 (0.41-1.36)	0.351
12	***Mother's nutritional status***	Normal BMI	468	87.15	1		1	
		Risk BMI	69	12.85	0.79 (0.48-1.29)	0.357	0.66 (0.36-1.22)	0.194
13	***Father's smoking habit***	No	172	35.54	1		1	
		Yes	312	64.46	1.03 (0.87-1.22)	0.675	1.30 (0.69-2.43)	0.413
14	***Household income***	Quartile 4	134	24.95	1.21 (1.07-1.36)	0.022	1.16 (0.89-1.51)	0.250
		Quartile 3	130	24.21				
		Quartile 2	138	25.70				
		Quartile 1	135	25.14				

Note: Significant p <0.05 (95% CI); COR: Crude Odds Ratio, AOR: Adjusted Odds Ratio

Low birth weight, low head circumference, short maternal stature, and breastfeeding duration <6 months are risk factors for the stunted non-catch-up status. Therefore, children who are not exclusively breastfed for six months are likely to experience stunting throughout their lives. A systematic review (14 studies) found that exclusive breastfeeding for the first six months of life, followed by continued breastfeeding for two years, has a protective effect against infection and stunting by providing an optimal source of nutrition for children.[24]

Low birth weight is strongly associated with stunting in children and can be persistent. Low birth weight can indicate fetal growth restriction in utero, a process that can contribute to linear growth faltering. A systematic review examined the association between a child's low birth weight and stunting as an outcome in countries in South Asia and Africa. In all studies, improved birth outcomes (i.e., increased birth weight or reduced low birth weight) were significantly associated with improved measures of child growth.[24] The main risk factors affecting head circumference (HC) were found to be similar to those affecting body length. Low HC was significantly associated with stunting. Children who recorded low HC at birth continued to have low HC at all time points until two years of age. Stunting was significantly associated with low head circumference in the first two years of life. HC measurement can be a simple tool that can be additionally used by clinicians as well as parents/caregivers to monitor child growth and predict stunting.[28] Low maternal stature was an important predictor of childhood height. The association between maternal stature and childhood height in Peruvian children remained significant even after controlling for environmental factors.[11]

A strength of our study is its longitudinal design, which provides a stronger relationship to predict the determinants of catch-up growth in children under five. Furthermore, the children included in the study are representative since they cover almost five major islands in Indonesia. In addition, we have height measurements that allow us to determine changes in nutritional status as the main dependent variable in this study. However, our study has several limitations; the catch-up growth was measured in children under five and not observed until adolescence. Also, the observed factors are only related to children, parents, and household income, and do not consider environmental factors and housing area.

CONCLUSION

Boys experience more stunted catch-up than girls. The nutritional status of the mother greatly determines the child's stunting status and catch-up growth. The late incident stunted and non-catch-up stunted groups is associated with head circumference, breastfeeding status, maternal height, and maternal nutritional status, while the stunted non-catch-up group is also influenced by gestational age. Therefore, we recommend regular follow-up and additional follow-up assessments for each group of catch-up and non-catch-up children.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

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