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The effect of early childhood stature on later cognitive functions in Indonesian adolescents: comparation using the National growth reference and the WHO growth standard

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Abstract

Background The prevalence of short stature in children under 5 using the National Growth Reference vs. the WHO Growth Standard is known to vary in many countries. Previous research has suggested possible associations between short stature early in childhood, frequently regarded as stunting, and later cognitive function.

Objective This study aimed to identify the effect of early childhood stature, using the National Indonesian Growth Chart (NIGC) vs. the WHO Growth Standard (WHO), on cognitive function in adolescence.

Methods The study used two cohort data from the Indonesia Family Life Surveys (IFLS) that had both anthropometric data at the age of 2–5 years and at adolescence, as well as information on cognitive function at adolescence. At the age of 2–5 years, the height-for-age Z-score (HAZ) of the subjects were classified using both NIGC and WHO as follows: Normal NIGC & Normal WHO; Normal NIGC & Short WHO; and Short NIGC & Short WHO. In adolescence, cognitive function were assessed. An analysis was performed to assess the associations between variables.

Results Cohort-1 included 866 subjects with complete information, while Cohort-2 included 1,436 subjects. After adjustment, subjects aged 2 to 5 years classified as Short NIGC & Short WHO had a consistent significantly negative effect on their later adolescent cognitive function: coefficient regression (95%CI): -2.82 {(-5.58)-(-0.06), $p = 0.046$}for Cohort-1 and −4.13 {(-7.22)-(-1.04), $p = 0.009$} for Cohort-2. On the other hand, those classified as Short for WHO but Normal for NIGC were not associated with later negative cognitive function: coefficient regression (95%CI): -1.88 {(-4.00)- 0.24, $p = 0.082$} for Cohort-1 and −1.32 {(-3.50)-0.87, $p = 0.237$} for Cohort-2. Cognitive function of both cohorts was also significantly influenced by the subjects' education, parental education and resicence in urban and Java-Bali ($p < 0.05$).

Conclusions Childhood stature was associated with later negative cognitive function only when the children were classified as short using NIGC. Classified as short stature using WHO, but not short using NIGC, was not associated with later negative cognitive function.

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Clinical trial number Not applicable.

Keywords Early childhood stature, National Indonesian growth chart, WHO growth standard, Cognitive function, Adolescent

Introduction

Previous studies have reported disagreements in the prevalence of short stature in children when WHO Growth Standard 2006 were contrasted with local or national growth references. In several countries such as Saudi Arabia, Zimbabwe, Pakistan, India, Thailand and Indonesia, the WHO Growth standard 2006 detected higher– sometimes a lot higher -- prevalence of children whose height-for-age z-scores (HAZ) were below −2 standard deviation. On the other hand, in most European countries, WHO Growth Standard 2006 failed to detect a lot of short children when compared to the local or national references [1–5].

This disagreement in the prevalence might have enormous public health consequences since in the developing countries, short stature early in childhood was often interpreted as stunting, i.e. impairment in linear growth associated with poor health or nutritional condition (WHO, 2014). As stunting was believed to be related to poor cognitive development, children who were shorter than certain z-score cut-offs were often believed to be at risk for impaired cognitive development later in life [6–10].

Previous studies on the relationship between early childhood height and later cognitive function have shown conflicting results. A meta-analysis from studies in low-to middle-income countries observed that, after multivariate adjustment, HAZ in children under two years of age was positively associated with cognition at the age of five to eleven [11]. Several previous studies showed similar results [12–14]. Studies in Brazil, Guatemala, the Philippines, and South Africa, showed that early life height was positively correlated with adult cognitive functioning, however, the association was diminished by the individuals' educational attainment [15]. On the other hand, previous study from Indonesia failed to show association between short stature in children ages 0 to 3 years with cognitive function at the ages of 7 to 10 years [16]. Similar studies in Malawi and in 8 LMCs (Bangladesh, Brazil, India, Nepal, Peru, Pakistan, South Africa, and Tanzani) had also reported no association between stature early in life with later cognitive functions [17, 18].

