



Correlation between Catch-up Growth in Early Childhood with Cognitive Ability among School-Aged Children (10–12 Years): A Longitudinal Study

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Abstract

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BACKGROUND: Children's cognitive abilities are influenced by the nutritional condition of children in early childhood. Catch-up growth in early childhood affects cognitive abilities at school age.

AIM: This study aims to analyze the effect of catch-up growth in early childhood on the cognitive abilities of school-aged children in Indonesia.

METHODS: This study was a cohort study incorporating 10 years of follow-up using three waves of secondary data (1997, 2000, and 2007) from the Indonesia Family Life Survey. Research studies and data analysis were carried out from April to September 2021. The initial data collection of the study was conducted in 1997 when the children were 0–23 months old, then followed in 2000 (age 3–5 years) and 2007 (age 10–12 years). The study subjects were 537 children aged 0–23 months in 1997. Cognitive ability was measured using the Raven Progressive Matrices method. Statistical analysis for cognitive ability scores with catch-up growth was carried out using one-way analysis of variance and multivariate analysis using the generalized linear model.

RESULTS: Significant differences were observed in the cognitive ability scores of normal children and stunted children who did not experience catch-up growth ($p < 0.001$), but the cognitive scores of normal children are not significantly different from the stunting catch-up growth group. Other factors that affect the cognitive ability score were as follows: (1) Child factors consist of child stunting status, head circumference, hemoglobin levels, duration of breastfeeding, and complete basic immunization history; (2) parental factors such as father's occupation, parental education, and number of parity; (3) household socioeconomic factors (household income and wealth index); and (4) environmental factors (housing area, father's smoking habit, defecation facilities, and household drinking water sources).

CONCLUSION: Cognitive abilities of school-age children were most influenced by catch-up growth, stunting status, duration of breastfeeding, number of parity, father's education, father's occupation, and father's smoking habit. Children who experience catch-up growth have better cognitive abilities than stunted non-catch-up group or who experience stunting during early life.

Introduction

One of the most important factors affecting children cognitive abilities is nutrition intake. In the first 1000 days of life, malnourished children are most likely to experience cognitive developmental issues if appropriate early intervention is missing [1]. At present, the Indonesian government put stunting as the most highlighted nutritional problem. Stunting is a condition of failure to grow and develop in children experiencing long-term nutritional deprivation, a history of infectious diseases, and suboptimal psychosocial stimulation. This condition is defined as a body length-for-age (LAZ) or height-for-age (HAZ) < 2 SD in the WHO Z-score. Stunting has short-term and long-term impacts. The short-term impacts of stunting include failure to thrive, cognitive and motor development disruption, suboptimal physical body size, and metabolic

disorders. The long-term impact of stunting can reduce intellectual capacity due to impaired brain development at an early age [2], [3]. The cognitive abilities of both pre-school-aged children (3–5 years old) and school-aged children (6–12 years old) can predict children's achievement and productivity as adults [4]. Data show that 200 million children under 5 years of age have developmental cognitive skills delays, especially in South Asia and sub-Saharan Africa [5]. The Program for International Student Assessment for children age 15-year olds in 2018 showed that Indonesia was ranked 72 out of 78 participating countries in the selection. Indonesian children's Mathematics scores were ranked 72 out of 78 countries, while the Science scores were ranked 70 out of 78 countries [6]. These ranks tend to be stagnant in the past 10–15 years. The trend in International Mathematics and Science Study for Grade 4 elementary school to Grade 2 junior high school students with an age range of 9–15 years shows

that Indonesian children's learning achievement is still below the average of other Southeast Asian countries.

