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ORIGINAL ARTICLE

Are stunted young Indonesian children more likely to be overweight, thin, or have high blood pressure in adolescence?

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Abstract
Objectives To determine whether stunted young children are at greater risk of (1) overweight/obesity or thinness, and (2) high blood pressure (HBP) in adolescence.
Methods A secondary data analysis using the Indonesian Family Life Survey waves 1 (1993) to 4 (2007). We generated a 14-year follow-up cohort (1993–2007) and two 7-year cohorts (1993–2000 and 2000–2007) of children aged 2.0–4.9 years. Stunting (HAZ < -2), thinness (BMIZ $<$ -2), and overweight/obesity (BMIZ $> +1$) were determined based upon the WHO Child Growth Standards. HBP (>90th percentile) was interpreted using the 4th Report on the Diagnosis of HBP in Children and Adolescents.
Results 765, 1083, and 1589 children were included in the 14-year cohort, and the two 7-year cohort analyses, respectively. In the 7-year cohorts, early life stunting was inversely associated with overweight/obesity (prevalence ratio 0.32 and 0.38, respectively; $P < 0.05$), but no significant association was found with the 14-year cohort. There was no significant association between childhood stunting and thinness at adolescence or in the odds/likelihood of having high systolic or diastolic blood pressure.
Conclusions We found no association between early life stunting and overweight/obesity, thinness and HBP in adolescence.

Keywords Stunting · Overweight/obesity · Double burden · Cohorts · Indonesia · Children

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Introduction

For many low- and middle-income countries, the rising prevalence of childhood obesity is in addition to the existing problem of stunting, leading to one of the forms of the double burden of malnutrition (IFPRI 2015). Stunting, defined as low length/height-for age, is a form of chronic malnutrition that has been a major nutritional problem mainly in developing countries. In 2011, there were approximately 25.7 % under five children globally who were stunted (length or height-for age z score <-2), 28.0 % in developing countries, and 7.2 % in developed countries (de Onis et al. 2013).

Several cross-sectional studies show that stunted children are more likely to be overweight/obese, compared to those with healthy heights (Bove et al. 2012; Popkin et al. 1996; Rachmi et al. 2016a). However, whether stunting is a risk factor for the *later* development of overweight/obesity is still contested. A 22-month longitudinal case–control study of Brazilian girls aged 7–11 years at baseline found an association between mild stunting and later obesity (Sawaya et al. 1998). Others have found no prospective relation between stunting in children less than six years and subsequent overweight/obesity in adolescence or adulthood (Benefice et al. 2001; Cameron et al. 2005; Schroeder et al.

1999; Timaeus 2012; Walker et al. 2001, 2007). Indeed, Gigante et al. (2007) found that stunting in early life was associated with a reduced fat mass index and body mass index in adolescence. Some have argued that previous cross-sectional studies have been hampered by errors in height measurement (Timaeus 2012). There are limited longitudinal studies in countries with high rates of stunting, and none has been conducted in Asia (Schroeder et al. 1999; Benefice et al. 2001; Cameron et al. 2005; Gigante et al. 2007; Walker et al. 2007; Timaeus 2012).

Children who are stunted in early life have also been found to have a higher mean systolic blood pressure in later childhood, irrespective of current size (Gaskin et al. 2000). A separate study showed that stunted adolescents who are currently overweight have a higher mean systolic blood pressure compared to their healthy height and overweight counterparts (Clemente et al. 2012). Both studies reported mean blood pressure with neither using cut-off points for hypertension. The use of hypertension cut-off points is important in determining whether stunting in early childhood poses a specific risk for hypertension in adolescence.

This paper is the third in a series of secondary data analyses on the double burden of malnutrition in Indonesia using data from the Indonesian Family Life Survey (IFLS). The previous papers focused on cross-sectional analyses of children aged 2.0–4.9 years. This paper focuses on stunted children aged 2.0–4.9 years in 1993, and follows them longitudinally through to 2007, i.e., 14 years later. We also performed analyses on two separate 7-year cohorts of children with the same baseline age group (one from 1993 to 2000, and the other from 2000 to 2007) to determine whether there were secular trends in any associations. We aimed to determine whether stunted young children are at greater risk, in adolescence, of (1) overweight/obesity or thinness, and (2) high blood pressure.

In 2013, one in every three Indonesian children was stunted (BPPK 2014). This study provides valuable information about the long-term effects of stunting. While many strategies are currently in place in Indonesia and other developing countries to reduce the prevalence of stunting, such information about early life stunting and later life outcomes would help with the development of new policies/strategies to deal with individuals who are already stunted.

