JICA Research Institute

JICA-RI Working Paper

Empirical Study of Growth and Poverty Reduction in Indonesian Farms:
The Role of Space, Infrastructure and Human Capital and Impact of the Financial Crisis

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No. 12

March 2010

JICA Research Institute

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Impacts of Prenatal and Environmental Factors on Child Growth

Evidence from Indonesia

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Abstract

This paper examines the impacts of prenatal conditions and water quality on child growth using recent data from Indonesia. Our empirical results show that an increase in birthweight has significant positive effects on children's subsequent height and weight-for-age z scores, whereas an improvement in drinking water quality, as measured by coliform bacteria count, increases the weight-for-height z score. Interestingly, there is seasonality in birthweight; this measure is significantly higher during the dry season than during the rainy season, and is also higher in a Christian-majority province than in Muslim-majority provinces, during the period shortly after Ramadan. Finally, the availability of modern water infrastructure improves the quality of drinking water. These findings show that interactions of environmental variations affect early childhood human capital formation and can have long-term impacts on their outcomes.

Keywords: Seasonality, Birthweight, Drinking Water, Child Growth, Indonesia

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We would like to thank Harold Alderman, Homi Kharas, Lora Iannotti, Megumi Muto, Takako Yuki, Sony Sumaryanto and seminar participants at the Indonesian Ministry of Agriculture for their useful comments. The research findings of this paper are based on the IMDG 2007 survey jointly conducted by the Japan International Cooperation Agency, the International Food Policy Research, and the Indonesian Center for Agriculture and Socio Economic Policy Studie. Any errors are our own.

Introduction

In developing countries, environmental factors interactively determine the setting in which children grow. Two important aspects of this environment are nutritional intake and water quality.

Seasonality in rainfall patterns can affect the production cycle, potentially creating seasonal fluctuations in nutrition intake and therefore child growth. Indeed, it has been increasingly recognized that seasonality seems to affect human ecology (Ulijaszek and Strickland 1993). When income-generating activities depend on seasonal factors, consumption and nutrition intake are also likely to fluctuate seasonally, unless storage and credits smooth the predictable components of within-year fluctuations (e.g., Behrman et al. 1997; Paxson 1993; Townsend 1994).

Seasonality in consumption patterns can impact maternal nutrition intake, thereby affecting preconceptional development and subsequent birth outcomes (e.g., Rayco-Solon et al. 2005a; Kramer 2003; Neggers and Goldenberg 2003).[1] Low birth weight is caused by prenatal conditions such as prematurity and intrauterine growth retardation, and insufficient nutrition intake during pregnancy increases the likelihood of intrauterine growth retardation (e.g., Ceesay et al. 1997; Moore et al. 2001, 2004; Verhoeff et al. 2001; Ramakrishnan 2004; Luude et al. 2007; Kaestel 2005).

Other environmental factors such as type of water source determine the quality and quantity of drinking water, thereby impacting the healthiness of children. Notably, however, water infrastructures can mitigate this direct causality.

As Alderman and Behrman (2006) summarized, low birth weight is an important factor that increases infant mortality and critically affects cognitive and physical growth. The authors

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[1] If this cyclical effect can be foreseen, it would be optimal for agents to choose fertilization timing in order to separate child-birth outcomes from the seasonality effects. However, there does not appear to be an observable pattern in the number of births by month in our sample, suggesting that the studied population does not optimize fertilization timing to maximize birth outcomes (assuming that gestation period does not vary).

showed that reducing the incidence of low birth weight created significant economic returns. However, caution should be taken when seeking to forge connections among birthweight, causality from prenatal conditions, child growth and adult outcomes. For example, many factors that affect prenatal conditions (e.g., household income) also directly influence the inputs to child growth. Even given that, however, Behrman and Rosenzweig (2004), Black et al. (2007), Buckles and Hungerman (2008) and Plug (2001) all demonstrated the causal effects of birthweight on later outcomes. Furthermore, several recent studies have examined the effects of environmental factors (e.g., rainfall and wildfires) experienced during gestation and early childhood on human capital outcomes (Godoy et al. 2008; Jayachandran 2005; Maccini and Yang 2008).

Food availability may differ between rainy (hungry) and dry (food-secure) seasons (Herdt 1989), leading to seasonal differences in birthweight (e.g., Rao et al. 2009; Simondon et al. 2004; Rayco-Solon et al. 2005b). Lokshin and Radyakin (2008), in a sample of data from India, found significant seasonality in the anthropometric measures of children, and further showed that the differences were statistically attributable to birth month.

Nutrition-related seasonality doesn't just arise from such ecoological conditions; it may also be based in societal norms. The majority of the population in Indonesia is comprised of Muslims, who fast during a certain period each year (Ramadan). Ramadan periods vary from year to year[2]. In principle, pregnant women are free from this practice. However, since food

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[2]

Year	Start	End
2002	6, November	5, December
2003	25, October	26, November
2004	15, October	15, November
2005	5, October	2, November
2006	23, September	22, October
2007	13, September	12, October

consumption is not perfectly separable across household members, due to the fact that household members are likely to share their pot, it is possible that pregnant women's nutrition intake may be negatively affected by the fasting of other family members.[3] Accordingly, we herein examine whether the birthweights of children born during or soon after Ramadan differ from those of children born during the remainder of the year. To help identify this effect, we make use of exogenous between-province differences in religion: the majority of people in North Sulawesi are Christian, while the other provinces in our sample are predominantly Muslim.[4]

As the second example of environmental factors that may affect child growth, we examine the effect of drinking water quality on child health. Clean drinking water is a scarce resource that is essential to the healthiness and growth of children (e.g., Lee et al. 1997; Van Derslice et al. 1994). The availability and accessibility of clean drinking water, however, depend on environmental factors (e.g., rainfall) and infrastructure (e.g., the availability of water supply facilities). It is widely recognized that the availability and accessibility of infrastructure has various impacts on different stages of the human life cycle (e.g., Strauss and Thomas 1995), but only a few recent empirical studies have examined the effects of water quality on child health and mortality (Merrick 1985; Jalan and Ravallion 2003; Lee et al. 1997; Van Derslice et al. 1994).[5]

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[3] The fasting of other family members could affect the consumption patterns of pregnant women through both economic and social channels. Economically, it would not be efficient to prepare meals for pregnant women separately from the two meals permitted during Ramadan (before sunrise and after sunset). Moreover, since pregnant women cannot eat much at once, their total consumption would be decreased if they tried to fast during the daytime. Societally, pregnant women may be pressured to constrain their food consumption (especially in the daytime) during the period of Ramadan. Recent studies have shown that stress can affect birth outcomes (e.g., Hobel and Culhane 2003).