A cohort study in Vietnam conducted for 3 years (2013–2016) showed an increase in the prevalence of stunting in pre-school-aged children (3–6 years) living in rural areas [7]. This chronic undernutrition condition also increases the risk of morbidity and mortality. In addition, it contributes to delayed neurocognitive development, low school achievement, low income in adulthood, and an increased likelihood of developing non-communicable diseases [8]. Research in various countries shows that most children who are stunted at an early age can experience catch-up growth after 2 years until they are teenagers, so they do not experience stunting in adulthood [9]. Children can still grow into not stunted adults if they continuously receive optimum nutritional intake and rarely experience infectious diseases in the catch-up period after 2 years. However, this growth will still not be as optimal as children who are not stunted [10].

A study shows that children who have catch-up growth after experiencing growth disruption or previous malnutrition conditions are at risk of declining cognitive abilities compared to normal children. Another report also shows that children who are not stunted in the first 1000 days of life who experience a decrease in HAZ Z-scores at the age of 5 years or called failure to thrive have lower cognitive abilities than children who have never been stunted [11]. The relationship between catch-up growth and cognitive function remains unclear. A cohort study conducted by Crookston *et al.* (2011) [12] who showed that children who experienced catch-up growth had the same cognitive scores as children who had never experienced stunting. Another study from Guatemala found that catch-up growth early in life (0–2 years) was predicted to reduce female achievement in adulthood [13]. Another study showed that children who successfully underwent catch-up growth early in life had lower cognitive scores than children who had never experienced stunting. However, the cognitive scores of children who experienced catch-up growth were higher than stunted children during the study period [11], [14].

At present, research in Indonesia only assesses the relationship between stunting or HAZ Z-scores with cognitive abilities using a cross-sectional design. Therefore, it is necessary to conduct a longitudinal study to determine catch-up growth in children when they reach the age of 3–5 years. In addition, this study also aims to see how the effect of catch-up growth on cognitive abilities after other factors is controlled.

Methods

This study has received ethical approval from the ethics committee of research and public health

service, University of Indonesia No: Ket-459/UN2.F10.D11/PPM.00.02/2021 and was conducted from April to September 2021. This study used secondary data from the Indonesia Family Life Survey (IFLS). Our research focuses on wave two, three, and four IFLS data; 1997, 2000, and 2007, respectively. The three survey years were chosen because the distance between the years of data collection is in accordance with our study objectives. This study used a retrospective observational cohort study design. Observations of catch-up growth of children were focused on two periods of analysis year; when children aged 0–23 months in 1997 and aged 3–5 years in 2000. Cognitive abilities were observed when children were in school age, 10–12 years in 2007.

We used multistage random sampling (according to the IFLS dataset), with the study sample which was children aged 0–23 months in 1997. The sample was determined purposively by meeting the inclusion criteria. The inclusion criteria for this study were (1) children who had complete baseline data on individual characteristics, parents, household, and living environment, (2) children with complete body length, weight, and birth weight data in 1997 and 2000, and (3) children have cognitive ability data in 2007. Based on the inclusion criteria, the sample size was 537 children from the total sample of children under 5 in 1997 which was 1215 children.

The dependent variable is a cognitive ability score based on data from the measurement results using the Raven's Colored Progressive Matrices method and mathematical ability. The questionnaire for measuring cognitive abilities consists of several questions using Raven's Colored Progressive Matrices is contained in the book EK 1 (measurement of logical development aged 7–14 years) in 2007. The main independent variable is catch-up growth, with the definition used which is the change in HAZ. A child is categorized as having catch-up growth if they recover from stunting (stunting recovery) [11]. Children with catch-up growth are observed by comparing the LAZ or HAZ measured in 1997 with 2000. Other variables analyzed in this study are cognitive abilities, such as children, parents, household socioeconomics, and living environment.

The group of children in this study at baseline was divided into two – stunting and normal children. Then, when children aged 3–5 years are grouped into four categories based on changes in the HAZ Z-score value and grouped into stunting non-catch-up growth (stunting during observation), stunting catch-up growth (stunting to normal), normal non-catch-up growth (normal to stunting), and normal during observation. Thus, the study begins with creating data sets and retrieval on the three waves of IFLS data. Furthermore, statistical analysis is carried out to prove the existing theory with the research conducted. Finally, bivariate data analysis was used to see the relationship between variables using the one-way analysis of variance test and multivariate analysis using the generalized linear model.

