The role of drinking water source, sanitation, and solid waste management in reducing childhood stunting in Indonesia

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Abstract. Indonesia still bears a significant public health problem of stunting among under-5 (U-5) children. Environmental factors have been demonstrated to be associated with stunting as indirect causes. However, the extent to which the environmental factors determine the stunting burden in rural Indonesia is still underexplored. Hence, this study investigates environmental factors that determine stunting among U-5 children in the rural areas of Indonesia. We employed data from the Indonesia Family Life Survey 2014/2015 (IFLS5) and selected a sample size of 2,571 children under five years of age residing in rural areas. We performed a multivariable logistic regression analysis and estimated the “population attributable fraction” (PAF) of drinking water, sanitation, and garbage collection on stunting. The results suggest that unimproved drinking water source and improper garbage collection correspond with higher odds of child stunting. Inadequate sanitation facility, however, was not found to be significantly influencing the odds of stunting. Moreover, household wealth is protective of risk of stunting. Furthermore, the PAF analysis demonstrated that 21.58% of the stunting burden among U-5 children residing in rural areas are preventable by providing access to an improved drinking water source and better household solid waste management to prevent repeated infections.

1. Introduction
Stunting among under-5 (U-5) children in Indonesia is still a pressing health problem, despite its reduction from 37.2% in 2013 to 30.8% in 2018 [1]. The burden of stunting Indonesia is higher in rural areas than in urban areas [2,3], which is similar to patterns of other countries [4,5]. Stunting is a widely used indicator of children’s health and nutritional status [6]. The World Health Organization (WHO) defines stunting as having a height-for-age more than two standard deviations below the median of the WHO Child Growth Standards based on a healthy reference population [7]. Stunting has many implications, both short term (i.e., stunted growth and underdeveloped brain) [8,9] and long term social and economic consequences [10-12].

Given its sheer adverse implications, the Sustainable Development Goals (SDGs) included stunting as one of the targets (Target 2.2) which states “by 2030, end all forms of malnutrition, including achieving, by 2025, stunting and wasting in children under five years of age…” [13]. Studies in Indonesia and other parts of the world have identified the drivers of stunting [2,14]. These consists of direct and indirect causes. As the causes of stunting are diverse, one will require a combination of nutrition-specific interventions (i.e., those that grapple with the direct causes of stunting) and nutrition-sensitive programs which ameliorate the underlying (indirect) causes of stunting [15-17].
One of the groups of indirect factors being the culprit behind stunting is the environment in which the children live [18]. Globally there is ample evidence linking environmental factors, such as water, sanitation, and hygiene, to malnutrition [3,19,20]. Headey and Palloni [21] analysed data from 218 rounds of Demographic and Health Surveys (DHS) and suggested that coverage of piped water source corresponds to a reduction in child stunting prevalence. Rah and colleagues [22] analysed data from the National Family Health Survey (NFHS) of India. They found that in the rural areas of India, access to latrine was associated with a reduction of stunting risk among children aged 0-23 months [22].

Moreover, Merel H. van Cooten et al [23] analysed data from the Ethiopian Demographic and Health Survey (DHS) and observed a negative relationship between improved toilet facilities and closer water source to home with the likelihood of wasting. Furthermore, Fregonese et al [24] analysed a household panel study in Burkina Faso and constructed an index of ‘contaminated environment’ as a proxy of faecal-oral transmission exposure from 12 variables representing water, sanitation, hygiene behaviours, yard cleanliness, and animal proximity. This variable was significantly associated with stunting.

Studies in the context of Indonesia are also pointing in a similar direction. Torlesse and colleagues [25] surveyed in 2011 and demonstrated that unimproved sanitation facility coupled with unsafe drinking water correspond to higher odds of stunting in Indonesia. Badriyah and Syafiq [26] analysed data from the 2013 Baseline Health Research of Indonesia and showed that waste management at the household level was one of the significant determinants of stunting. Rahman et al. conducted a case-control study in Petobo village, Palu, Indonesia, and demonstrated a significant relationship between environmental sanitation and stunting [27]. Although these studies demonstrated the significant relationship between environmental variables and stunting, they have yet to quantify how much the environmental factors determine the stunting burden in rural Indonesia. Therefore, this study aims at addressing the role of environmental factors in determining stunting among U-5 children in the rural areas of Indonesia.

2. Materials and method

2.1. Data source
This paper is a further analysis of publicly available secondary data. We obtained the data for this analysis from the latest wave of the Indonesia Family Life Survey (IFLS), which was fielded in 2014/2015 (IFLS5) [28]. IFLS5 is a part of an ongoing longitudinal survey that began in 1993 which collected data from more than 22,000 individuals residing in 7,224 households in 13 provinces; representative of 83% of the Indonesian population in that year (IFLS1). Afterwards, there were four follow-up surveys conducted in 1997 (IFLS2), 1998 (IFLS2+), 2000 (IFLS3), 2007 (IFLS4), and 2014/2015 (IFLS5). Although the survey is longitudinal, for this analysis, we only used IFLS5.

