[Makara Journal of Health Research](https://scholarhub.ui.ac.id/mjhr)

Volume 28
Issue 2 *August*

Article 2

8-31-2024

Unraveling the Multilevel Dynamics of Water, Sanitation, and Child Anthropometry in Indonesia

Rifa Kirana
Department of Economics, Faculty of Economics and Business, Universitas Padjadjaran, West Java 45363, Indonesia, rifa19003@mail.unpad.ac.id

Ahmad Komarulzaman
Department of Economics, Faculty of Economics and Business, Universitas Padjadjaran, West Java 45363, Indonesia

Makara J Health Res. 2024;28(2):81−88
doi: 10.7454/msk.v28i2.1622

Makara Journal of
Health Research

Unraveling the Multilevel Dynamics of Water, Sanitation, and Child Anthropometry in Indonesia

Rifa Kirana*, Ahmad Komarulzaman[2]

Department of Economics, Faculty of Economics and Business, Universitas Padjadjaran, West Java 45363, Indonesia

Abstract

Background: Anthropometrics, reflecting nutritional status, growth, and development, are crucial elements that can predict a person's health and well-being. However, low anthropometric measures among children under 5 years remain a significant issue in Indonesia, often influenced by various factors at the household and community levels. Access to clean water and adequate sanitation has been identified as major determinants of these adverse health outcomes. This study analyzes the relationship between anthropometric measures and access to water and sanitation at household and community levels using a multilevel analysis approach.

Methods: The study employs cross-sectional data from the Indonesian Family Life Survey (IFLS) waves 4 (2007) and 5 (2014), comprising a combined sample of 7,583 children. Furthermore, height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ) serve as the dependent variables, while improved water and sanitation access are the main independent variables. To account for the hierarchical nature of the data, a multilevel linear regression model is employed, clustering individuals, households, and communities at various levels.

Results: The results indicate that improved sanitation at the household level and water coverage at the community level are significantly associated with higher HAZ, increasing the scores by 0.171 standard deviation (SD) ($p < 0.01$) and 0.004 SD ($p < 0.1$), respectively. However, the water and sanitation variables do not reveal a significant association with WHZ.

Conclusions: The results of the study emphasize the importance of household-level sanitation and community-level water sources in influencing children's health. Effective interventions must target improvements in water and sanitation facilities at household and community levels simultaneously to enhance children's health and well-being. Recognizing and addressing the contextual factors at multiple levels is crucial for developing comprehensive health strategies.

Keywords: anthropometry, child, Indonesia, sanitation, water

INTRODUCTION

In 2022, approximately 2.2 billion people, or 27% of the global population, faced challenges in accessing safely managed water.[1] This predicament was marked by reliance on basic and limited services, unimproved sources, and surface water for drinking purposes. Furthermore, 3.4 billion individuals lacked access to adequately managed sanitation facilities, including those with basic, limited, or unimproved facilities, in addition to those practicing open defecation.[1] These issues are particularly severe in rural areas lacking even basic facilities,[1] and they commonly occur in developing countries, including Indonesia.[1]

In 2022, 94% and 88% of the Indonesian population had access to at least basic drinking water sources and basic sanitation, respectively.[1] However, these percentages vary across provinces, revealing regional disparities in access to clean water and sanitation.[2] Moreover, approximately 4% of the population still practices open defecation.[1] The persistence of these issues underscores the ongoing challenge of inadequate water, sanitation, and hygiene (WASH) services.

***Corresponding author:**
Rifa Kirana
Department of Economics, Faculty of Economics and Business, Universitas Padjadjaran, West Java, Indonesia
E-mail: rifa19003@mail.unpad.ac.id

The lack of safe WASH access can lead to diseases such as diarrhea, intestinal worm infection, and environmental enteropathy,[3] significantly disrupting children's nutrient absorption and protein utilization.[3] Further, these conditions contribute to poor anthropometric measures, including height-for-age (HAZ, stunting), weight-for-height (WHZ, wasting), and weight-for-age (WAZ, underweight).[4] Undernutrition, indicated by low anthropometrics, affects children's cognitive abilities[5] and long-term health and stature.[6] Body measurements, reflecting health status, dietary intake, growth, and development, are crucial indicators in this context.[7]

Undernutrition remains a pressing issue in Indonesia, as revealed by Indonesia Nutrition Status Survey (SSGI) 2022. The survey underscored stunting, wasting, and underweight prevalence rates of 21.6%, 7.7%, and 17.1%, respectively.[8] Furthermore, these rates are notably higher in lower-income regions.[9] As inadequate access to improved water and sanitation is recognized as a contributing factor to low anthropometrics,[10–12] investigating this issue further is imperative, especially in Indonesia.