Results

The results of the univariate analysis were carried out to describe the characteristics of the sample and the variables observed in this study. Results are presented in frequency and percentage distributions for categorical variables and mean \pm standard deviation for numerical variables. The characteristic data of the sample in this study are shown in Table 1. Children's cognitive abilities in this study were measured using the Raven's Colored Progressive Matrices Questionnaire and Mathematics test, consisting of 17 questions. The average cognitive score of children aged 10–12 years in this study was 12.31 points, equivalent to an average cognitive ability percentage of 70.58%. If cognitive abilities are categorized based on the mean value, it is found that 52.3% of children have cognitive scores above the average. The percentage of stunting children who experienced catch-up growth was 14.74%, non-catch-up stunting was 26.68%, normal non-catch-up (late incident) was 20.15%, and normal children throughout the observation were 38.43%. This study used the distribution of children in four categories of stunting recovery status as a catch-up growth variable. The frequency distribution of the catch-up growth variable is shown in Table 2.

The study data distribution shows that the stunting prevalence in children aged 0–23 months is 41.53%, and this figure has increased by 5.3 points when children are 3–5 years old (46.83%). In our observations, the age group of children showed that most of the children were in the age group of 12–23 months (49.72%) in 1997 and aged 36–47 months (50.47%) in 2000. The child factor variables analyzed were stunting status, gender, birth weight, head circumference, history of infection, hemoglobin level, duration of breastfeeding, complementary feeding, and complete basic immunization. Most of the study samples were female (51.40%) with a history of low birth weight of 21.56%. Most of the children had a head circumference Z-score in the normal category (78.73%) and had no history of infectious diseases such as diarrhea, acute respiratory infections, and helminthiasis (72.44%). Some of the children had their hemoglobin levels measured at 0–23 months and found an average blood hemoglobin level of 10.2 mg/dL. The average duration of breastfeeding was 10 months, and only 29.8% of children were breastfed for <6 months. Children who were given the first food <6 months were 62.57%, where most of the mothers gave honey or bananas when the child was only 2–4 months old. The basic immunization history was seen from the completeness of the children receiving immunizations for hepatitis, BCG, Polio, DPT-HB, and measles. The results of this study indicate that basic immunization was not given to the 372 Indonesian children (69.27%) who were the sample of this study.