2.2. Study population and sample size
The study population is U-5 children living in rural areas of Indonesia. We performed a listwise deletion process to take care of missing values, and selected children living in rural households only. These processes yielded a final analytic sample size of 2,571 U-5 children.

2.3. Ethics statement
The IFLS has been approved by the Institutional Review Board of RAND Corporation in the United States, and the University of Gadjah Mada in Indonesia [28]. The dataset has been de-identified by the RAND Corporation to preserve its anonymity of the respondents. No additional ethical review is needed as such.

2.4. Dependent variable
The primary outcome of interest is stunting represented by a binary variable (1 = the U-5 child is stunted, 0 = the U-5 child is not stunted). Stunting is the condition where a child experience impaired
growth and development. A child is stunted if their height-for-age (z-score) is more than two standard deviations below the WHO Child Growth Standards median [29]. We used the STATA user-written program “zscore06” by Leroy to convert height and age into standardised values of z-scores [30]. This program has been used by previous studies [31,32]. The anthropometric z-scores calculated by this program follows the WHO [2] Child Growth Standards [7].

2.5. Explanatory variables
We selected the explanatory variables from the IFLS questionnaire based on the potential association with the risk of child stunting based on previous studies [3,25,33]. We grouped these variables as follows: demographics (age of child, sex of child, household size, sex of household head, age of household head, marital status of household head [currently married vs. the otherwise]), child’s recent illnesses (experience of diarrhoea, experience of acute lower respiratory infection [ALRI]), environmental (drinking water source [improved vs. unimproved], sanitation facility [improved vs. unimproved], proper garbage disposal, main source of cooking fuel [solid fuels, kerosene, or safer fuels]), and socioeconomic (household wealth index). The last variable was obtained by computing wealth index scores from household assets and housing variables using the polychoric principal component analysis (PCA) method [34].

Following the guideline from the World Health Organization (WHO) [35], drinking water sources are considered improved if it is of suitable quality. These sources include piped water into dwelling/plot/yard, public tap/standpipe, tubewell/borehole, protected dug well, protected spring, and rainwater collection. Source other than these is considered unimproved. Likewise, a sanitation facility is considered improved if it hygienically prevents human contact with human faeces [35]. These facilities include flush/pour flush to piped sewer system/septic tank/pit latrine, VIP latrine, pit latrine with slab, composting toilet. Facilities other than these are considered unimproved. Proper garbage disposal means that the household garbage is routinely collected by sanitation service. Safer cooking fuels include gas and electricity.

2.6. Statistical analyses
The statistical analysis was twofold. First, we fitted a multivariable logistic regression model of the aforementioned explanatory variables using the odds ratio (OR) as the measure of association [36]. Statistical significance was evaluated at 1%, 5%, and 10% levels of significance. Second, to assess the role of environmental variables in determining stunting among children, we estimated the population attributable fraction (PAF), the proportion of stunting among U-5 children that can be attributed to the factor(s) in questions, holding other factors constant. In this case, the factors of interest are drinking water, sanitation, and garbage collection on stunting. The basic formula of PAF is as follows.

\[
P\text{AF} = \frac{\text{Pr}(\text{disease}) - \text{Pr}(\text{disease}|\text{no exposure})}{\text{Pr}(\text{disease})}
\]

The PAF for the combined environmental factors were estimated using formulas for estimating PAFs after fitting a logistic regression model that was introduced by Greenland and Drescher [37]. This procedure was done using the STATA user-written program “punaf” command written by Roger Newson [38,39]. This program has been used in previous studies [40,41]. All of the statistical analyses were performed using STATA version 15 (StataCorp LP, College Station, Texas, USA).

3. Results and discussion

3.1. Sample characteristics and multivariable logistic regression analysis
Table 1 presents the characteristics of the sample and the results of the multivariable logistic regression analysis. The prevalence of stunting in the study sample was 41.54% (95% confidence interval [CI]: 39.63-43.47). The proportion of male child was slightly higher than that of female children. Levels of risk factors were common in the sample including diarrhoea experience (17.58%),
ALRI experience (51.65%), unimproved drinking water source (40.26%), unimproved sanitation facility (34.46%), and improper garbage disposal (90.28%).