Cognitive functions begin to develop in infancy and more specific functions maturing through early childhood. Each component of cognitions develops at its own pace across childhood and adolescence. Some abilities, continue to improve into young adulthood before gradually declining later in life [19, 20].

Therefore, we aimed to see the association between early childhood stature and cognitive function in adolescence, and also to further see whether difference in cut offs of short stature might result in different outcomes. As the National Indonesian Growth Chart (NIGC) had lower cut-offs for short stature than the WHO Growth Standard (WHO) 2006, we wanted to compare which cut off better predicts possibility of future cognitive impairment. We used data of children age 2–5 years old as the parameter of early childhood linear growth as many studies had observed stabilization in HAZ at these ages after previous persistent faltering in height, as compared to the international growth standard [21].

Methods

This study used data from four IFLS (Indonesia Family Life Surveys) waves: 1993–1994, 2000, 2007, and 2014 performed by The RAND Corporation in partnership with Universitas Indonesia and Universitas Gadjah Mada. The sample represented approximately 83% of the Indonesian population living in 13 of Indonesia's 26 provinces [22–25].

For this study, two-separate cohorts were identified. Cohort-1 used data of children aged 2 to 5 years in IFLS 1993–1994 and their follow up in IFLS 2007 when they had reached adolescence. Cohort-2 used IFLS 2000 for information in childhood, while their follow up in adolescence used data from IFLS 2014 [22, 23].

Childhood heights were converted into height-for-age Z-score (HAZ) using the National Indonesia Growth Chart (NIGC) and the WHO Growth Standard (WHO). HAZ for WHO was calculated using the Zanthro Stata command (Stata/MP 14.0) [26]. HAZ for NIGC was calculated using their LMS data [27].

HAZ of less than −2 was considered as short stature. Using both growth references, a child could be classified as "Normal NIGC - Normal WHO" when both HAZ were above or at -2; "Normal NIGC - Short WHO" when he/ she had HAZ above or at -2 for NIGC and below −2 for WHO; and "Short NIGC - Short WHO" when both NIGC and HAZ were below −2. As the cut off for −2 was lower for NIGC, no child had NIGC below −2 and WHO above −2.

Cognitive function was measured using Raven's Colored Performance Matrices modification (Raven) and math scores in IFLS 2007 and 2014. Raven's Colored Performance Matrices modification (Raven) used eight pictorial questions for subjects aged 15–24 years old (Raven 15–24). Math scores consisted of five questions. Each question had to be answered with true/false. Cognitive function scores were defined as the percentage of correct answers on both the tests. We divided all correct answers by total number of questions (thirteen) [24, 25].

We also retrieved available sociodemographic information such as parental education, urban or rural living, living on the island of Java-Bali or outer, as well as the household economy status. This information was retrieved from the databases of the start of the cohort (waves 1993–1994 and 2000) and of the end of the cohort (waves 2007 and 2014). We analyzed all gap information between baseline and follow-up data using the baseline data for the priority data. From the databases at the end of the cohort we also retrieved information on the subjects' education and marital status [24, 25].

Table 1 Characteristics of the subjects at the start of the cohort (Cohort 1 vs. Cohort 2)