[4] However, it is not possible to completely distinguish seasonality caused by production cycles from that caused by social norms, as the two are also correlated. Each province has a different timing of its rainy season, and this differentiates crop seasons across provinces. The rainy season starts in the months of October, November and December, and occurs earlier in the eastern provinces versus the western provinces. Therefore, we must be cautious when interpreting differences between the Muslim-majority and Christian-majority provinces, as their production cycles are inherently different.

[5] Recently, Galiani, Gertler and Schargrodsky (2005) examined the effects of water service privatization on child mortality in Argentina. However, it was unclear from their analysis whether privatization resulted in better drinking water quality. Gamper-Rabindran et al. (2009) examined the impact of piped water provision on infant mortality in Brazil, while Whittington et al. (2002) examined residents' willingness to pay for improved piped water in Kathmandu (Nepal) and found that it was much higher than their current water bills.

Here, we attempt to causally connect water infrastructure to child human capital formation.

In addition to impacting water quality, water infrastructure may also determine the amount of time required to fetch water, thereby impacting the household's time allocation (Burger and Esrey 1995). Thus, water infrastructure also affects the mothers' time inputs for child growth. We examine this effect, and compare it with the quality-improvement effect. Our results indicate that, in our empirical setting, the presence of modern water infrastructure does not significantly change the time required to fetch water, but it significantly improves the quality of the drinking water.

Our findings on the impacts of prenatal and environmental factors on early-stage child growth in Indonesia are directly linked to an emerging body of literature on the long-term impacts of early childhood investments on subsequent human capital and labor-market outcomes (e.g., Alderman et al. 2006; Hoddinott et al. 2008; Yamauchi 2008).[6] These studies show that early childhood growth, which is typically measured using the height-for-age z-score, has long-term impacts on human capital formation, as measured by schooling attainment and labor-market outcomes. Malnutrition during early childhood is increasingly known to adversely affect child growth at later stages.[7] Therefore, prenatal conditions, social norms and water quality issues that influence early childhood growth and health can also have potentially long-term impacts on the inequality in human capital among children born in different seasons.

This paper is organized as follows. The next section discusses the econometric framework utilized in our analysis. Section 3 describes our survey data from Indonesian villages, and Sections 4 and 5 show our empirical results on birthweight seasonality and water quality, respectively.

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[6] See Stechel (2009) for a recent review of heights and human welfare.

7 The literature on consumption smoothing in the developing-country context has largely focused on the welfare implications of income fluctuation and consumption-smoothing mechanisms (e.g., Townsend 1994; Ligon and Schechter 2003). Some empirical studies have shown that income shock affects nutrition intake among children at the early stage, and therefore has long-term impacts on human capital formation (e.g., Alderman et al. 2006; Hoddinott and Kinsey 2001).

1. Econometric method

We first examine the seasonality effects discussed above, as follows:

$$w_{ij} = \alpha_1 + Z_{ij}\gamma + \varepsilon_{ij} \qquad (1)$$

where w_i is an input for child growth, such as the (log) birth weight of child i in household j or the water quality in household j; Z_{ij} is a set of variables that capture exogenous factors, such as natural/human seasonality or the presence of infrastructure that affects w_{ij} 、 but does not directly affect child growth; and ε_{ij} is an error term. Z_{ij} also includes a gender dummy, birth year and village-fixed effects.

In the second stage, we estimate the child-growth equation, as follows:

$$h_{ijt} = \alpha_2 + w_{ijt}\beta + X_{ijt}\delta + v_{ijt} \qquad (2)$$

where h_{ijt} is a child anthropometry measure, such the height-for-age, weight-for-age and weight-for-height z-scores; X_{ijt} includes a gender dummy, age in months, birth year and village-fixed effects; and v_{ijt} is an error term. The controls in (1) and (2) vary, depending on whether we are analyzing the effects of birthweight seasonality on child growth or the effects of water quality on child health.

In the analysis of birthweight effects, we can instrument birthweight in the first stage equation under the condition that birth month is uncorrelated with v_{ijt}. Since birth month approximately implies fertilization month, the above condition means that the decision on (and occurrence of) fertilization and the likelihood of prematurity are not correlated with unobserved components of child growth after nine months from the time of fertilization.[8] Furthermore, the

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[8] Variations in lactation period are less important than nutritional variations in determining child-birth outcomes.

birth month may correlate with sanitation conditions that could affect the likelihood of a child becoming infected with disease, thereby impacting growth. We do not have the means to directly examine this potential causality, but our preliminary analysis did not find evidence that birth month was significantly associated with the studied child growth measures, such as the height-for-age z-score.

Notably, birthweight could affect the infant mortality rate, thereby creating a potential selectivity bias in our estimates. We understand that the importance of this issue depends on the empirical setting. Unfortunately, we do not have birthweight data for those infants who died, so this issue cannot be examined herein. However, a preliminary analysis showed that the number of births did not show a seasonal pattern in our sample (addressed below in Table 1).

In our analysis of water quality effects, we use different types of water infrastructure (source) as instruments for water quality (measured by the number of coliform bacteria detected) in the child growth equation, under the assumption that water infrastructure is uncorrelated with v_{ijt}. This assumption may be too strong if better drinking water facilities are only available to relatively well-off households, in which children are likely to have better nutrition intakes and correspondingly better health conditions. If there is a significant positive correlation between water facilities and health, it will create an upward bias in the estimate. In addition, better health endowments are believed to be negatively correlated with the number of coliform bacteria in drinking water, which could cause a downward bias. Therefore, if more modern water infrastructures are correlated with health endowments (after controlling for village effects), the estimate will be biased upward, not downward. Since water quality is believed to affect the incidence of diarrhea and therefore short-run weight fluctuations,[9] we herein use weight-for-height z-scores for children aged 0-6 years. We also used the height-for-age and weight-for-age z scores, but do not find significant water-quality effects with these measures. In

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[9] We also used body mass index in our preliminary analysis. The results are qualitatively quite similar to those shown in this paper

Eq.(2), we control for the effects of age (in months) or birth month/year. We also use observations with the number of coliform bacteria of 40 or less to avoid survey measurement errors.