Table 1. Results of the multivariable logistic regression analysis of the explanatory variables and stunting (N = 2,571).

| Variables                        | N    | %     | Adjusted OR |
|----------------------------------|------|-------|-------------|
| Age of child                     | 2571 | n.a.  | 1.00        |
| Sex of child                     |      |       |             |
| Male (Ref.)                      | 1390 | 54.06 | 1.00        |
| Female                           | 1181 | 45.94 | 1.03        |
| Diarrhoea experience             |      |       |             |
| No (Ref.)                        | 2119 | 82.42 | 1.00        |
| Yes                              | 452  | 17.58 | 1.09        |
| ALRI experience                  |      |       |             |
| No (Ref.)                        | 1243 | 48.35 | 1.00        |
| Yes                              | 1328 | 51.65 | 0.93        |
| Drinking water source            |      |       |             |
| Improved (Ref.)                  | 1536 | 59.74 | 1.00        |
| Unimproved                       | 1035 | 40.26 | 1.21 **     |
| Sanitation facility              |      |       |             |
| Improved (Ref.)                  | 1685 | 65.54 | 1.00        |
| Unimproved                       | 886  | 34.46 | 0.98        |
| Household garbage disposal       |      |       |             |
| Proper (Ref.)                    | 250  | 9.72  | 1.00        |
| Improper                         | 2321 | 90.28 | 1.43 **     |
| Household size                   | 2571 | n.a.  | 1.01        |
| Sex of HH head                   |      |       |             |
| Male (Ref.)                      | 2338 | 90.94 | 1.00        |
| Female                           | 233  | 9.06  | 0.91        |
| Age of HH head                   | 2571 | n.a.  | 1.00        |
| HH head is married               |      |       |             |
| No (Ref.)                        | 124  | 4.82  | 1.00        |
| Yes                              | 2447 | 95.18 | 0.59 **     |
| Cooking fuel                     |      |       |             |
| Solid fuel (Ref.)                | 860  | 33.45 | 1.00        |
| Kerosene                         | 145  | 5.64  | 0.88        |
| Safer fuels                      | 1566 | 60.91 | 0.76 ***    |
| Wealth index score               | 2571 | n.a.  | 0.83 ***    |

Note: HH refers to household; Ref refers to the reference category; n.a. refers to not applicable. Age of child, household size, age of household head, and wealth index are numerical variables. Statistical significance denoted at ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors’ calculation of the IFLS5 data.

As for the final logistic regression model, it is statistically significant (Likelihood Ratio \( \chi^2_{14} = 77.77; P<0.001 \)). From the table above, it can be observed that children living in households with an unimproved drinking water source are more likely to be stunted (OR = 1.21) than those living in households with access to improved sources. This association is consistent with that found in previous studies conducted by Torlesse et al [25], Batiro et al [42], and Corsi et al [41]. Inadequate sanitation facility, however, was not found to be significantly associated with child stunting. This finding is consistent with research done by Headey and Palloni [21] where they did not find an association between improvements in sanitation and changes in stunting.

Moreover, improper garbage collection of households was found to be associated with higher odds of stunting among children (OR = 1.43). This association would be exacerbated by the fact that more than half the population of Indonesia manages its waste poorly [43], which means that their living environment is more likely to be contaminated. Fregonese et al [24] have demonstrated that environmental contamination corresponds with a higher risk of child stunting in Burkina Faso. Furthermore, children residing in more affluent households have a lower risk of stunting (OR = 0.83). This relationship is consistent with extant studies [25,41].
3.2. Estimating population attributable fractions (PAFs)

Table 2 presents the results of the PAF analysis, which was based on a scenario where the three environmental variables of interest (drinking water source, sanitation facility, and garbage disposal) are set to its best category. Put differently, the PAF represents the proportion of the disease burden of stunting that might be eliminated if all the households have access to an improved drinking water source, improved sanitation facility, and proper garbage disposal. The analysis demonstrated that 21.58% of the stunting burden among U-5 children residing in rural areas are preventable through the provision of access to an improved drinking water source and better household solid waste management. This finding corroborates that water and sanitation are key interventions to prevent stunting [20].

| Mean/ratio | Std. Err. | z  | P > | z  | 95% CI |
|------------|-----------|----|-----|----|--------|
| Scenario 0 | 0.4154    | 0.0096 | -38.12 | P < 0.001 | 0.3971 | 0.4346 |
| Scenario 1 | 0.3258    | 0.0309 | -11.83 | P < 0.001 | 0.2705 | 0.3923 |
| PUF        | 0.7842    | 0.0713 | -2.67  | P = 0.008 | 0.6562 | 0.9373 |

95% CI for the population attributable fraction (PAF)

| Estimate | Minimum | Maximum |
|----------|---------|---------|
| PAF      | 0.2158  | 0.3438  |

Source: Authors’ calculation of the IFLS5 data.