Methods

Indonesian family life survey

Data collection

The Indonesian Family Life Survey is the only Indonesian survey that provides longitudinal data tracing the same families, and their individual members, from wave 1 in 1993 to the most recent survey. IFLS details have been described in several reports, including our first paper (Frankenberg et al. 1995; IFLS 2014; Serrato and Melnick 1995; Rachmi et al. 2016b). In summary, there are four waves of the survey for which data have been publicly released, i.e., 1993, 1997, 2000, and 2007. The survey sampled families from 13 out of Indonesia's 27 provinces in 1993 using stratified random sampling. It comprised questionnaires followed directly by anthropometric measurements, with each subsequent survey using similar methods to the first wave. The data collection included direct interviews for adults and proxy interviews for children and infants. Questionnaires covered a broad range of issues including relationships between members of the household, economic, and non-economic measures of household wealth, individual data for adults and children, and location of the house. These data were recorded in seven different books. Trained nurses also weighed and measured all adults and children in each household. In this study, we combined information from several books and divided them into three clusters: the child, household, and community level factors. This longitudinal survey has a high recontact rate (>90 % of households and individuals) in every wave as compared to wave 1 (Frankenberg et al. 1995; Frankenberg and Thomas 2000; IFLS 2014; Serrato and Melnick 1995).

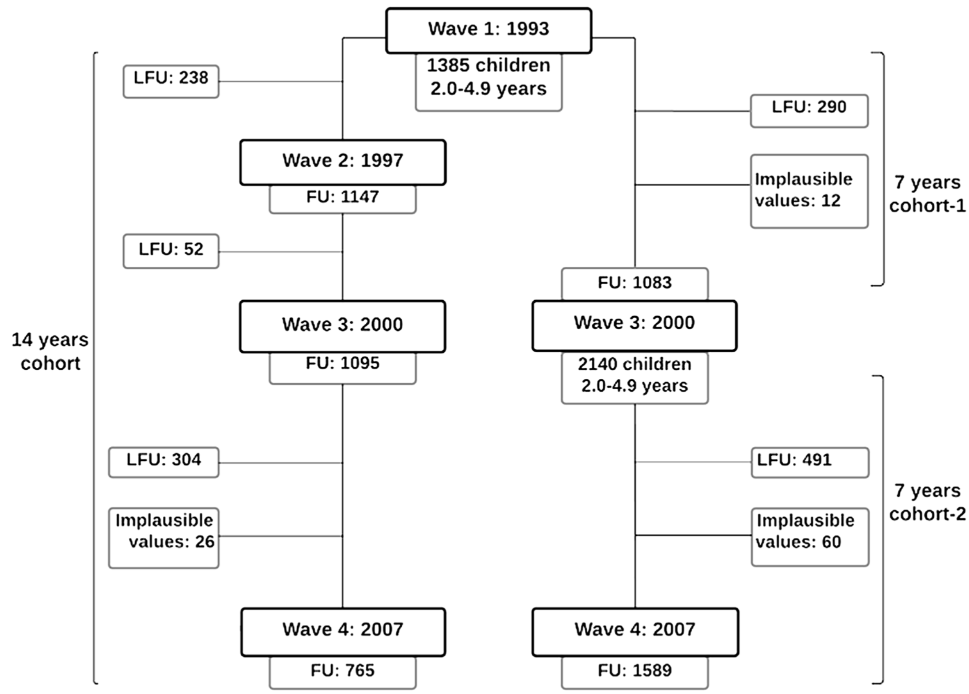
Study participants

The survey's design allowed us to follow children aged 2.0–4.9 years at baseline in year 1993 to age 15.0–18.9 years in 2007. In addition, we also followed children aged 2.0–4.9 years in either 1993 or 2000 in two 7-year cohorts, i.e., to 2000 and to 2007, respectively.

For the purposes of this study, we only included children with complete records of child level factors [birth dates, sex, height, weight, and blood pressure (only in wave 4)], household level factors (mothers' education and household wealth index), and community level factors (housing area and region). The flowchart in Fig. 1 shows the total number of eligible participants in each original cohort and the final number of children included in the analysis. From 1385 children available in wave 1 (1993), only 765 children had complete records in all four waves. The Electronic Supplementary Materials Table 1 shows there were no differences in mean values for the baseline variables between those who completed all four waves and those who did not apart from a slight decrease in the prevalence of underweight (33.3 vs 34.3 %, $P = 0.001$) This suggests that the results of the analysis will not be affected by censored data.