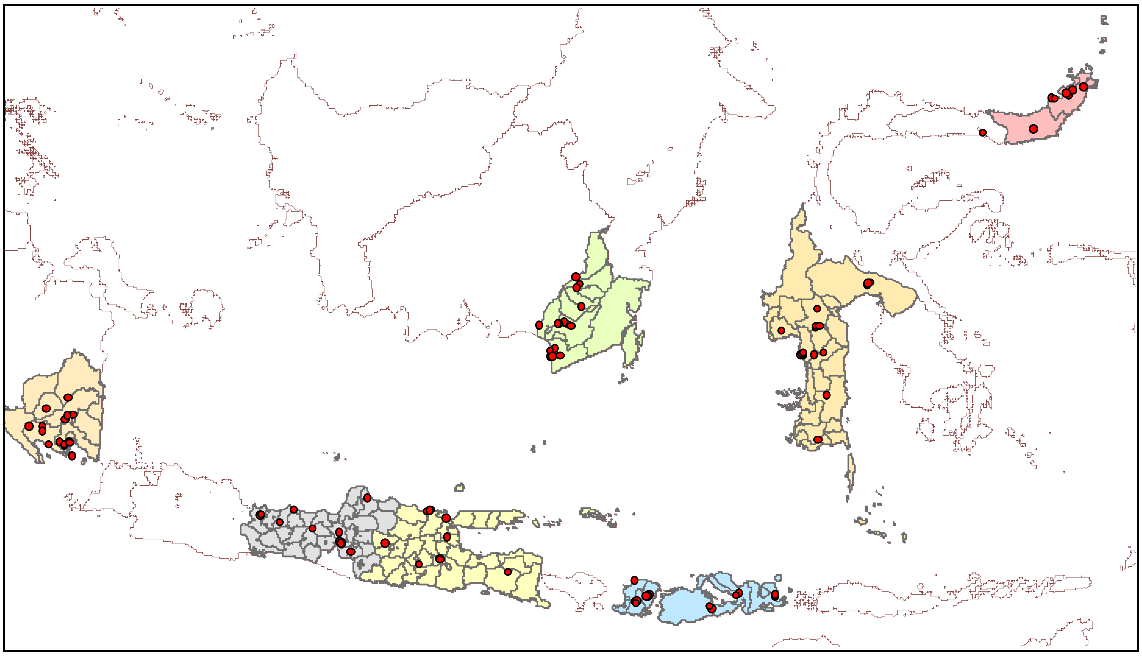
2. Data

Our data primarily come from village- and household-level surveys that we conducted in 2007, covering 98 villages in seven provinces (Lumpong, Central Java, East Java, West Nusa Tenggara, South Sulawesi, North Sulawesi, and South Kalimantan) under the Japan International Cooperation Agency's Study of Effects of Infrastructure on Millennium Development Goals in Indonesia (IMDG). The 2007 village survey captured the physical and economic distances from the village to various economic activity points, such as markets, stations, and capital towns.

The survey was designed to overlap with villages covered in the 1994/95 PATANAS survey conducted by the Indonesia Center for Agriculture and Socio Economic Policy Studies to build household panel data. The 1994/95 Patanas survey focused on agricultural production activities in 48 villages chosen from different agro-climatic zones in the seven provinces listed above. In 2007, we revisited those villages to expand the scope of research through a general household survey, as part of the IMDG project, and then further expanded the work by surveying 51 additional villages in the seven provinces.

In the previously surveyed villages, we re-sampled 20 households per village, and followed the split households. In the new villages, we sampled 24 households from the two main hamlets in each village. Since one of the 48 villages included in the 1994/95 PATANAS survey (in West Nusa Tenggara province) was not accessible in 2007 due to safety concerns, the overall sample consisted of 98 villages. The locations of the sampled villages are shown in Figure 1.

Figure 1. Locations of survey villages



(Provinces: Lampung, Central Java, East Java, West Nusa Tenggara, South Kalimantan, North Sulawesi, South Sulawesi)

During our survey round, we completed a child anthropometry module, in which we recorded the current height, current weight and birthweight for children aged 0-60 months. In addition, we tested drinking water quality using a coliform bacteria test kit (discussed in Section 5.1).

3. Birthweight seasonality and its impacts on child growth

3.1 Observations

Figure 2 shows the relationship between birth month and the residuals of (log) birth weight that we obtained after controlling for gender, birth year and village-fixed effects. It is interesting to note that: (i) there is a peak in the middle of year (from May to August), which corresponds to the dry season in many parts of the country; and (ii) there is a drop between September and November. Given a potential lag in the effect of consumption on birthweight, the above cycle could be caused by production seasonality. [10]