Distinguishing between household and community-level access is crucial, as these factors can impact children's health differently.[13,14] This is especially relevant in hierarchical data structures, where individuals with similar backgrounds tend to share similar characteristics.[15] Therefore, it is essential to account for these differences at each level through data clustering. In addition, the study focuses on early childhood because it is a critical period for development, as growth failure due to poor nutrition and infection is more likely to happen at this time.[16]

This paper analyzes the relationship between access to water and sanitation and anthropometric measures among children under 5 years in Indonesia, considering household- and community-level factors. By employing multilevel estimation techniques, we offer a comprehensive understanding of the issue and increasingly reliable estimates.

METHODS

Data source

This study used cross-sectional secondary data from the Indonesian Family Life Survey (IFLS) waves 4 and 5. The IFLS data was collected by the Research and Development Corporation in collaboration with research centers, such as Survey METRE, and universities, such as the University of Indonesia and University of Gadjah Mada. The IFLS comprises a longitudinal survey spanning five waves, which were conducted in 1993, 1997, 2000, 2007, and 2014. Moreover, it represents approximately 83% of the country's population, covering 13 of 27 provinces.[17] IFLS 4 and 5 were conducted from 2007 to 2008 and from 2014 to 2015, respectively.[17] By using data from waves 4 and 5, the study captures a broad picture of the situation across different years, thus enhancing the findings' robustness and reliability.

The study focused on children under 5 years. Out of 10,744 children, only 7,583 were eligible for the sample after excluding cases with missing data on outcome variables (N = 914) and predictors (N = 2,247). The eligibility criteria included having complete data for the anthropometric measures and key predictors of interest. Ethical approval of the survey and its procedures was obtained from institutional review boards in the United States and the University of Gadjah Mada in Indonesia before the commencement of fieldwork.[17]

Outcome variables

While WAZ could be beneficial for assessing underweight, the result might be influenced by stunting, wasting, or both, making the interpretation increasingly complicated.[18] Therefore, HAZ and WHZ were chosen as the dependent variables. HAZ reflects a long period of nutrient intake, and low HAZ (below −2 SD) indicates stunting (typically due to insufficient nutrients or repeated illness).[18] Meanwhile, WHZ implies recent dietary intake, where low WHZ (below −2 SD) suggests wasting (usually resulting from extreme food shortages or diseases that drastically reduce weight), and high WHZ (above 2 SD) indicates excessive weight.[18] These indicators were calculated according to the World Health Organization (WHO) Child Growth Standards.[18] The z-score denotes how far the measurement deviates from average values or, in other terms, how many SDs the score is below or above the mean value. In addition, a higher z-score indicates a greater deviation of the anthropometric value from the population average.

Individual-level variables

Control variables at the individual level included child-level factors such as age in months, gender (1 = girl, 0 = boy), birth weight in kilograms, and full immunization status (1 = yes, 0 = no). Full immunization was defined as having received one dose of BCG and measles, four doses of Polio, and three doses of DPT and Hepatitis B for 9-month-old children and older, adjusting the required injections and doses according to age for children younger than 9 months old, based on the Decree of the Minister of Health No 1611/MENKES/SK/XI/2005.[19,20]

Household-level variables

The main predictor variables at the household level included improved water and sanitation. Improved water was defined as mineral water, piped water, well/pump, well water, spring water, and rainwater, while unimproved water sources were rivers/creeks, ponds/fishponds, water collection basins, and others. Moreover, improved sanitation was defined as households' using private toilets with septic tanks, while unimproved sanitation included toilets without septic tanks, shared toilets, public toilets, creeks/rivers/ditches without toilets, yards/fields without toilets, sewers, ponds/fishponds, animal stables, seas/lakes, and others. Household-level control variables comprised the routine boiling of water (1 = yes, 0 = no), years of schooling completed by the child's mother, the mother's body mass index category (−1 = underweight, 0 = healthy weight, 1 = overweight, 2 = obesity), and the natural logarithm of per capita expenditure (calculated by dividing the total monthly expenditure of the household by the number of people in the household).

Community-level variables

Community-level WASH variables comprised the proportion of households using improved water and sanitation in the community, expressed as a percentage. Moreover, control variables at this level included the natural logarithm of community per capita expenditure (calculated by dividing the total monthly expenditure of people in the community by the number of people in the community), average number of years of schooling for individuals aged 15 and above, and urban/rural residency (1 = urban, 0 = rural).