Mothers' education was categorized as: never attended any formal education, attended primary school, and

Fig. 1 The number of participants in each original cohort and the final number of eligible participants in the analysis; Data from Indonesian Family Life Survey, Indonesia wave 1 (1993), 2 (1997), wave 3 (2000), and wave 4 (2007). *FU* followed-up, *LFU* lost to follow up, *Implausible values* using cut-off points from the WHO Anthro software (WHO 2011) for child growth standards (igrowup)



attended middle school or higher. We calculated the Household Wealth Index by giving a score involving the possession of eleven household assets, and ranked them in five quintiles from poorest to richest using principal components analysis method. Households in the bottom two quintiles were categorized as poor, those in the middle two quintiles as middle and the highest quintile as rich households (Filmer and Pritchett 2001). Housing area was classified as urban or rural areas and the regions were divided into four regions: Sumatra, Java, Bali and Nusa Tenggara Barat (NTB), and Kalimantan and Sulawesi.

Anthropometry and blood pressure calculations

Trained nurses measured children's height using Shorr measuring boards Model 420. Children's weight was measured using Seca Floor Model 770 scales (SECA, Los Angeles, CA, USA), with digital read out (Frankenberg et al. 1995). The same methods were used in the next three waves. Blood pressure was measured twice in the same visit using an Omron self-inflating meter that produced a digital read out (Frankenberg and Thomas 2000). We used the mean of two measurements in the analysis. Blood pressure measurement started in wave 2 of the survey, and was only collected in children aged 15 years or older. Thus, we only analyzed blood pressure in wave 4 in this study, because the children were >15 years by then.

We calculated age based on the birth dates and dates of anthropometric measurements. Body mass index (BMI; weight/height^2), height, and weight were expressed as *z* scores using the LMS Growth program (LMS 2010). *Z* scores were calculated against the 2006 WHO Child Growth Standard (WHO 2006) for children under five years in the first wave and the 2007 WHO Growth Reference for School-aged Children and Adolescents for the three subsequent waves (WHO 2007). We identified and then discarded biologically implausible values using cut-off points from the WHO Anthro software (WHO 2011) for child growth standards (igrowup) as the following: weight-for-age *z* score (WAZ) <−6 and WAZ >5, height-for-age *z* score (HAZ) <−6 and HAZ >6, BMI *z* score (BMIZ) <−5 and BMIZ >5. We defined stunting as an HAZ <−2, thinness as a BMIZ <−2, and overweight/obesity as a BMIZ >+1 according to the 2006 WHO Child Growth Standards for Children <5 years (WHO 2006) and the 2007 WHO Standard Growth Reference for School-aged Children and Adolescents (WHO 2007). In children under five, we combined the 'at risk of overweight/obesity, overweight, and obesity' categories, defined as BMIZ >+1, as suggested by de Onis et al. (2010).

Systolic and diastolic blood pressures (SBP and DBP) were interpreted using the percentile table in the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (NHBPEP 2004). High systolic or diastolic blood pressure was defined as a blood pressure >90th percentile, unless the 90th percentile was >120 mmHg for systolic or >80 mmHg for diastolic, in which case the latter cut-off points were used (NHBPEP 2004).

Statistical analysis

We merged data files from several separate questionnaires and anthropometry files, and analyzed the data using STATA Data Analysis and Statistical Software version 13 (Stata Corp 2014). We generated two data sets. The first consisted of children aged 2.0–4.9 years in 1993 who were followed over 14 years to 2007. The second consisted of two sets of 7-year follow-up of children in the same age bracket at baseline in 1993 and 2000, who were followed to years 2000 and 2007, respectively. We conducted frequency tabulations to describe distributions. Results are presented as numbers and prevalence or means and standard deviations. The next step was performed using the Survey ('Svy') commands that adjust for cluster sampling design and weights. The process comprised calculating 95 % confidence intervals around prevalence estimates. The prevalence of stunted children in 1993 who become overweight/obese 14 years later (2007), as well as the prevalence of stunted children in 1993 and 2000 who become overweight/obese seven years later (in 2000 and 2007), is presented with 95 % confidence intervals (CIs). Likewise, we computed the prevalence of stunted children in 1993 who fell in the thinness category fourteen years later in 2007.

The prevalence ratio of stunted children being overweight/obese in later childhood or adolescence were computed by dividing the likelihood of being overweight/obese in previously stunted children to the likelihood in children with healthy heights. The same calculations were also used to compute the likelihood of thinness (14 years later) in previously stunted children. The prevalence of high blood pressure in adolescents who were either stunted or of healthy height in early childhood is presented with 95 % CIs, along with the odds ratio. Comparisons were undertaken using the Chi-squared test.