Figure 2. Seasonality in birthweight

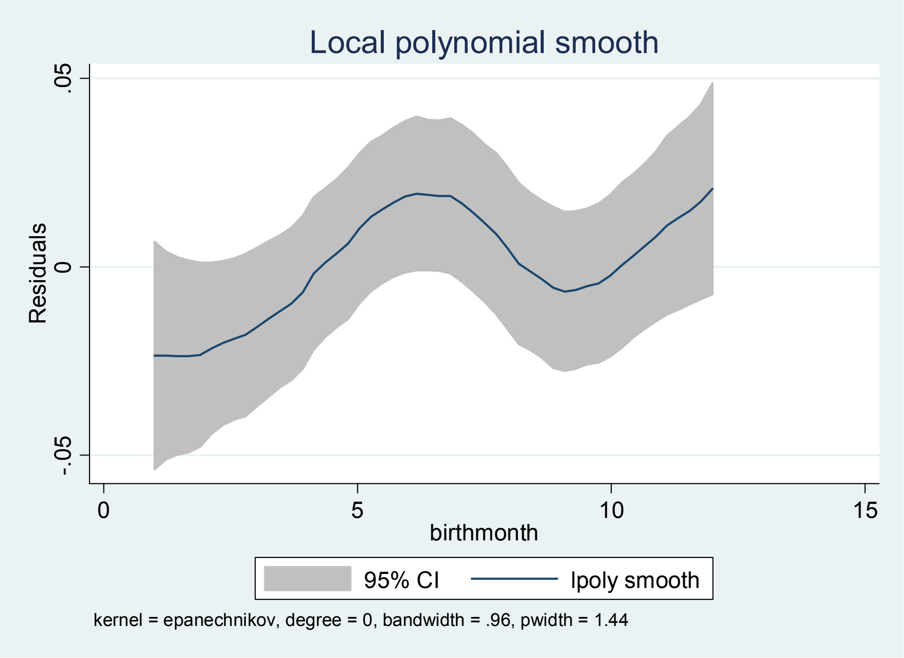
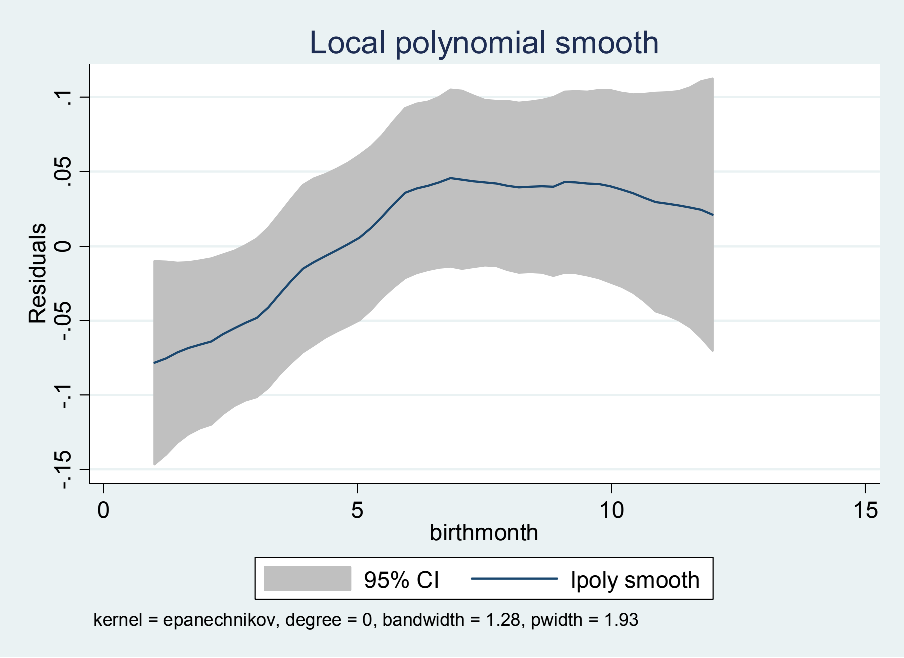


Figure 3a. Seasonality in birthweight: North Sulawesi



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[10] 51% in January-April (3% Bali & Nusa Tenggara, 30% Java, 3% Kalimantan, 0% Maluku & Irian Jaya, 4% Sulawesi, 12% Sumatra), 31% in May-August (2% Bali & Nusa Tenggara, 19% Java, 1% Kalimantan, 0% Maluku & Irian Jaya, 4% Sulawesi, 5% Sumatra), and 18% in September-December (1% Bali & Nusa Tenggara, 8% Java, 1% Kalimantan, 0% Maluku & Irian Jaya,34% Sulawesi, 6% Sumatra). See USDA (2002).

Figure 3b. Seasonality in birthweight: Other provinces

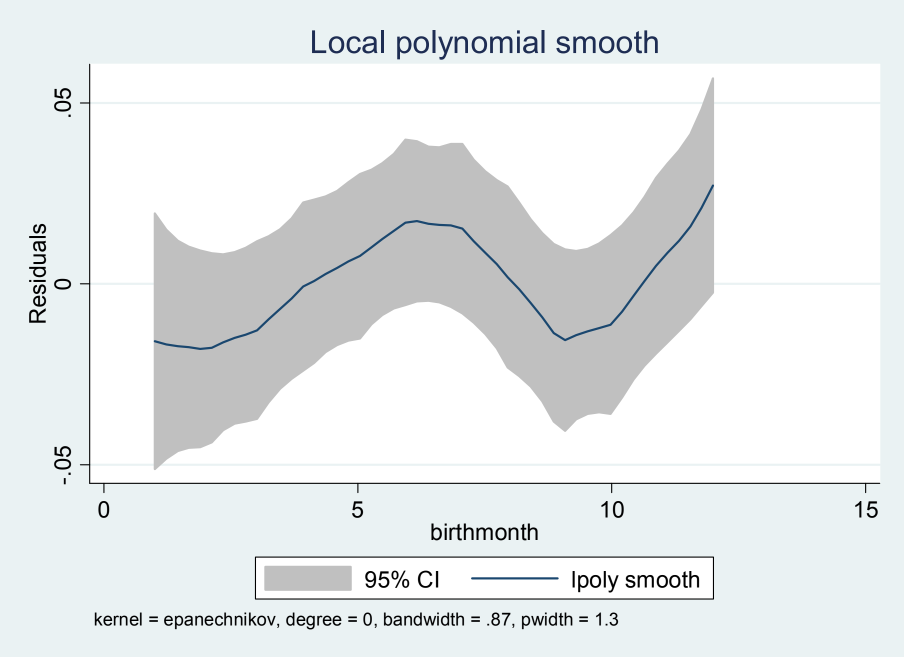

Figure 3 separates the sampled provinces into Christian-majority (North Sulawesi; Figure 3a) and Muslim-majority (Lampong, Central Java, East Java, West Nusa Tenggara , South Kalimantan, and South Sulawesi; Figure 3b) provinces. Notably, the September-November decrease is not seen in North Sulawesi (Figure 3a), while the other provinces (Figure 3b) show seasonality, with a peak in May-August and a drop in September-November.

Herdt (1989) reported that the Indonesian rice harvest is concentrated in April-June, suggesting that rice is most available after May. The seasonal fluctuations of birthweight in Figure 3b are therefore largely consistent with the seasonal fluctuations in rice supply.