Table 1: Characteristics of study participants

Variables	Category	Mean/n	SD/percent	Total
Cognitive ability scores (10–12 years)		12.31 (70.58%)	2.8	537
Catch-up growth (0–5 years)	Normal	206	38.43	536
	Stunting catch-up	79	14.74	
	Normal not catch-up	108	20.15	
	Stunting not catch-up	143	26.68	
Child factors				
Stunting 0–2 years	Normal	314	58.47	537
	Stunting	223	41.53	
Stunting 3–5 years	Normal	285	53.17	536
	Stunting	251	46.83	
Sex	Male	261	48.60	537
	Female	276	51.40	
Birth weight	Normal	421	78.44	537
	Low	116	21.56	
Head circumference (Z-score)	Normal	422	78.73	536
	Small	114	21.27	
Infection 0–2 years	No	389	72.44	537
	Yes	148	27.56	
Hemoglobin level 0–2 years		10.2	1.41	466
Duration of breastfeeding		10.62	6.88	537
Complementary food	≥ 6 months	201	37.43	537
	<6 months	336	62.57	
Basic immunization 0–2 years	Yes	165	30.73	537
	No	372	69.27	
Parental factors				
Father's education	No school	26	5.37	484
	Elementary school	224	46.28	
	Junior high school	78	16.12	
	Senior high school	120	24.79	
	College	36	7.44	
Mother's education	No school	32	5.96	537
	Elementary school	287	53.45	
	Junior high school	89	16.57	
	Senior high school	109	20.3	
	College	20	3.72	
Mother's height		149.8	5.18	537
Father's nutritional status (BMI/Age)	Underweight	56	13.43	417
	Normal	308	73.86	
	Overweight	53	12.71	
Mother's nutritional status (BMI/Age)	Underweight	77	14.34	537
	Normal	391	72.81	
	Overweight	69	12.85	
Gestational age	Aterm	495	92.18	537
	Preterm	42	7.82	
Number of parity		2.88	2.06	537
Father's occupation	Entrepreneur	192	39.67	484
	Government employee	36	7.44	
	Private sector employee	177	36.57	
	Unpaid family work	79	16.32	
	Entrepreneur	70	13.04	
Mother's occupation	Government employees	18	3.35	537
	Private sector employee	56	10.43	
	Unpaid family work	393	73.19	
Household socioeconomic factors				
Household income	Quartile 4 (High)	134	24.95	537
	Quartile 3 (Good)	130	24.21	
	Quartile 2 (Medium)	138	25.7	
	Quartile 1 (Low)	135	25.14	
	Quartile 4 (Good)	134	24.95	
Wealth index	Quartile 3 (Medium)	134	24.95	537
	Quartile 2 (Lower)	135	25.14	
	Quartile 1 (Poor)	134	24.95	
Environmental factors				
Housing area	Rural	313	58.29	537
	Urban	224	41.71	
Father's smoking habit	No	172	35.54	484
	Yes	312	64.46	
Mother's smoking habit	No	533	99.26	537
	Yes	4	0.74	
Drinking water	Other than	420	78.21	537
	Bottled/tap water	117	21.79	
Defecation facilities	Yes have	211	39.29	537
	Do not have	326	60.71	

BMI: Body mass index.

Parental factors and household socioeconomic status observed in this study are father and mother's education, mother's height at birth, nutritional status of father and mother, gestational age, parity, father and mother's occupation, monthly household income, and household wealth index. The education level of parents is divided into five categories according to IFLS data, namely, no school, elementary school, junior high school, high school, and college. For the level of education of fathers and mothers when children are 0–23 months old, the most education is up to elementary school. The mean height of the mother during childbirth is 149.8 cm. The nutritional status of the father and mother was measured by looking at the body mass index (BMI) by age or BMI for age. Fathers and mothers of children aged 0–23 months had normal nutritional status with a percentage of 73.86% and 72.81%, respectively. Maternal gestational age of children <2 years old was in the term category (92.18%). The average number of deliveries experienced by mothers in this study sample was 2–3 deliveries. The occupations of fathers of children <2 years old are mostly entrepreneurs and private employees, while mothers of children <2 years old are mostly household moms. The income category and household wealth index were spread over four levels and had almost the same proportions, so no distinct group stands out in the household socioeconomic category.

Table 2: Distribution of catch-up growth category

Catch-up growth category	Boys	Girls	n	%
Normal	97	109	206	38.43
Stunted catch-up	47	32	79	14.74
Normal non catch-up (late incident)	53	55	108	20.15
Stunted non catch-up	64	79	143	26.68

The environmental factors observed in this study are the housing area – divided into a rural and urban area, smoking habits of parents, sources of drinking water, and defecation facilities in the household. In 1997, 58.29% of households with children aged 0–23 months were in rural areas. Almost all children aged 2 years have a father who used to smoke (64.46%). Most of the family's drinking water sources come from wells and do not consume bottled or tap water. Defecation facilities are also only available for 39.19% of households with children aged 0–23 months.