Results

Characteristics of participants

765 children were included in the 14-year, and 1083 and 1589 children were included in the two 7-year cohort analyses, respectively. Characteristics of the children included in the 14-year follow-up, by wave, are shown in Table 1. In the 14-year cohort, there were a slightly higher percentage of boys compared to girls in the survey, with a similar mean age for boys and girls within each wave. The prevalence of stunting decreased from wave 1 (49.0 %; aged 2.0–4.9 years) to wave 4 (30.5 %; aged 16.0–18.9 years). The prevalence of at risk/overweight or obesity was highest in wave 1 (10.0 %), then decreased to wave 2 (5.0 %), before rising again to wave 4 (7.6 %). The prevalence of thinness increased from wave 1 (6.3 %) to wave 3 (12.9 %), and then decreased in wave 4 (8.9 %). In wave 4, 35.3 % of adolescents had high SBP and 29.0 % had high DBP. The characteristics of the two 7-year cohorts are available in Electronic Supplementary Materials (ESM Tables 2, 3).

Stunted children and overweight/obesity in adolescence: 14-year cohort analysis

Of the children who were either stunted or of healthy height in 1993, 8.6 % (95 % CI 6.2–11.9) and 6.5 % (95 % CI 4.5–9.5), respectively, were overweight/obese in 2007 (Table 2).

Stunted children and thinness in adolescence: 14-year cohort analysis

Table 2 shows the prevalence of previously stunted children in wave 1 who were thin in wave 4. The prevalence of thinness within previously stunted children was 8.4 % (6.0–11.6), which did not differ significantly from the prevalence of thinness in those who were previously of healthy height [9.4 % (6.9–12.8)]. The prevalence ratio of stunted children becoming thin 14 years later, compared to those of healthy height, was not significant at 0.9 (95 % CI 0.6–1.4); $P = 0.497$.

Stunted children and overweight/obesity in adolescence: 7-year cohort analyses

Table 3 shows that the prevalence of overweight/obesity at 7 years follow-up (i.e., 2000 or 2007) in children who were stunted at baseline (i.e., 1993 and 2000) differed significantly, [1.7 % (0.9–3.1) and 5.0 % (3.4–7.3), respectively], as did the prevalence in those who were of healthy height at baseline [7.7 (5.6–10.4) and 16.5 (13.6–20.0), respectively].

Prevalence ratio of stunted children being overweight/obese

Figure 2 shows the prevalence ratio of those who were stunted at baseline being overweight/obese either seven or 14 years later, compared to their healthy height peers. The 14-year analysis showed that the prevalence ratio of stunted young children becoming overweight/obese 14 years later was not significant at 1.26 (95 % CI 0.76–2.07). In both of the 7-year analyses, stunting had a significant inverse association toward later overweight/obesity (PR 0.32; 95 % CI 0.17–0.60 and PR 0.38; 95 % CI 0.27–0.53, respectively).

Table 1 Characteristics of children aged 2.0–4.9 years in waves 1 (1993) and followed-up to wave 4 (2007): prevalence (*n* [%]) and mean [95 % confidence intervals (CI)]

	Wave 1 (1993)	Wave 2 (1997)	Wave 3 (2000)	Wave 4 (2007)
Age (years) [mean (95 % CI)]				
Girls	3.4 (3.3–3.5)	7.4 (7.3–7.5)	10.2 (10.1–10.3)	17.5 (17.4–17.6)
Boys	3.4 (3.4–3.5)	7.5 (7.4–7.5)	10.2 (10.1–10.3)	17.6 (17.5–17.6)
Sex				
Girls				349 (45.6 %)
Boys				416 (54.4 %)
Weight for age *z* score[a]				
Underweight	255 (33.3 %)	296 (38.7 %)	N/A[b]	N/A[b]
Not underweight	510 (66.7 %)	469 (61.3 %)	N/A[b]	N/A[b]
Height for age *z* score[c]				
Stunted	382 (49.9 %)	315 (41.2 %)	315 (41.2 %)	233 (30.5 %)
Healthy height	383 (50.1 %)	450 (58.8 %)	450 (58.8 %)	532 (69.5 %)
Body mass index *z* score[d]				
Thinness	48 (6.3 %)	77 (10.0 %)	99 (12.9 %)	68 (8.9 %)
Healthy weight	640 (83.7 %)	650 (85.0 %)	622 (81.3 %)	639 (83.5 %)
(At risk and) overweight/obese	77 (10.0 %)	38 (5.0 %)	44 (5.8 %)	58 (7.6 %)
Mother's education				
Middle school or more				200 (26.1 %)
Primary school				510 (66.7 %)
No education				55 (7.2 %)
Household's wealth index				
Poor	380 (49.7 %)	748 (97.8 %)	323 (42.2 %)	347 (45.4 %)
Middle	101 (13.2 %)	11 (1.4 %)	161 (21.1 %)	156 (20.4 %)
Rich	284 (37.1 %)	6 (0.8 %)	281 (36.7 %)	262 (34.2 %)
Housing area				
Rural				402 (52.5 %)
Urban				363 (47.5 %)
Region				
Sumatra				167 (21.8 %)
Java				429 (56.1 %)
Bali and Nusa Tenggara Barat				107 (14.0 %)
Kalimantan and Sulawesi				62 (8.1 %)
Systolic blood pressure (mmHg)				
Normal	N/A	N/A	N/A	495 (64.7 %)
High	N/A	N/A	N/A	270 (35.3 %)
Diastolic blood pressure (mmHg)				
Normal	N/A	N/A	N/A	543 (71.0 %)
High	N/A	N/A	N/A	222 (29.0 %)