The above graphs suggest that birthweight, which is affected by seasonality and social norms, has impacts on early childhood growth and subsequent long-run human capital formation. In other words, we can use seasonality or social norm effects (differentiated by provinces) as instruments for birthweight in the child-growth equation, and from there identify the effects of birthweight on child growth.

Because our child anthropometry data only pertain to those who are alive at the time of survey, we do not know the birthweights of children who died, and are therefore unable to control for sample selection caused by infant mortality related to low birthweight. This issue can be particularly important in a high-mortality environment (e.g., Lee et al. 1997); however, infant mortality is not high in our empirical setting, making this less of a problem.

Table 1. Birth months

Birth month	Frequency	Percent
1	58	6.52
2	71	7.99
3	78	8.77
4	81	9.11
5	78	8.77
6	74	8.32
7	79	8.89
8	80	9.00
9	71	7.99
10	81	9.11
11	82	9.22
12	56	6.30
Total	889	100.00

Sample consists of children aged <= 60 months.

We must also be wary of the potential correlation between birth month and the incidence of infant mortality, which could bias the estimates. Table 1 shows the number of living children aged less than 60 months by their birth months. We do not observe any significant pattern here. The constant number of births across months indicates that infant mortality is not systematically correlated with birth month, therefore removing this as a possible source of bias.

4.2 Empirical Results on Birthweight Seasonality and its Impacts on Child Growth

This section summarizes our empirical results on birthweight seasonality and its impact on child growth. Table 2 shows the determinants of birthweight.

Table 2. Birthweight

Dependent: Log of birth weight Age 0-60			
Season 1: May – August	0.0454 (2.70) ***		
Season 2: September – December	0.0350 (1.90)*		
Ramadan		-0.0719 (1.30)	-0.0134 (0.65)
Ramadan * Lampong		0.0427 (0.55)	
Ramadan * East Java		0.1253 (1.70)*	
Ramadan * NTB		0.0570 (0.90)	
Ramadan * South Kalimantan		0.0805 (0.91)	
Ramadan * North Sulawesi		0.2191 (2.64)***	0.1607 (2.46)**
Ramadan * South Sulawesi		0.0622 (0.92)	
Female	-0.0184 (1.30)	-0.0176 (1.25)	-0.0179 (1.27)
Village-fixed effects	yes	yes	yes
Birth year dummies	yes	yes	yes
Birth year dummies * Province dummies	yes	yes	yes
R squared	0.2274	0.2285	0.2258
Number of observations	767	767	767

Numbers in parentheses are absolute t values using robust standard errors. The above specifications include village dummies and the interactions of birth year and province dummies. Given that the Ramadan period changes every year, the random indicator is defined as taking the value of one if the child was born within 45 days from the start of the Ramadan in the birth year.

Column 1 uses season indicators that divide the year into three periods based on the crop production seasons: January-April, May-August and September-December (the period of January-April is omitted). The estimation controls for birth year and village-fixed effects. The results show significant positive effects for May-August and September-December. This finding is consistent with the patterns shown Figure 2, where we see a peak in (log) birthweight during May-August.

In Column 2, we use a Ramadan indicator that takes the value of one if the child's birth was within 45 days from the start of Ramadan, and zero otherwise.[11] To help with this identification, we also use province dummies interacted with the Ramadan indicator. Central Java is omitted in the estimation. In East Java, Ramadan has a negative effect on (log) birthweight, but the effect is statistically insignificant. Interestingly, the effect is significantly positive in North Sulawesi, where Christians comprise the majority. The birthweight difference between Muslim-majority and Christian-majority provinces is significant during and immediately after Ramadan.

It should be noted that although our results suggest that there is significant seasonality in birthweight, it is difficult to distinguish between fluctuations due to natural production cycles and those related to the practice of fasting. The difference between North Sulawesi and the other provinces is consistent with the social norm hypothesis. However, Yamauchi et al. (2009) recently showed from the same survey that rainfall patterns differ between Sulawesi and the Lampong-Java-NTB regions. The type of crop production also differs between the regions. Therefore, our present analysis is not sufficient to identify the specific factors behind the observed seasonality of birthweight.

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[11] A preliminary analysis showed that this result holds when the exposure to Ramadan is less than half of a trimester period (about 45 days). This suggests that the fasting effect (and difference between North Sulawesi and others) is potentially important in changing childbirth weight during the final stage of pregnancy.

Table 3. Child growth: Height and weight

Age 0-30 months Dependent:	Height-for-age z score		Weight-for-age z score	
	No IV	IV	No IV	IV
Log birthweight	3.2520	3.2459	2.4102	2.1493
	(2.64)***	(1.94)*	(2.95)***	(1.92)*
Log birthweight * age	-0.1761	-0.0906	-0.0636	-0.0039
	(2.40)**	(0.99)	(1.32)	(0.06)
Age in months	0.1417	0.0621	0.0183	-0.0399
	(1.57)	(0.57)	(0.33)	(0.55)
Female	0.2129	0.2805	0.4335	0.4686
	(0.92)	(1.18)	(2.74)***	(3.04)***
Birth year-fixed effects	yes	yes	yes	yes
Village-fixed effects	yes	yes	yes	yes
Durbin-Wu-Hausman (chi-sq)		4.87		4.34
P-value		0.08755		0.11407
R squared	0.3438	0.3308	0.3761	0.3676
Number of observations	366	366	372	372

Numbers in parentheses are absolute t values (Columns 1 and 3 using robust standard errors). Log birthweight is treated as an endogenous variable.

Columns 1 and 2 of Table 3 show the effect of birthweight on the height-for-age z-score among sampled children aged < 30 months.[12] Columns 1 and 2 show non-instrumented and instrumented results, respectively. Birth months interacted with province indicators are used as identifying instruments. First, we find that the effect of birthweight is positive and significant in the instrumental variable (IV) estimation (Column 2). Second, we see that the parameter in the IV estimation is quite similar to that in the non-IV (OLS) estimation.

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[12] In children aged 30-60 months, the relationship between birth weight and height is not clear. However, recent studies have shown that child nutrition and growth during ages 0-3 years critically determine schooling outcomes and labor-market outcomes at the adult stages .

estimation is quite similar to that in the non-IV (OLS) estimation.