The statistical analysis of the relationship between variables showed that catch-up growth in early childhood was significantly related to the cognitive abilities of school-age children (10–12 years; $p = 0.0002$). Stunting status at the age of 0–23 months ($p = 0.0075$) and age 3–5 years ($p = 0.0001$) was significantly correlated to the cognitive abilities of school-age children. Children who are stunted at an early age have lower cognitive abilities than normal children at the age of 0–23 months. Factors that had a significant relationship with children's cognitive abilities were head circumference Z-score ($p = 0.0484$), hemoglobin level ($p = 0.002$), duration of breastfeeding ($p = 0.044$), and history of basic immunization (0.0409). For the variables of gender, birth weight, and history of

infectious diseases, giving children complementary foods were not statistically related to the cognitive abilities of school-age children (10–12 years) in this study. Factors from parents and household socioeconomics that were significantly related to children's cognitive abilities were father's education ($p = 0.000$), mother's education ($p = 0.000$), parity (0.002), father's occupation (0.032), wealth index level (0.001), and households income per month (0.001). The cognitive abilities of children whose fathers and mothers have higher education are significantly different when compared to children whose fathers and mothers do not attend school and only finish elementary and junior high school.

Factors related to the area of residence that was significantly related to cognitive ability were housing area ($p = 0.0072$), father's smoking habit ($p = 0.0006$), family drinking water sources ($p = 0.0397$), and defecation facilities ($p = 0.0001$). Thus, most children living in rural areas have lower cognitive abilities than children in urban areas. The analysis of cognitive ability variables with independent variables in the form of stunting status was carried out utilizing catch-up growth defined as the condition of recovery from stunting. The analysis is shown in Table 3.

Table 3: Analysis of factors related cognitive ability

Variable	Category	Mean±SD	p-value	95% CI	
				Lower	Upper
Catch-up reference: Normal			0.0002		
Stunting 0–23 months	Normal	12.59 ± 1.71	0.0075	12.29	12.89
	Stunting	11.92 ± 3.04		11.52	12.32
Stunting 3–5 years	Normal	12.78 ± 2.53	0.0001	12.48	13.07
	Stunting	11.78 ± 3.14		11.39	12.17
Sex	Male	12.21 ± 2.76	0.4068	11.87	12.54
	Female	12.41 ± 2.97		12.06	12.76
Birth weight	Normal	12.36 ± 2.84	0.1198	12.11	12.6
	Low	11.46 ± 3.24		10.15	12.77
Head circumference (Z-score)	Normal	12.44 ± 2.81	0.0484	12.17	12.71
	Small	11.84 ± 3.04		11.27	12.4
Infection 0–2 years	No	12.29 ± 2.89	0.9237	11.82	12.76
	Yes	12.32 ± 2.86		12.03	12.6
Hemoglobin level 0–2 years			0.002		
Duration of breastfeeding			0.044		
Complementary food	≥6 months	12.38 ± 2.86	0.4637	12.07	12.69
	<6 months	12.19 ± 2.88		11.79	12.6
Basic immunization 0–2 years	Yes	12.69 ± 2.81	0.0409	12.26	13.12
	No	12.14 ± 2.88		11.85	12.44
Father's education			0.0000		
Mother's education			0.0000		
Mother's height				0.121	
Father's nutritional status (BMI/Age)			0.3837		
Mother's nutritional status (BMI/Age)			0.6947		
Gestational age	Aterm	12.32 ± 2.88	0.8979	12.06	12.57
	Preterm	12.26 ± 2.72		11.41	13.11
Number of parity			0.002		
Father's occupation			0.032		
Mother's occupation			0.096		
Wealth index			0.0001		
Household income (per months)			0.0001		
Housing area	Rural	12.03 ± 2.96	0.0072	11.7	12.36
	Urban	12.7 ± 2.69		12.35	13.06
Father's smoking habit	No	12.97 ± 2.7	0.0006	12.56	13.38
	Yes	12.03 ± 2.94		11.7	12.36
Mother's smoking habit	No	12.3 ± 2.87	0.6333	12.06	12.55
	Yes	13 ± 2.16		9.56	16.43
Defecation facilities	Yes have	12.92 ± 2.64	0.0001	12.56	13.28
	Do not have	11.92 ± 2.94		11.59	12.24
Drinking water	Other than	12.18 ± 2.94	0.0397	11.89	12.46
	Bottled/tap water	12.79 ± 2.57		12.32	13.26