Data from Indonesian Family Life Survey, Indonesia, 1993–2007

[a] Based upon the WHO Growth Standards for wave 1 (WHO 2006) and WHO Growth Reference for waves 2, 3, 4 (WHO 2007)

[b] *N/A* not available because weight for age *z* score calculations only available until age 10 years

[c] Based upon the WHO Growth Standards for wave 1 (WHO 2006) and WHO Growth Reference for waves 2, 3, 4 (WHO 2007)

[d] Based upon the WHO Growth Standards for wave 1 (WHO 2006) and WHO Growth Reference for waves 2, 3, 4 (WHO 2007)

Table 2 14-year cohort analysis: 765 children aged 2.0–4.9 years in 1993 and their weight status (overweight/obesity and thinness) in 2007, according to height status in 1993

Stunted[a] in 1993 (wave 1) (n = 382)	Overweight/obesity		
	2007 (wave 4) Overweight/obese[b] [% (95 % CI)]	Healthy height[a] in 1993 (wave 1) (n = 383)	2007 (wave 4) Overweight/obese[b] [% (95 % CI)]
Overall	8.6 (6.2–11.9)	Overall	6.5 (4.5–9.5)
Sex		Sex	
Girls	5.4 (2.8–10.0)	Girls	4.4 (2.2–8.6)
Boys	11.2 (7.6–16.2)	Boys	8.4 (5.3–13.1)
Mothers' education		Mothers' education	
Middle school or more	2.6 (0.6–9.8)	Middle school or more	8.2 (4.4–14.6)
Primary school	10.9 (7.6–15.2)	Primary school	5.4 (3.1–9.0)
No education	5.4 (1.3–19.9)	No education	11.1 (2.7–36.3)
Household wealth index		Household wealth index	
Poor	8.2 (4.7–13.9)	Poor	6.3 (3.4–11.3)
Middle-class	8.0 (4.6–13.6)	Middle-class	7.1 (3.9–12.3)
Rich	10.6 (5.6–19.2)	Rich	5.9 (2.2–14.8)
Housing area		Housing area	
Rural	10.4 (7.1–15.1)	Rural	5.8 (3.1–10.5)
Urban	5.9 (3.1–11.0)	Urban	7.1 (4.3–11.5)
Stunted[a] in 1993 (wave 1) (n = 382)	Thinness		
	2007 (wave 4) Thinness[b] [% (95 % CI)]	Healthy height[a] in 1993 (wave 1) (n = 383)	2007 (wave 4) Thinness[b] [% (95 % CI)]
Overall	8.4 (6.0–11.6)	Overall	9.4 (6.9–12.8)
Sex		Sex	
Girls	7.7 (4.5–12.9)	Girls	9.4 (5.9–14.6)
Boys	8.9 (5.7–13.5)	Boys	9.4 (6.1–14.3)
Mothers' education		Mothers' education	
Middle school or more	9.0 (4.3–17.6)	Middle school or more	9.0 (5.0–15.6)
Primary school	8.6 (5.8–12.6)	Primary school	9.1 (6.0–13.3)
No education	5.4 (1.3–19.9)	No education	16.7 (5.3–41.8)
Household wealth index		Household wealth index	
Poor	8.1 (4.6–14.0)	Poor	8.1 (4.7–13.5)
Middle-class	8.6 (5.1–14.3)	Middle-class	8.4 (4.9–14.0)
Rich	8.2 (3.9–16.4)	Rich	14.7 (8.0–25.3)
Housing area		Housing area	
Rural	10.9 (7.4–15.6)	Rural	8.7 (5.3–14.0)
Urban	4.6 (2.2–9.4)	Urban	10.0 (6.6–14.8)

Data from Indonesian family life survey, Indonesia, 1993–2007

The prevalence [95 % confidence intervals (CI)] presented was unadjusted

[a] Height for age z score below −2 standard deviation according to the WHO Growth Standards (WHO 2006)

[b] BMI for age z score below −2 standard deviation according to the WHO Growth Reference (WHO 2007)

Stunted children and high blood pressure

Figure 3 shows there was no statistically significant difference in the prevalence of high systolic/diastolic blood pressure in adolescence between those who were stunted or of healthy height at baseline. The odds ratio of stunted children having high systolic or diastolic blood pressure was not significant (OR 0.80; 95 % CI 0.59–1.07 and OR 0.84; 95 % CI 0.62–1.15, respectively).