We next interact age and the (log) birthweight to examine age-varying effects, which are treated as endogenous. Interestingly, the non-IV results show that age has a significant negative effect, suggesting that the importance of birthweight in determining child growth decreases as the child grows (ages). If we do not include this term, the IV estimate of the birthweight effect becomes much larger than that in the non-IV estimation, suggesting that there is a downward bias in the OLS analysis, along with a convergence in the process of child growth. These interpretations are mutually consistent.

Columns 3 and 4 use the weight-for-age z score, which provides qualitatively similar results. First, birthweight has a significant positive effect on child weight in both the non-instrumented and instrumented estimations. This is not surprising, since birthweight is a large portion of a child's weight at ages 0-30 months. Second, the parameter estimate in the IV estimation is smaller than that in the OLS estimation, suggesting that there is a diverging process of child weight. Third, girls have a larger weight than boys, whereas we do not see a gender-related difference in child height.

4. Effects of water quality on child growth

4.1 Testing drinking water quality

During our survey, we used Suncoli No. 6 (Sun Chemical Co., Ltd.) testing papers to detect coliform bacteria in drinking water. Supervisors or enumerators dipped a testing paper into a water sample at each household, dampening the testing paper with approximately 1 cc of sample water per test. The testing papers were then packed in the transparent sheets provided with the testing kits. The temperatures in the survey areas were warm enough that incubators were not required; instead, the testing papers were kept in the supervisors' (or enumerators') pockets for enrichment culture. After 24 hours of enrichment culture (as per the manufacturer's instructions), the number of spots (colonies) on each testing paper was counted, and taken to represent the total number of coliform bacteria in the 1-cc sample. In our results, “coliform-negative” means that the coliform count was smaller than the lower limit of detection, not necessarily that the sample was coliform-free. In principle, the sensitivity of this simple testing kit is 1/100 that of other popular methods for detecting coliform bacteria from 100 cc of water.

One water sample was tested per household, for a total projected sample size of 2261 water samples. The supervisors/enumerators failed to test 40 cases (approximately 1.8%) among the 2261 households, so the final sample size was 2221 water samples. Table 4 shows the distribution of the test results.

Table 4. Distribution of water quality test scores

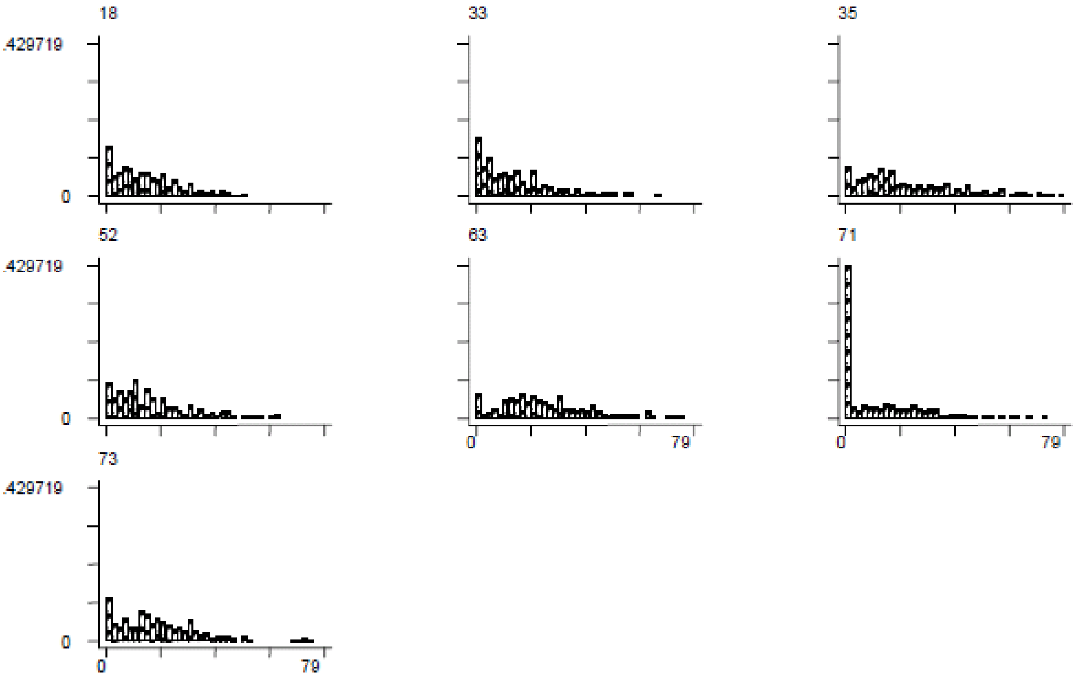
Category*	Number of Spots	Number of samples by water source**									
		1	2	3	4	5	6	7	8	9	Total
A	0	66	55	92	27	6	8	0	9	3	266 (12%)
B	1 - 4	41	39	70	41	1	3	0	4	10	209 (9%)
C	5 - 10	57	66	116	75	2	5	1	15	19	356 (16%)
D	> 10	155	251	575	216	49	42	0	53	49	1,390 (63%)
	Total	319	411	853	359	58	58	1	81	81	2,221 (100%)

* The categories are based on an index of water quality for sea bathing places (which considers high contamination level. ** Water source: 1 – piped, 2 – pump well, 3 – well, 4 – spring, 5 – rain, 6 – river/creek, 7 – pond/fish pond, 8 – basin, 9 – bottled water.

Tap water is not chlorinated in Indonesia, so we do not expect that piped water will necessarily be coliform-negative. Instead, coliform negativity is expected to depend on the water source, purification process, conditions of water pipes, etc. Out of 319 households receiving piped water, the samples from 66 (~21%) were coliform-negative, yielding the best result among all water sources. Although we might expect bottled water to be coliform-negative, only three out of 81 (approximately 3.7%) bottled samples were coliform-negative. This is the worst result among the water sources, with the exception of pond/fish pond water (only one case).

Figure 4 graphs the distributions of coliform counts by province.

Figure 4. Drinking water quality test results by province



Province= 18 Lumpong
33 Central Java
35 East Java
52 West Nusa Tenggara (NTB)
63 South Kalimantan
71 North Sulawesi
73 South Sulawesi

X axis: coliform test result
Y axis: density

We do not see clear differences across provinces, with the exception that a large number of coliform-negative cases are observed in North Sulawesi.