Discussion

Cognitive ability is a construction of thinking processes including remembering, solving problems, learning, understanding ideas, planning, and decision-making from childhood to adulthood [15]. Thus, childhood is a critical period for the growth and development of cognitive abilities, assessed by academic achievement. Children's cognitive abilities are influenced by multifactor consisting of underlying factors (life in early pregnancy, gender, and genetic factors), socioeconomic factors (education, occupation, and income), behavioral factors (food intake, physical activity, and availability of health services), environmental factors (physical and social environment), and individual factors (physical and psychological factors) [16].

There are several definitions of catch-up growth in the literature because there is debate about the extent to which a child can be said to have succeeded in reaching the catch-up growth period [17], [18], [19]. Catch-up growth describes a phase of rapid growth that allows a child to accelerate growth until he fully recovers his genetic growth rate. Postnatal normal growth is a condition resulting from the interaction of endogenous factors, hormones, genetics, and exogenous factors that affect growth [20].

Cognitive ability is directly or indirectly influenced by nutritional status. A study was conducted to observe the height growth pattern of children aged 1 and 8 years with cognitive achievement and learning performance in school. The four groups of children compared were children who grew normally (never stunted), children who experienced recovery (stunting at the age of 1 year and not stunting at the age of 8 years), children who experienced growth faltering (not stunting at the age of 1 year and stunting at the age of 8 years), and persistent stunting (stunting at the age of 1 year and still stunting at the age of 8 years). Cognitive achievements and performance of children who experienced recovery were better than children who were persistently stunted. However, in general, cognitive achievements are different from children who experience growth faltering [21].

Definition of catch-up growth used in this study is the child experienced a recovery from stunting such that HAZ at 5 years fell within the "normal" range [11]. This study showed that stunted children who experienced catch-up growth at the age of 3–5 years had better cognitive ability scores at the age of 10–12 years compared to children who did not experience catch-up growth. The cognitive scores of children with catch-up growth and normal non-catch-up stunting were lower than the cognitive scores of normal children aged 0–59 months but not statistically significant. Based on a study conducted in South Africa, children who were stunted at the age of 2 years who later experienced catch-up growth, on average, had lower cognitive test results compared to children who

had never been stunted. Thus, children who experience catch-up growth have different cognitive scores from children who do not experience catch-up [11].

The study results in several developing countries state that children's cognitive abilities must be considered starting from the prenatal period and pay attention to children's nutritional intake until the age of 8 years [22]. This finding needs to be taken into account because there is a possibility that children will succeed in pursuing their growth and improving their cognitive abilities. Several studies have shown that stunting in the first 1000 days of life will have a major effect on the cognitive abilities of schoolchildren to adults if not given the right intervention. This study finding indicates that stunting has a significant relationship with children's cognitive abilities. Stunting children in the first 1000 days of life have lower cognitive scores than normal children.

Several catch-up growth studies in low-middle-income countries (LMICs) report that growth without intervention in poor and developing countries impacts inconsistent catch-up growth conditions. So that several studies in LMIC show that there has been an increase in stunting while several other countries have reported a decrease in stunting. Children who are stunted at an early age may impact catch-up growth or non-catch-up conditions as adults [9]. Children who experience catch-up growth after being stunted have average cognitive test results at the age of 5 years lower when compared to children who have never been stunted. However, there is an exception to this finding, where children who experience growth spurts between the ages of 2–5 years will achieve normal growth with a HAZ value ≥ -1 SD, so that at the age of 5 years, the average score on the child's cognitive test is almost the same with normal children. Hence, it is important to pay attention to children's growth after 2 years of age because many present studies have found that children's growth can still be improved after 2 years of age [11].