	Cohort 1 (1993–2007)	**Cohort 2 (2000–2014)**	
	(*N* = 1,485)	**(*N* = 1,986)**	**p**
Cognitive score (mean, SD)	78.9 (15.0)	63.7 (19.9)	< 0.0001
Sex			
● Female	693 (46.7)	988 (49.8)	
● Male	792 (53.3)	998 (50.2)	0.076
Age in childhood (years) (mean, SD)	3.54 (0.9)	3.55 (0.8)	0.4899
Number of household members (n, SD)	7 (3)	7 (3)	1.00
Education (n,%)			
● Low (< = 9 years)	531 (35.8)	481(24.2)	
● High (> 9 years)	954 (64.2)	1,505 (75.8)	< 0.0001
Marital status (n,%)			
● Not married	1,317 (95.2)	1,705 (93.3)	
● Married	67 (4.8)	122 (6.7)	0.0186
Household food expenditure share (n, %)			
● High (< 0.2)	805 (54.2)	1,065 (53.6)	
● Low (≥0.2)	680 (45.8)	921 (46.4)	0.7258
Residence (n, %)			
● Rural-Outside Java Bali	378 (25.5)	509 (25.6)	
● Rural-Java Bali	420 (28.3)	580 (29.2)	
● Urban-Outside Java Bali	247 (16.6)	272 (13.7)	
● Urban-Java Bali	440 (29.6)	625 (31.5)	0.1068
Parental Education[1] (n, %)			
● Basic Father - Basic Mother	721 (48.6)	760 (38.3)	
● High Father - Basic Mother	151 (10.2)	209 (10.5)	
● Basic Father - High Mother	251 (16.9)	342 (17.2)	
● High Father - High Mother	362 (24.4)	675 (34.0)	< 0.0001
WHO Growth Standard 2006			
● HAZ (mean, SD)	-2.02(1.36)	-1.79 (1.36)	< 0.0001
National Indonesian Growth Chart			
● HAZ (mean, SD)	-0.77 (1.36)	-0.53 (1.35)	< 0.0001
Classification of stature (n, %)			
● NIGC & WHO ≥ -2 SD	678 (45.7)	1,095 (55.1)	
● NIGC ≥ -2 SD & WHO <-2 SD	546 (36.8)	643 (32.4)	
● NIGC & WHO <-2 SD	261 (17.6)	248 (12.5)	< 0.0001

HAZ = height for age z score; NIGC = National Indonesian Growth Chart; WHO = WHO Child Growth Standard 2006. [1]Parental education were classified into basic education i.e. 9 years of schooling or less and high-level education, i.e. more than 9 years of education

We used the definition of the Indonesian Bureau of Statistics to classify area of residence into rural or urban. The classification were based on the size of the area, the population's size and density, the main occupation of its people, and the availability of public facilities. Educational levels were classified into basic education i.e. 9 years of schooling or less and high-level education, i.e. more than 9 years of education [28]. Household economy was defined using household food expenditure share, the lower the food expenditure share, the higher the economic status. Families with household food expenditure shares less than 0.2 were considered to have high economic status, otherwise classified as low economic status [29].

Statistical analyses

Continuous variables were presented as means (SDs), while categorical variables were presented as percentage. Univariate and multivariate linear regression analysis, i.e. either from complete and imputed data, were performed to assess the regression coefficients of predictors of cognitive functions in adolescence. Multiple data imputations were performed using Stata multiple imputation reference manual release 18 [30]. Statistical analyses were performed using STATA/SE 16.1 with a 95% confidence interval (CI).

Results

We included informations from 3,471 subjects aged 2–5 years: 1,485 subjects from Cohort-1 and 1,986 subjects from Cohort-2. Out of those subjects, 866 subjects (58%) of Cohort-1 and 1,436 subjects (72%) of Cohort-2 had complete follow-up data. Subjects of cohort-1 and of cohort-2 had comparable characteristics at the start of the cohorts (Table 1). The baseline characteristics between Cohort 1 and Cohort 2 were comparable in terms of sex, age, number of household members, proportion of household food expenditure share, and place of residence of the subjects. Characteristics varied in parental education, height for age z-score based on WHO and NIGC, and classification of short stature. Subjects who had complete follow up data had also comparable characteristics with those who had missed follow up or had incomplete information at follow up. Imputation for results of the cognitive function test were performed on 619 subjects (42%) of Cohort-1 and 550 subjects (28%) of Cohort-2. Informations on marital status were imputed in 84 subjects (6%) of Cohort-1 and 386 subjects (19%) of Cohort-2.