Comparison of drinking water sources between the 1995 and 2007 survey rounds shows that among the 319 households using piped water in 2007, 52 had been drinking well water (or water from another source) in 1995. However, only 10 cases were found to have coliform-negative piped water. We also found that the majority of all households boiled their drinking water to some extent.

4.2 Empirical results on effects of water quality on child

This section summarizes our estimation results on the determinants of the number of coliform bacteria in drinking water, and its impact on the weight-for-age z score (which captures short-run changes in weight relative to an irreversible measure of growth, i.e. height).

Table 5. Water quality test score and water expenditure

Dependent:	Test	Test	Expenditure
Pump well	4.300	1.548	-10421.95
	(2.58)***	(1.30)	(4.14)***
Well water	4.459	1.616	-10197.65
	(3.30)***	(1.27)	(4.25)***
Spring water	2.431	-1.714	-6478.92
	(1.56)	(1.15)	(3.10)***
Rain water	4.282	-0.642	-6401.78
	(1.01)	(0.22)	(1.83)*
River/creek	2.514	-8.124	-9824.82
	(0.96)	(2.46)**	(3.27)***
Water collection basin	-1.883	-2.684	-5850.64
	(0.74)	(1.21)	(1.77)*
Aqua/bottled water	-0.342	-6.100	6877.73
	(0.06)	(1.67)*	(1.34)
Province-fixed effect	yes		
Village-fixed effect		yes	yes
R squared	0.1045	0.2965	0.2630
Number of observations	2140	2140	2217

Numbers in parentheses are absolute t values using robust standard errors with village-level clusters. Pipe water is omitted.

Table 5 shows the determinants of water quality, as measured by the number of coliform bacteria detected in household drinking water samples. Having a piped water source is used as the omitted case. In Column 1, we control for province-level fixed effects and find that pumped, well and spring water have significantly more coliform bacteria compared to piped water. In Column 2, where we control for village-fixed effects, these differences disappear. This suggests that the significant variations observed in drinking water quality (as well as in the availability of a modern water infrastructure) come from cross-regional heterogeneity rather than from differences within a given village. When we control for village-fixed effects, the river and bottled water samples have significantly fewer coliform bacteria compared to piped water.

Water quality could be heterogeneous across villages. First, we included village fixed effects, which control for the average water quality in each village. However, second, gaps across different water sources may vary across villages. We are making an assumption that the gaps are uniform across villages. This problem may cause imprecise estimates in the above table.

Table 6. Weight-for-height z score: Village fixed effects

Age 0-60 months Dependent:	Weight-for-height z score			
	No IV	IV	No IV	IV
Drinking water test score	-0.0020	-0.1628	-0.0009	-0.1611
	(0.22)	(2.33)**	(0.09)	(2.33)**
Female	0.0957	0.1179	0.0911	0.0838
	(0.62)	(0.60)	(0.57)	(0.41)
Age in months	-0.0098	-0.0096		
	(2.24)**	(1.70)*		
Birth month-fixed effect			yes	yes
Birth year-fixed effect			yes	yes
Village-fixed effect	yes	yes	yes	yes
Durbin-Wu-Hausman (chi-sq)		11.15		11.36
P-value		0.00084		0.00075
R squared	0.2826	na	0.3168	n.a.
Number of observations	600	600	589	589

Numbers in parentheses are absolute t values (Columns 1 and 3 show results with robust standard errors). Observations with 40 or more coliform bacteria counted from the sample are excluded.

Table 6 shows the effect of coliform bacteria count on the weight-for-height z-score among children aged 0-60 months. As identifying instruments (IVs), we use the various water infrastructure variables. To control for age effects, Columns 1 and 2 (3 and 4) use age in months (birth year and month-fixed effects). Our results show that with instruments, the number of detected coliform bacteria has a significant negative effect on child weight.[13] This is also

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[13] Many of the surveyed households reported that they boiled their drinking water. This is puzzling, as our results show that the number of coliform bacteria has a significantly negative effect on the weight-for-height z-score. If boiling removes the bacteria, we should not observe this negative impact. Our interpretation is that not all drinking water is boiled, given that boiling itself incurs some cost (gas and wood).

significant in the OLS estimation. The difference between non-IV and IV estimates suggests that the OLS estimate has an upward bias, which further implies that lower-quality drinking water is positively associated with unobserved components of child weight. The above result remains robust with birth year and month-fixed effects, as seen in Columns 3 and 4.

In a preliminary analysis, we split the sample into children aged 0-30 and 31-60 months, and examined potential heterogeneity between these two growth stages. In the IV estimation, the effect of drinking water quality on the weight-for-height z score was negative and significant for both groups (not shown here).

Table 7. Height-for-age and weight-for-age: Village FE

Age 0-60 months				
Dependent:	Height-for-age		Weight-for-age	
	No-IV	IV	No-IV	IV
Drinking water test score	-0.0014	0.0741	-0.0049	-0.0518
	(0.17)	(1.23)	(0.84)	(1.37)
Female	-0.0616	-0.0693	0.0104	0.0132
	(0.40)	(0.42)	(0.10)	(0.12)
Age in months	-0.0110	-0.0109	-0.0129	-0.0131
	(2.60)***	(2.31)**	(4.45)***	(4.29)***
Village-fixed effect	yes	yes	yes	yes
Durbin-Wu-Hausman (chi-sq)		2.20		2.11
P-value		0.13787		0.14597
R squared	0.2399	0.1342	0.2729	0.1803
Number of observations	604	604	611	611

Numbers in parentheses are absolute t values (Columns 1 and 3 show results with robust standard errors). Observations with 40 or more coliform bacteria counted from the sample are excluded.

Next, we conduct an exercise similar to Table 6 using the height-for-age and weight-for-age z-scores to examine the water quality effects on child growth (Table 7). Our results clearly contrast with the above results on the weight-for-height z-score, in that drinking-water quality is found to affect short-run fluctuations in weight (probably due to diarrhea), but not stock measures of child growth.