This study found that head circumference and hemoglobin levels of early childhood influence cognitive abilities of school age (10–12 years). A greater head circumference at birth is associated with better cognitive abilities in childhood. These abilities include learning abilities, long-term and short-term memory, and visuospatial [23]. In addition, head circumference and brain volume are positively correlated with children's cognitive abilities, where subjects with very low head circumferences usually have below-average brain volumes [24]. Therefore, measuring the head circumference, especially at 4 years of age, is suitable for predicting total brain growth and neurodevelopment for a child's cognitive development.

Low hemoglobin levels will have an impact on the occurrence of anemia. Anemia is a problem that must be considered because it is closely related to cognitive abilities. The cause of anemia is inadequate Fe intake. Fe deficiency conditions in the body will

affect hemoglobin levels because hemoglobin is a protein that contains most of the iron [25]. Low levels of hemoglobin in the body in children have the effect of decreasing cognitive abilities. Therefore, giving iron (Fe) supplementation to pregnant women is highly recommended so that children born do not lack Fe and cause a decrease in hemoglobin levels. Good hemoglobin levels in the body during early childhood can improve children's cognitive abilities at school age [26].

The duration of exclusive breastfeeding has a significant effect on increasing children's cognitive abilities. A longitudinal study on children in South Korea showed a positive correlation between breastfeeding duration and Mental Development Index scores. These results indicate that the long duration of breastfeeding affects increasing the child's cognitive development [27]. Cognitive abilities in babies who are breastfed are better and have a faster body response than babies who are not breastfed. Other factors that affect cognitive abilities are a history of childhood disease and genetic factors. However, in this study, the history of childhood infection at the age of 0–23 months was not significantly associated with cognitive abilities. The history of the child's illness will impact metabolic disorders and malnutrition so that there is a risk of reducing cognitive abilities [28].

In addition to child factors, parental factors, household socioeconomics, and living environment are related to the cognitive abilities of school-age children. Several studies have shown that the socioeconomic status of adults, such as education, income, and employment, is protective factors against the decline in children's cognitive abilities in a family [16]. The results of a 2020 study with observations of 3–18 years in children to adolescents concluded that avoiding exposure to cigarette smoke children and adolescents will be able to improve cognitive function in adulthood [29]. The findings support our study's results that children under 2 years of age whose fathers smoke have lower cognitive abilities than children whose fathers do not smoke.

The type of fuel used for cooking, sources of drinking water, home sanitation facilities, and household wealth index, which are built as proxies for household economic status, are associated with improving children's nutritional status and preventing stunting. Prevention of stunting in the long term will be associated with cognitive improvement in children. This variable is formed from an inventory of household facilities and assets using Principal Component Analysis [30]. In our study, family welfare index, drinking water sources, and defecation facilities were significantly related to cognitive abilities.

Other studies mention factors that affect cognitive abilities are the environment in which they live and the nutritional adequacy of the family. Children aged 7–18 years in the developing countries have

low cognitive, motor and social development due to malnutrition, poverty, poor health services, and low stimulation from the environment. Malnourished children in Indonesia tend to have poor performance in school and ultimately reduce academic ability and productivity in adolescence and adulthood [31]. However, the study has limitations, where the relationship between children's food intake and cognitive abilities was not observed in this study. This condition might be because, in IFLS secondary data, food intake is not measured in children under 5. In addition, monitoring of weight and height also does not perform every year.

Recommendation

From this study, it can be suggested to conduct additional feeding interventions and monitoring nutritional status regularly in stunted children after 2 years because many studies have found that children's growth can still be improved after 2 years of age. Catch-up growth in children can improve cognitive status from school age to adulthood. In addition, support from parents and the household environment in improving the nutritional status of children is also very much needed.

Conclusion

Catch-up growth in early childhood affects the cognitive abilities of school-age children (10–12 years). Stunting children who experience catch-up growth have higher cognitive abilities than non-catch-up stunting children. In addition, from the results of our study, the most influential factors on cognitive ability were catch-up growth, stunting status of children at an early age, duration of breastfeeding, number of parity, father's education, father's occupation, and father's smoking habit.

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