Statistical analysis
Descriptive statistics were first used to summarize the key characteristics of the data sample. This offered an overview of the demographic, household, and community variables. Following the descriptive analysis, a random intercept multilevel linear model was employed to investigate the relationship between the anthropometric features of children under 5 years and access to water and sanitation. This multilevel model was chosen to account for the hierarchical nature of the data, [15] which was structured at three levels, namely, individual, household, and community (sub-districts). The hierarchical structure within the data necessitated a nuanced approach beyond traditional linear regression, as this structure could signify influences exerted by the group or generated by individual members within the group.[15] Further, this effect, often referred to as a contextual effect, cannot be separated from the individuals within the group.[21]

The study set the levels of statistical significance at 0.10, 0.05, and 0.01. The likelihood ratio (LR) test was used to assess whether the data exhibited a hierarchical structure. This test compared the intercept-only model (without explanatory variables) with the complete model (with all explanatory variables). A significant LR test indicated that the multilevel model was appropriate, signifying that the null model was nested within the complete model.[22] Confidence intervals were reported at 99%, 95%, and 90% levels to provide a range of estimates for the parameters. The statistical analysis software that will be used is Stata version 17.

RESULTS

Overall, the data from both IFLS waves suggest a high usage of improved water sources and sanitation facilities among children's households. Table 1 provides an overview of the statistics summary of the data, revealing that children's households predominantly use improved water sources (>96%) and sanitation facilities (>69%) and adopt the practice of boiling water before consumption (>54%). The mean number of years of schooling attained by the children's mothers ranges from 9 to 10, and more than half of the sample comprises mothers with a healthy weight. Moreover, at the community level, the mean coverage for improved water exceeds 96% in both IFLS waves, while improved sanitation coverage stands at 68.5% (wave 4) and 74.3% (wave 5). The average educational attainment for individuals aged 15 and above in the community is over 8 years.

Table 1 also provides information on children's nutritional status, indicating a decreasing trend in malnutrition across all three indices (stunting, wasting, and overweight) in the two datasets. Stunting is the most prevalent of the three malnutrition conditions, affecting over 34% of the children sampled.

Table 2 presents the results of the multilevel linear regression for HAZ and WHZ. Two LR tests were conducted: one that compares the multilevel regression model with the ordinary linear model and another that compares the full model with the null model. For HAZ, the first LR test showed that the multilevel model provided a better fit than the simple linear model (LR $\chi^2 = 46.3$, $p < 0.001$). The second LR test, which compares the full model with the null model, also indicated a significant improvement in fit (LR $\chi^2 = 489.66$, $p < 0.001$). For WHZ, the first LR test similarly demonstrated that the multilevel model was superior to the simple linear model (LR $\chi^2 = 63.62$, $p < 0.001$). The second LR test confirmed that the three-level model was a better fit than the single-level model (LR $\chi^2 = 229.57$, $p < 0.001$). These results suggest that the multilevel model significantly outperforms both the ordinary least squares and intercept-only models, which indicates a better fit with the data.

The results demonstrate that children who reside in households with improved sanitation exhibit a height advantage of 0.17 SD ($p < 0.01$) compared with those without improved sanitation. Furthermore, a 1% increase in improved water coverage at the community level correlates with an increase of 0.004 SD ($p < 0.1$) in children's average height-for-age Z-scores (HAZ). Conversely, improved water and sanitation at the household and community levels, respectively, show no significant association with HAZ, and none of the WASH variables at any level demonstrate significance for weight-for-height Z-scores (WHZ).

Of the control variables at the individual level, birth weight is positively significant with HAZ and WHZ. When the child's age increased by one month, HAZ and WHZ scores decreased, by −0.01 SD and −0.007 SD, respectively. The results indicate that full immunization status is not significantly associated with anthropometry. Of the control variables at the household level, boiling water and per capita expenditure exhibit a positive correlation with HAZ. Meanwhile, underweight mothers demonstrate a negative association with WHZ and HAZ, while overweight and obese mothers are associated with higher WHZ in their children. As expected, higher education levels attained by mothers correlate with higher anthropometric features. At the community level, only community education ($p < 0.1$) and urban residency ($p < 0.05$) variables are significant for HAZ. Finally, the year 2014 variable is significant only for children's WHZ.

Multiple linear regression is performed as a robustness check and presented in Table 3. While the estimates are only marginally different from the multilevel model, the standard error of the OLS model is lower. Some differences in p-values are observed, where improved water coverage, boiling water, the mother's BMI (underweight), and the urban variable show a stronger relationship with HAZ than indicated by the multilevel results. These findings were anticipated as the LR test establishes data clustering, rendering the use of OLS a