Subjects aged 2 to 5 years classified as short by both the NIGC and the WHO 2006 had consistent and significant negative associations with their adolescent cognitive function, i.e. coefficient regression (95%CI) of -2.82 {(-5.58) to (-0.06)}, $p = 0.046$ for Cohort-1 and −4.13 {(-7.22) to (-1.04)}, $p = 0.009$ for Cohort-2, respectively. On the other hand, classification as short for the WHO 2006 but not short for the NIGC did not have significant associations with later cognitive function in both cohorts, i.e. coefficient regression (95%CI) of -1.88 {(-4.00)- 0.24}, $p = 0.082$ for Cohort-1 and −1.32 {(-3.50)-0.87}, $p = 0.237$ for Cohort-2. Other variables significantly influencing adolescent cognitive functions were the subjects' level of education, parental education and places of residence (rural vs. urban or Java-Bali vs. outer Java-Bali ($p < 0.05$) (Table 2). Similar findings were observed when dataset with multiple data imputation were used (Table 3).

Discussion

This study showed that using the NIGC and the WHO Growth Standard/Reference would lead to different results in the assessment of linear growth and also in the prevalence of short stature. There is a discrepancy of more than 30%. Several previous studies in Indonesia demonstrated similar results [4, 27, 31–33]. Other findings in children in Southeast Asia also indicated that using WHO growth standards/references resulted in increased diagnosis short stature [2, 5, 34]. Also, our study showed that HAZ was different using both curves. As mentioned in previous studies, the difference between the two curves was more than +1 SD [4, 31].

Our study classified stature into 3 groups: (Normal NIGC & Normal WHO), (Normal NIGC & Short WHO), and (Short NIGC & Short WHO). The stature was worst affected in third category and was more severe than the first and second. Classifying linear growth into more than two categories (stunted or not-stunted) would possibility help in better assessement of the impact of stunted growth severity [35]. Our study has revealed that the use of NIGC provides evidence that short stature in children aged 2 to 5 years consistently had negative impacts on later cognitive function in adolescents. Short stature in the second category (Normal NIGC-Short WHO) was not associated with cognitive function, either in complete data or in imputation analysis (Tables 2 and 3). A meta-analysis study in 29 low-and-middle income countries explained the positive and small association between linear growth in children under 2 years of age and cognitive function at 5 to 11 [11]. A previous study, which also used IFLS data and the WHO growth standard to assess

Table 2 Multiple linear regression of association between childhood stature classification and adolescent' subsequent cognitive function on subjects with complete follow-up

	Cohort-1, *n* = 866 (1993–2007)			**Cohort-2, *n* = 1,436 (2000–2014)**		
	Coef.	**95% CI**	***p***	**Coef.**	**95% CI**	***p***
Classification of early childhood stature (2–5 y.o)						
● NIGC & WHO ≥-2 SD	ref.			ref.		
● NIGC ≥ -2 SD & WHO <-2 SD	(-1.88)	(-4.00) - (0.24)	0.082	(-1.32)	(-3.50)– 0.87	0.237
● NIGC & WHO <-2 SD	(-2.82)	(-5.58) - (-0.06)	**0.046**	(-4.13)	(-7.22)– (-1.04)	**0.009**
Age (years)	0.38	(-0.60) -1.37	0.443	0.21	(-0.89)-1.30	0.711
Gender (female as ref.)						
● Male	(-0.42)	(-2.34)– 1.51	0.669	(-2.00)	(-3.98)-(-0.01)	0.049
Marital Status (not married as ref.)						
● Married	(-2.77)	(-7.71)– (2.17)	0.271	(-8.44)	(-12.70) - (-4.17)	**0.000**
Areas and Islands group (Urban Java-Bali as ref.)						
● Rural-Outer Java-Bali	(-6.46)	(-9.12) - (-3.81)	**0.000**	(-4.52)	(-7.23)–(-1.81)	**0.001**
● Rural- Java-Bali	(-4.39)	(-7.00) - (-1.81)	**0.001**	(-0.61)	(-3.17)-1.96	0.642
● Urban-Outer Java-Bali	(-2.90)	(-5.80)-(-0.003)	**0.050**	(-4.18)	(-7.45)-(-0.92)	**0.012**
Household food expenditure share[1] (high as ref.)						
● Low	(-0.86)	(-2.81)– 1.09	0.384	(-0.61)	(-2.64)-1.42	0.555
Subjects' education (high education as ref.)[2]						
● Basic education	(-6.43)	(-8.53)– (-4.32)	**0.000**	(-10.01)	(-12.34)-(-7.68)	**0.000**
Parental education level[2] (High-father & High-mother as ref.)						
● Low-father & Low-mother	(-4.07)	(-6.59)-(-1.56)	**0.002**	(-4.15)	(-6.69)-(-1.61)	**0.001**
● High-father & Low-mother	(-2.35)	(-5.82)-1.12	0.184	0.04	(-3.37)-3.46	0.980
● Low-father & High-mother	(-5.24)	(-8.40)-(-2.10)	**0.001**	(-4.07)	(-7.07)–(-1.06)	**0.008**
Adj. R2	0.136			0.125		