Table 3 Two cohort analyses of children age 2.0–4.9 years in baseline and their overweight status 7 years later: 1,083 children in 1993 and 1589 children in 2000

Stunted[a] in 1993 (wave 1) ($n = 544$)	7-years cohort 1		
	2000 (wave 3) Overweight/obese[b] [% (95 % CI)]	Healthy height[a] in 1993 (wave 1) ($n = 539$)	2000 (wave 3) Overweight/obese[b] [% (95 % CI)]
Overall stunted	*1.7 (0.9–3.1)*	Overall	*7.7 (5.6–10.4)*
Sex		Sex	
Girls	1.0 (0.3–2.7)	Girls	7.9 (5.0–12.4)
Boys	2.3 (1.0–4.9)	Boys	7.5 (4.9–11.3)
Mothers' education		Mothers' education	
Middle school or more	6.1 (2.2–15.9)	Middle school or more	14.6 (9.7–21.3)
Primary school	0.9 (0.4–2.2)	Primary school	5.9 (3.7–9.2)
No education	1.8 (0.2–12.1)	No education	0.0
Household wealth index		Household wealth index	
Poor	1.5 (0.6–3.7)	Poor	9.9 (6.2–15.4)
Middle-class	1.6 (0.6–4.2)	Middle-class	5.4 (3.1–9.4)
Rich	2.1 (0.5–8.4)	Rich	8.4 (4.4–15.6)
Housing area		Housing area	
Rural	1.3 (0.5–3.1)	Rural	*3.7 (1.8–7.4)*
Urban	2.8 (1.2–6.6)	Urban	*13.7 (9.9–18.6)*
Stunted[a] in 2000 (wave 3) ($n = 709$)	7-years cohort 2		
	2007 (wave 4) Overweight/obese[b] [% (95 % CI)]	Healthy height[a] in 2000 (wave 1) ($n = 880$)	2007 (wave 4) Overweight/obese[b] [% (95 % CI)]
Overall Stunted	*5.0 (3.4–7.3)*	Overall	*16.5 (13.6–20.0)*
Sex		Sex	
Girls	4.2 (2.5–6.9)	Girls	10.9 (7.6–15.4)
Boys	5.8 (3.4–9.7)	Boys	21.8 (17.3–27.2)
Mothers' education		Mothers' education	
Middle school or more	2.9 (1.1–7.5)	Middle school or more	21.5 (15.7–28.7)
Primary school	5.5 (3.6–8.4)	Primary school	14.9 (11.5–19.1)
No education	6.2 (1.4–23.2)	No education	2.3 (0.3–16.0)
Household wealth index		Household wealth index	
Poor	3.6 (2.0–6.7)	Poor	15.7 (11.4–21.1)
Middle-class	5.5 (3.0–9.8)	Middle-class	20.2 (14.9–26.7)
Rich	7.0 (3.2–14.7)	Rich	11.8 (7.2–18.7)
Housing area		Housing area	
Rural	4.7 (2.9–7.6)	Rural	14.3 (10.5–19.1)
Urban	5.8 (3.1–10.3)	Urban	19.7 (15.3–24.9)

Data from Indonesian Family Life Survey, Indonesia, 1993, 2000, and 2007

The prevalence [95 % confidence intervals (CI)] presented was unadjusted

$P < 0.05$ are presented in *italic*

[a] Height for age z score below −2 Standard Deviation according to the WHO Growth Standards (WHO 2006)

[b] BMI for age z score below −2 Standard Deviation according to the WHO Growth Reference (WHO 2007)