Table 8. Total time per day required to fetch water

Dependent:	Total time per day required to fetch water			
	Dry season		Rainy season	
	OLS	Tobit	OLS	Tobit
Pump well	-17.995	-70.453	-17.641	-67.466
	(0.88)	(1.67)*	(1.17)	(1.89)*
Well water	-2.047	30.089	-3.618	24.220
	(0.09)	(0.94)	(0.23)	(1.03)
Spring water	-9.463	-40.799	0.2578	-16.239
	(0.58)	(1.14)	(0.03)	(0.66)
Rain water	-5.852	2.817	-12.998	-13.208
	(0.24)	(0.05)	(0.84)	(0.32)
River/creek	9.022	72.983	-0.0561	41.226
	(0.45)	(1.50)	(0.00)	(1.00)
Water collection basin	14.814	-24.144	-19.628	-70.401
	(0.40)	(0.36)	(1.16)	(1.60)
Aqua/bottled water	-5.145	-14.271	-0.9803	-6.315
	(0.28)	(0.31)	(0.08)	(0.18)
Village-fixed effect	yes	yes	yes	yes
R squared	0.1407	0.0382	0.1445	0.0453
Truncated (zero)		808		813
Number of observations	1552	1552	1535	1535

Numbers in parentheses are absolute t values generated using robust standard errors with village-level clusters. Pipe water is omitted. Total time in minutes is the product of the average number of person-trips per day and minutes per trip. If respondents did not need to fetch water, this is assumed to be zero minutes.

As shown in Table 8, we also examine the effects of water infrastructure on the time required to fetch water, using both OLS and Tobit estimations. About half of our sample households reported that they did not need to fetch water (e.g., due to the availability of piped water), and our results generally show that the type of water infrastructure is not related to the amount of time required to fetch water in our empirical setting. These results are qualitatively similar between the dry and rainy seasons. Access to a water pump marginally reduces the time needed for fetching water, compared to piped water access (Columns 2 and 4). This is because piped water may not reach the actual house.

Table 9. Robustness check: Food consumption

Dependent:	Log food consumption	Water quality test	Weight-for-height z score	
Drinking water quality			-0.1628	-0.1610
			(2.38)**	(2.33)**
Female			0.1203	0.0928
			(0.61)	(0.46)
Age in months			-0.0097	
			(1.70)*	
Log food consumption		0.0224	0.0340	0.0734
(adult equivalence scale)		(0.07)	(0.29)	(0.61)
Pump well	0.0145	1.5472		
	(0.13)	(1.30)		
Well water	0.0368	1.6153		
	(0.48)	(1.27)		
Spring water	0.0855	-1.7155		
	(0.67)	(1.15)		
Rain water	-0.1000	-0.6401		
	(0.66)	(0.22)		
River/creek	-0.1231	-8.1214		
	(0.67)	(2.46)**		
Water collection basin	-0.2121	-2.6792		
	(1.49)	(1.21)		
Aqua/bottled water	-0.0441	-6.0995		
	(0.25)	(1.66)*		
Birth month-fixed effect				yes
Birth year-fixed effect				yes
Village-fixed effect	yes	yes	yes	yes
Durbin-Wu-Hausman (chi-sq)			11.21	11.37
P-value			0.00081	0.00074
R squared	0.4116	0.2965	n.a	n.a.
Number of observations	2140	2140	600	589

Numbers in parentheses are absolute t values (Columns 1 and 2 show results with robust standard errors with village clusters). Columns 3 and 4 use water infrastructure indicators as identifying instruments and treat the other variables, including log of per-capita food consumption (adult equivalence scale), as exogenous.

We then examine the possibility that water infrastructure is correlated with food consumption, thereby determining child nutrition intake and subsequent child health, as measured herein by the weight-for-height z score. Column 1 in Table 9, which shows the effects of water infrastructure on (log) adult-equivalent scaled food consumption, indicates that water infrastructure does not significantly explain food consumption.

In Column 2, we use the water quality test results as the dependent variable, and include (log) food consumption and water infrastructure indicators. As noted above, river and bottled water is significantly cleaner than piped water. The effect of food consumption is not significant. When we examine this relationship using province dummies, our findings confirm the above results with the exception that (log) food consumption has a marginally significant positive effect on the number of coliform bacteria.

In Columns 3 and 4, we include (log) food consumption in the weight-for-height equations, with (log) food consumption treated as exogenous. In a preliminary analysis, we treated this variable as endogenous while instrumenting water infrastructure (even though these are jointly insignificant), but the result was almost the same. The results shown in these columns confirm our previous findings, which collectively suggest that access to water infrastructure is not significantly correlated with food consumption (which directly affects child growth).

The results in Tables 6 and 7 indicate that a switch from pumped water to piped water, which costs nearly 10,000 Rupea, decreases the number of coliform bacteria by about 4.3 dots and increases the weight-for-height z score by 0.7.

Conclusion

The present analysis demonstrates the importance of natural and human factors in determining child growth and health in Indonesia. Seasonality in birthweight, potentially caused by the agricultural production cycle (rainfall patterns) and social norms, significantly affects the height-for-age and weight-for-age z scores. Water quality, mainly determined by natural endowment but also affected by the availability and type of water infrastructure, also significantly influences the weight-for-height z score, which measures short-run fluctuations in child weight.

Our findings have some potentially important policy implications. In particular, these findings do not merely pertain to child human capital in the short-run, but also have implications on the long-term formation of their human capital. First, public investments in infrastructures capable of improving drinking water quality (e.g., piped water facilities) and smoothing seasonal fluctuations in food production/supply (e.g., advanced market and distribution networks) could promote early childhood human capital formation. Second, we highly recommend campaigns aimed at educating families on the importance of clean drinking water, as well as advising mothers (especially those whose expected due dates are in the January-April period) to take compensatory measures such as additional nutrition intakes.

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Abstract (in Japanese)

要約

本稿では、子供の出生前の状況や出生後に摂取する水の質が成長にどのような影響を与えるかを、インドネシアのデータを用いて分析する。子供の出生時の体重は、その後の成長（height and weight -for -age z score）に影響を与える。子供の出生時の体重には季節性が観察され、その要因としては、出生前の期間における雨季と乾季のパターンや、家計の摂食行動のパターンが候補に挙げられる。また、家計が用いる水の質も子供の成長(weight -for -height z score)に影響を与えるが、給水インフラによりそれを改善することが可能であることが示唆される。

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