[1] Household food expenditure share: < 0.2 (high) and ≥ 0.2 (low)

[2] Parental education were classified into basic education i.e. 9 years of schooling or less and high-level education, i.e. more than 9 years of education

Table 3 Multiple linear regression of association between childhood stature classification and adolescent' subsequent cognitive function on subjects with complete follow-ups and those whose missing information were imputed

	Cohort-1, *n* = 1,485 (1993–2007)			Cohort-2, *n* = 1,986 (2000–2014)		
	Coef.	**95% CI**	***p***	**Coef.**	**95% CI**	***p***
Classification of early childhood stature (2–5 y.o)						
● NIGC & WHO ≥ -2 SD	ref.			ref.		
● NIGC ≥ -2 SD & WHO <-2 SD	(-1.61)	(-4.26) - (1.04)	0.224	(-1.35)	(-3.50) – 0.75	0.207
● NIGC & WHO <-2 SD	(-2.96)	(-5.70) - (-0.21)	**0.035**	(-4.32)	(-7.49)– (-1.15)	**0.008**
Age (years)	0.45	(-0.70) -1.59	0.431	(-0.51)	(-1.49)-0.47	0.307
Gender (female as ref.)						
● Male	(-0.44)	(-2.36)– 1.48	0.646	(-1.85)	(-3.75)-0.05)	0.056
Marital Status (not married as ref.)						
● Married	(-2.40)	(-7.62)– 2.82	0.356	(-7.94)	(-12.79) - (-3.10)	**0.002**
Areas and Islands group (Urban Java-Bali as ref.)						
● Rural-Outer Java-Bali	(-6.78)	(-9.42)–(-4.15)	**0.000**	(-4.07)	(-7.43) - (-0.71)	**0.019**
● Rural-Java-Bali	(-4.45)	(-6.62)-(-2.28)	**0.000**	(-0.82)	(-3.49)- 1.84	0.542
● Urban-Outer Java-Bali	(-2.39)	(-5.22)-0.44	**0.096**	(-2.85)	(-6.34) – 0.65	**0.108**
Household food expenditure share[1] (high as ref.)						
● Low	(-0.69)	(-2.40)– 1.02	0.427	(-1.08)	(-3.42)-1.26	0.356
Subjects' education (high education as ref.)						
● Basic education	(-6.69)	(-8.74)– (-4.65)	**0.000**	(-10.39)	(-12.67) - (-8.10)	**0.000**
Parental education level (High-father & High-mother as ref.)						
● Low-father & Low-mother	(-3.68)	(-6.14)-(-1.21)	**0.004**	(-3.38)	(-6.36)- (-0.41)	**0.027**
● High-father & Low-mother	(-2.17)	(-5.18)-0.84	0.156	(-0.08)	(-4.01)-3.85	0.966
● Low-father & High-mother	(-3.21)	(-6.11)-(-0.31)	**0.030**	(-3.19)	(-6.25)– (-0.13)	**0.041**

[1] Household food expenditure share: < 0.2 (high) and ≥ 0.2 (low)

[2] Parental education were classified into basic education i.e. 9 years of schooling or less and high-level education, i.e. more than 9 years of education

the association between stunted growth in children aged 0 to 3 years and later cognitive function on aged 7 to 10 years, did not show a significant association [16].