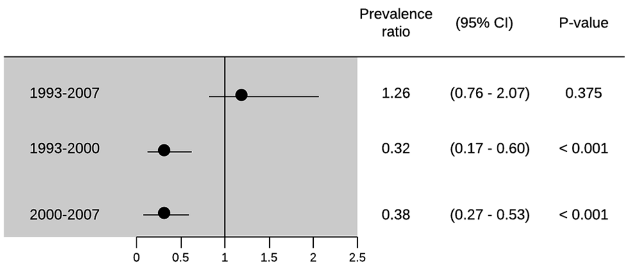


Fig. 2 Adjusted prevalence ratio (PR), 95 % confidence intervals (CI), and *P* values of stunted children aged 2.0–4.9 years at baseline to being overweight/obese 14 or 7 years later; data from the Indonesian family life survey, Indonesia, 1993–2007. The PRs, CIs, and *P* values are presented in the following order: wave 1 (1993) to 4 (2007) [14 years], wave 1 (1993) to 3 (2000) [7 years], and wave 3 (2000) to 4 (2007) [7 years]. Independent variables adjusted for are sex, mother's education, housing area (rural/urban), and household's wealth index

Discussion

In the 14-year follow-up, just 8.6 % of young children who were stunted were overweight/obese in adolescence. The prevalence of thinness in previously stunted children was also relatively low at 8.4 %. Stunting in young children was inversely associated with overweight/obesity 7 years later in both of the 7-year cohort analyses ($P < 0.05$), but there was no significant association in the 14-year follow-up. We did not find any significant association between early childhood stunting and later thinness in adolescence. While a third of the adolescents had high systolic and diastolic blood pressure, no difference in prevalence was found between those who in early life were stunted, versus those who were of healthy height. There was no significant association found for stunted children with high systolic or high diastolic blood pressure.

The prevalence of overweight/obesity in stunted children, while relatively low, was significantly higher in the more recent 7-year cohort [5.0 % (3.4–7.3) compared to 1.7 % (0.9–3.1)], and even higher in the 14-year cohort [8.6 % (6.2–11.9)]. We explored the probability of stunted young children becoming overweight/obese seven and 14 years later. In contrast with our previous findings in four-repeated *cross-sectional* surveys within four different years, where stunted children were significantly more likely to be overweight compared to their healthy heights counterparts (Rachmi et al. 2016a), in this study, we found no significant *prospective* association between stunting in early childhood and overweight/obesity 14 years later. This finding supports those of previous longitudinal studies in adolescents in South Africa (Cameron et al. 2005; Timaeus 2012), Senegal (Benefice et al. 2001), and Jamaica (Walker et al. 2001). We also found a significant inverse association of stunting in early childhood towards overweight/obesity in both 7-year cohorts. This is similar to the results of Gigante et al. (2007), although their study consisted only of adolescent males. One prospective cohort study found that non-stunted girls (aged 9–24 months) in Jamaica were significantly more likely to be overweight in adolescence (17–18 years), compared to their stunted counterparts, with no significant difference being found in the boys (Walker et al. 2007).

The association between stunting in early childhood and later overweight/obesity was different between the two 7-year cohorts and the 14-year cohort. We are uncertain of the explanation for this, although a 'puberty effect' might be in operation. One longitudinal study in Senegalese girls aged 11.4 years at baseline who were followed up to age 15.5 years showed that stunted girls continued to have a

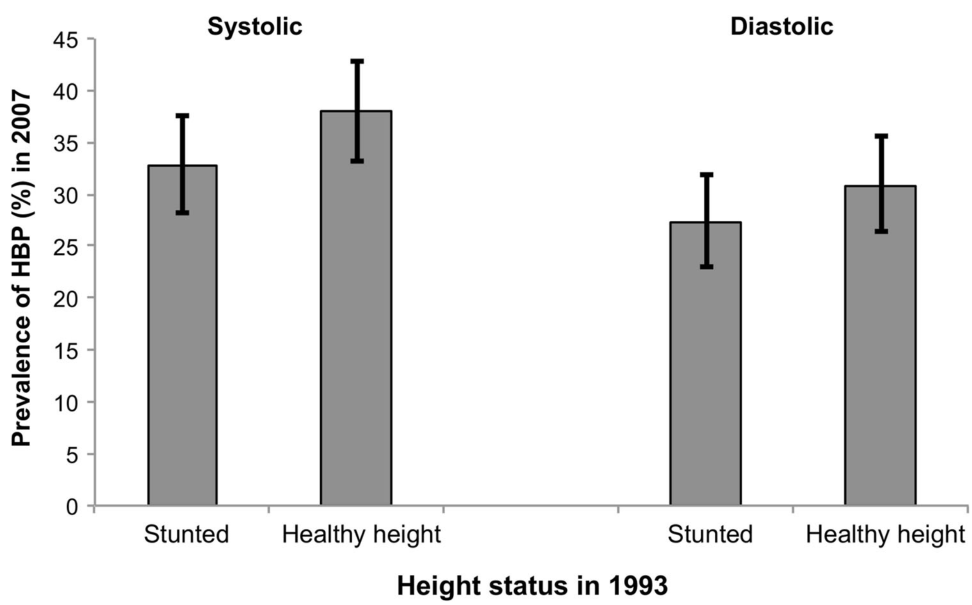


Fig. 3 Height status of 765 Indonesian children age 2.0–4.9 years in wave 1 (1993) and the prevalence (95 % confidence intervals) of high systolic and diastolic blood pressure status in wave 4 (2007); data from Indonesian family life survey, Indonesia, 1993 and 2007. Height status was determined based upon the 2006 WHO Child Growth Standards (WHO 2006) for children <5 years. High systolic/diastolic blood pressure was determined based upon the 4th Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (NHBPEP 2004)