3.3. Policy implications

Several researchers have also studied the correlates of stunting. However, not many policymakers in Indonesia are aware of them. As a result, many interventions to prevent stunting have not yet considered the indirect causes, such as the role of water, sanitation, and hygiene to prevent water-related diseases causing repeated infections among U-5 children [44,45]. Since the responsible sectors between direct cause and indirect cause are different, they have little attention to the importance of collaboration among relevant sectors. As such, the implementation of nutrition programs has been ineffective for preventing stunting. Even though the Baseline Health Research (Riset Kesehatan Dasar – Riskesdas) 2013 and 2018 convince us that the prevalence of stunting decreased significantly, the latest prevalent is still above the international targets, which is 30.8% compared to the target of 20% [1]. As for the international target, by 2025, the prevalence of stunting should be reduced by 40% [46]. This challenge should be achieved by collaboration among stakeholders using strategic interventions.

The further analysis of IFLS5 datasets revealed that there were three significant variables of the environment relating to the prevalence of stunting. First, improved drinking water sources are related to reducing the risk of infections that cause diarrheal disease [47]. A study conducted by Azhar and colleagues [48] showed that children living in households that use unimproved drinking water source were more likely to obtain diarrhoea in Indonesia. The result of a study by Patunru [49] is also inline. Second, sanitation is also related to the risk of orofaecal infections. For instance, unsafe disposal of child faeces was associated with an elevated risk of diarrhoea among children in Indonesia [50].

Since the determinants of stunting are complex, an urgent effort is needed to involve many stakeholders in mutual collaboration in combating stunting through proper interventions. In the health sector, for instance, current interventions which are considered to be direct are needed to be evaluated regarding its effectiveness. However, this study only focuses on the indirect causes, particularly on water, sanitation and household waste management. Regarding policy concerning nutrition improvement, Law Number 36 in 2009 concerning Health states that nutrition improvement should be implemented across the life course of human beings. This Law has been followed by President Regulation Number 42 of the year 2013 emphasising the importance of coordination among
stakeholders concerned. Indonesia has several regulations from central government to local governments across 34 provinces consisting of 416 districts and 98 regencies. Among them, there is a Government Regulation Number 16 of the year 2006 concerning the Development of Drinking Water Supply System. However, the coverage of improved drinking water source was only 58.15% [51]. Even, Irianti et al [52] found that several areas tend to be vulnerable in access to an improved water source.

Therefore, several recommendation options can be implemented in rural areas of Indonesia as follows:

- Strengthen stakeholder collaboration in all levels of governments since stunting is a global challenge involving the responsibilities of many sectors to overcome. An explicit agreement on the role of each sector would be a prerequisite to work together in combating stunting.

- The central government should provide guidelines for appropriate intervention technologies in drinking water and sanitation to accelerate access to improved drinking water and sanitation services by improving the five pillars of the Community-Led Total Sanitation (CLTS) approach. This effort can be achieved by developing appropriate technologies based on operations research. As such, reduction of repeated infections suffered by Indonesian children can be achieved, and stunting can be prevented. Local governments can then adopt the model of interventions.

- Continue the mobilisation of village and community funds for accelerating the improvement of water and sanitation facilities. The funds can be used for integrated intervention between nutrition programs and WASH programs to bring about cost-effective interventions.

- Strengthen community-managed water supplies since the availability of piped water system mostly covers urban people. This effort includes empowering rural people to adapt to the negative consequences of climate change by promoting water conservation and utilisation of rainwater, which is abundant in many parts of Indonesia during rainy seasons.

- Promote open defecation free (ODF) approach regularly to sustain behavioural changes and to shift the type of sanitation facility from unimproved facilities to improved ones. More importantly, managing this approach should be more focused on prone disaster areas as the ODF effort is likely to fail to maintain.

3.4. Study limitations
The small sample size of the IFLS5 may undermine the statistical power of the analysis in this study. However, this study still adds to the wealth of knowledge by going beyond statistical associations and calculated the PAFs of the environmental variables.

4. Conclusion
This study employed data from the 2014 IFLS and investigated the role of environmental factors on stunting. This study’s contribution is twofold. First, it adds to the stock of knowledge by quantifying the role of environmental factors on stunting among U-5 children living in rural areas. Second, it shows that environmental factors have to be considered when creating interventions to reduce stunting in Indonesia as these factors contribute to the decreasing of child stunting of about 21.58%. These findings will convince policymakers in Indonesia through evidence-based policy recommendations, elaborating proper interventions, as discussed in the policy implications section, supported by relevant regulations. Further studies with more considerable statistical power or more robust methods such as controlled experiment are recommended to corroborate the findings of this study.

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