Our study provided evidence that the impact of linear growth on cognition depends on the severity of the growth stunting as other prior literature mentioned. Our results also supported the previous statement that utilizing a growth chart for a specific region can increase sensitivity in identifying linear growth affections in children with negative outcomes [2]. Our study supports the probability that, when national references are used, biological mechanisms underlie the impairment of linear growth in low- and middle-income countries to predict their subsequent cognitive function [36]. Subjects with short stature defined by using NIGC/national reference might be caused by pathological conditions such as malnutrition, chronic infection, chronic disease, prematurity, or intrauterine growth retardation. These pathological conditions could impair brain functional connectivity and cognitive outcomes as noted in a Bangladeshi study on the role of malnutrition and cognitive development [37]. Priority may be given to this group rather than assigning individuals with short stature as defined by the WHO growth standard.

Stunted growth according to the WHO growth standard would include short stature caused not only by malnutrition or chronic infection but also by other causes such as familial short stature, constitutional delay of growth, or the delayed catch-up period in small for gestational age subjects [38]. This was also explained by a previous study that dietary interventions were inappropriate for changes in height and that health programs monitoring using stunting prevalence, defined by WHO growth standard, was also ineffective [36]. We need further research to overcome all etiologies of stunted growth problems using NIGC and the effect on long-term cognitive function improvement.

Based on the data from previous 4 cohorts, there were partially shared correlates between linear growth and several development scores [39, 40]. It might explain why our study also found other factors that contributed to adolescents' cognitive function. Subjects' education, parental education and living in urban areas and Java-Bali were consistently associated with positive cognitive function.

Adjusted to other variables, the subjects' adolescent education showed the strongest coefficient correlation with their cognitive function. According to previous study conducted in Malawi, subjects' cognitive function at the age of 15 was influenced by school-related factors. This educational factor even eliminated the linear growth factor's influence on cognitive function at 15 years old (correlation coefficient 0.89; 95%CI 0.62–1.17) [41]. A previous prospective study in four birth cohorts identified the role of schooling on adult IQ. Schooling attenuated the effect of linear growth in children at aged 2 years on their adult IQ. The study also pointed out the role of children's IQ. Children's IQ and children's schooling have a significant influence on adult IQ [15]. Unfortunately, our study did not have data on children's IQ. IFLS (Indonesia Family Life Survey) did not conduct cognitive assessments in children younger than 5 years of age. Therefore, we were unable to demonstrate the role of cognition in children to their later cognitive function in adults.

The association between marital status and cognitive function shows inconsistent results. In Cohort 1, there was no significant relationship, whereas in Cohort 2, the association was statistically significant. This inconsistency may be due to the limited scientific evidence directly linking marital status to cognitive impairment. On the other hand, evidence suggests that early marriage, as a form of early life adversity and family disruption, is likely to have negative effects on adolescent cognitive development. Furthermore, findings indicate that the age at which mothers marry has a positive and significant impact on their children's educational achievement [42, 43].

The level of education of parents is an important factor for the cognitive function of adolescents/adults. Parental education, which in this study was determined by the length of father's and mother's education, had an influence on the subject's cognitive function (Table 3). Various results from previous research demonstrated the dominant influence of parental education on children's intelligence [44–47]. Furthermore, higher parental educational attainment is linked to enhanced cognitive skills in adolescents, including improved vocabulary, attention, and working memory [48, 49]. This is also correlated with differences in brain structural patterns, such as increased cortical surface area and altered functional connectivity, particularly in somatosensory and subcortical areas [48, 50]. Additionally, adolescents from more educated families illustrate distinct brain activation patterns during inhibitory control tasks [51, 52].