low height-for-age throughout puberty but had a catch-up in body mass (Benefice et al. 2001). Another study proposed a 'catch-up period' in stunted girls during puberty, since stunted girls who were thinner compared to their healthy height counterpart in baseline have shown no significant difference in body mass by the age of 17–18 years (Walker et al. 2007).

About one-third of our main cohorts had high systolic and diastolic blood pressure in adolescence. This is comparable to a study in 10,453 Chinese students aged 15-17 years, where the prevalence rates of relative high blood pressure (defined as systolic and/or diastolic blood pressure ≥95 % percentile, specific for age and sex) for the 15-, 16-, and 17-year age groups were 29.4, 30.7, and 30.3 %, respectively (Ying-Xiu et al. 2015). Similarly, a study involving 1203 Taiwanese junior-high school students aged 12–14 years showed the prevalence of hypertension (systolic blood pressure or diastolic blood pressure ≥95th percentile, specific for age, sex, and height) was 29.7 % in boys and 20.7 % in girls (Lin et al. 2012). In our study, we found no difference in the prevalence of high systolic/diastolic blood pressure in adolescence between those who were stunted and those who were of healthy height as young children. We did not find any association between stunting and hypertension in adolescents. There is little evidence regarding the prospective association between childhood stunting and high blood pressure in adolescence, irrespective of weight status. One longitudinal study in Jamaica found that stunting at 9–24 months was significantly associated with higher systolic blood pressure at age 7–8 years, although they compared mean blood pressure and did not use cut-off points for high blood pressure, as in our analysis (Gaskin et al. 2000).

This is the first Asian study to show the prospective associations between stunting in early life and later overweight/obesity, thinness, and high blood pressure. To ensure we identified stunted young children, we started at age two years, by which age the process of stunting is generally already established (Victora et al. 2010). Strengths of the study include the relatively long-term follow-up (14 years) of the main cohort; the high recontact rate and the fact that trained professionals collected both questionnaire and anthropometric data, reducing potential measurement errors. The nature of the study (i.e., secondary data analysis) meant we were limited to performing analyses on the existing data. Other potential factors that might indicate an association between early childhood stunting and adolescent weight status—such as fat mass, lean mass, waist circumference—were not available in the data set. A further potential limitation is the reduced number of participants who completed all four waves of the survey; however, comparisons between those who completed the survey and those who did not showed no difference in most of the baseline characteristics, apart from the prevalence of underweight in those who were in four waves of the study compared to those who were not.

Some authors have suggested that stunted young children are at greater risk of overweight or obesity in later years (Martins et al. 2004; Sawaya et al. 1998; Sawaya and Roberts 2003). If this was the case, many low- and middle-income countries that currently have high rates of stunting would face very high prevalence rates of adult obesity, as well as obesity-related diseases, in future years. For example, stunting prevalence is very high in countries, such as Myanmar (35.1 %), Ethiopia (40.4 %), Pakistan (45.0 %), Papua New Guinea (49.5 %), and Timor Leste (57.7 %) (IFPRI 2016). However, using BMI as an indicator of overweight/obesity, we found that, among 382 children who were stunted at age 2.0–4.9 years, 83.0 % had a healthy BMI in adolescence, with 8.6 % of them being overweight/obese and 8.4 % being thin. While BMI z scores is a valid measure of overweight/obesity, future research of overweight and obesity in early childhood should consider using other body composition parameters to detect the possibility of central obesity, with follow-up into young and mid-adulthood.

Chronic undernutrition and overnutrition in Indonesia and other Asian countries are of great importance. In those countries where undernutrition remains a major health concern in early childhood, the development of policies and programs should combine the prevention and management of both under and overnutrition, and implement close monitoring of growth starting as early as possible.

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Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethics approval for IFLS was provided in the United States of America (Institutional Review Board at Rand Corporation, Santa Monica, California) and Indonesia (Ethics Committees of the Universitas Indonesia and the Universitas Gadjah Mada).

Informed consent Informed consent was obtained from all individual participants included in the study.

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