Previous studies suggest that living in urban areas can have positive impacts on adolescent cognition through improved living conditions and income, and access to digital technology, while also noting potential risks associated with urban-related exposures like pollution and socioeconomic factors [53–56]. Our study showed that living in Java-Bali and urban area were consistently associated with positive cognitive function. The islands of Java and Bali were the most populous and prosperous areas of Indonesia with the better infrastructure availability, especially easy transportation and connectivity. More than half of Indonesia's population lives in Java and Bali [57, 58].

Limitations and further study

Despite the strength of this study, being a cohort study with a fairly large sample, there were still some limitations. Our cohort study had lost a significant number of subjects. We performed multiple imputation procedures to fill in missing values in data variables, which resulted similar results. With the understanding that each predictor of cognitive function in adolescents is potentially correlated with each other, we need complex models with a larger number of variables (socio-economy households, biological aspects) that could be used to better understand the mechanism related between linear growth and cognitive function. Further study using a structured equation model could be performed.

Our study showed that the change in cognitive score between Cohort 1 and Cohort 2 was significant. The change is negative and it needs to analysed further, whereas the factors contributing to the positive change were more significant. (Table 1) The change of intelligence test in general population overtime and generations was defined as the Flynn effect. Previous study have shown an overall increase of around two standard deviations between 1909 and 2013, corresponding to an estimated 0.28 IQ points per year or 2.8 points per decade globally. The totality of empirical evidence points to factors of life-history change, such as increased educational and nutritional factors, as well as a reduction in pathogen-related factors. The magnitude of the increase in IQ fluctuates over time. The gains were stronger between World Wars I and II but showed a marked decline during World War II years. After the 1940s, gains increased and remained stable until the 1970s, but then decreased again. However, the evidence of declining cognition in recent decades is considered robust. This trend is observable in different IQ domains (full-scale, fluid, crystallized) [59].

Our study used Raven's Colored Performance Matrices modification (Raven) and math scores used in IFLS. Raven is a test to measure general intelligence and abstract reasoning ability using pictures [60]. Math score is a tool to assessed numerical abilities. Amongst the many cognitive subdomain functions, our study tested only the general cognition and numerical abilities. We need further analysis using other cognitive subdomain assessments, such as short-term or long-term memories, language, executive function, abstract reasoning as the dependent variables. A more substantial cognitive function measure if the IQ assessment used more complete instruments such as WISC, Griffiths III, etc.

Conclusions

Childhood stature was associated with later negative cognitive functioning in adolescents only when children were classified as short by NIGC. Classified as short stature using WHO, but not short using NIGC, was not associated with later negative cognitive function. We recommend using national growth references to better predict the impact of childhood height on their later cognitive functions.

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Author contributions
AGM: conception of the work, data collection, data analysis and interpretation, drafting the article, critical revisions of the article, and final approval of the version to be published. ABP: critical revisions of the article, and final approval of the version to be published. MNS: conception of the work, data analysis and interpretation, critical revisions of the article, and final approval of the version to be published. MJ: conception of the work, data analysis and interpretation, critical revisions of the article, and final approval of the version to be published.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Ethical approval of this study was obtained from the Ethics Committee of the Faculty of Medicine Universitas Gadjah Mada (number KE-FK-0034-EC- 2023). The IFLS surveys and their procedures have been reviewed and approved by IRBs (Institutional Review Boards) in the United States (at RAND) and in Indonesia at the University of Gadjah Mada for IFLS 2007 and IFLS 2014, and at the University of Indonesia for IFLS 1993 (https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html). The ethical clearance number is s0064-06-01-CR01 from RAND's Human Subjects Protection Committee (RAND's IRB) for IFLS 2014 (https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/datanotes.html# ethical). All methods were carried out in accordance with relevant guidelines and regulations. All participants in the IFLS survey gave written informed consent that was obtained prior to data collection [22, 24, 25].

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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