TABLE 1. Statistics summary

Variable	IFLS 4		IFLS 5	
	N (%)	Mean ± SD	N (%)	Mean ± SD
Child characteristics				
HAZ		−1.44 ± 1.57		−1.39 ± 1.47
WHZ		−0.17 ± 1.51		−0.26 ± 1.43
Age		28.87 ± 17.17		28.86 ± 17.10
Gender				
Girl	1,665 (48.26)		1,978 (47.86)	
Boy	1,785 (51.74)		2,155 (52.14)	
Birth weight		3.20 ± 0.60		3.16 ± 0.62
Fully immunized				
Yes	1,016 (29.45)		1,353 (32.74)	
No	2,434 (70.55)		2,780 (67.26)	
Household factors				
Water source type				
Improved water	3,366 (97.57)		4,006 (96.93)	
Unimproved water	84 (2.43)		127 (3.07)	
Sanitation type				
Improved sanitation	2,399 (69.54)		3,114 (75.34)	
Unimproved sanitation	1,051 (30.46)		1,019 (24.66)	
Boiling water				
Yes	2,745 (79.57)		2,265 (54.80)	
No	705 (20.43)		1,868 (45.20)	
Mother's education		9.63 ± 3.64		10.27 ± 3.50
Mother's BMI				
Underweight	342 (9.91)		292 (7.07)	
Healthy weight	2,105 (61.01)		2,225 (53.83)	
Overweight	752 (21.80)		1,124 (27.20)	
Obesity	251 (7.28)		492 (11.90)	
Per capita expenditure		809,858 ± 3,124,493		1,018,314 ± 1,416,838
Community factors				
Improved water coverage		96.96 ± 11.66		97.21 ± 9.03
Improved sanitation coverage		68.50 ± 27.79		74.29 ± 24.05
Community education		8.51 ± 2.25		8.91 ± 2.05
Community per capita expenditure		1,096,559 ± 2,280,421		1,176,104 ± 1,408,741
Community area				
Urban	1,998 (57.91)		2,442 (59.09)	
Rural	1,452 (42.09)		1,691 (40.91)	
Children malnutrition status				
Stunting	1247 (36.14)		1429 (34.58)	
Wasting	339 (9.83)		368 (8.9)	
Overweight	270 (7.83)		271 (6.56)	
Total observations	3,450		4,133	
Total households	3,097		3,740	
Total communities	928		1,094	

HAZ: height-for-age; WHZ: weight-for-height; BMI: body mass index; N: number of observations; SD: standard deviation

TABLE 2. Association between access to water and sanitation and children's height-for-age (HAZ) and weight-for-height (WHZ) scores: Multilevel linear regression analysis

Variable	HAZ		WHZ	
	β (SE)	CI (95%)	β (SE)	CI (95%)
WASH Variables				
Improved water Ref: Unimproved	0.123 (0.136)	−0.143 – 0.389	−0.124 (0.133)	−0.386 – 0.137
Improved sanitation Ref: Unimproved	0.169 (0.048)***	0.074 – 0.263	−0.053 (0.047)	−0.146 – 0.040
Improved water coverage (%)	0.004 (0.002)*	0.000 – 0.009	0.002 (0.002)	−0.003 – 0.006
Improved sanitation coverage (%)	0.000 (0.001)	−0.002 – 0.002	0.001 (0.001)	−0.001 – 0.003
Individual Level				
Age (Years)	−0.010 (0.001)***	−0.012 – −0.008	−0.007 (0.001)***	−0.009 – −0.005
Girl Ref: Boy	0.099 (0.034)***	0.033 – 0.165	−0.005 (0.033)	−0.070 – 0.060
Birth weight (Kilograms)	0.343 (0.028)***	0.288 – 0.398	0.218 (0.028)***	0.164 – 0.272
Full immunization Ref: Not full	0.045 (0.037)	−0.027 – 0.118	−0.001 (0.037)	−0.072 – 0.071
Household Level				
Boil water Ref: Not boil	0.097 (0.040)**	0.019 – 0.175	−0.009 (0.039)	−0.087 – 0.068
Mother's education (Years)	0.030 (0.006)***	0.018 – 0.042	0.012 (0.006)**	0.000 – 0.023
Mother's BMI: underweight Ref: Normal weight	−0.124 (0.063)*	−0.248 – 0.000	−0.233 (0.062)***	−0.355 – −0.111
Mother's BMI: overweight Ref: Normal weight	−0.003 (0.041)	−0.084 – 0.078	0.189 (0.041)***	0.110 – 0.269
Mother's BMI: obesity Ref: Normal weight	0.043 (0.060)	−0.074 – 0.160	0.339 (0.059)***	0.223 – 0.454
Per capita expenditure (ln)	0.146 (0.028)***	0.090 – 0.202	0.068 (0.028)**	0.013 – 0.123
Community Level				
Community education (Years)	0.022 (0.012)*	−0.002 – 0.045	0.010 (0.012)	−0.013 – 0.034
Community per capita expenditure (ln)	0.015 (0.035)	−0.053 – 0.083	0.026 (0.035)	−0.043 – 0.094
Urban Ref: Rural	0.089 (0.045)**	0.001 – 0.177	−0.003 (0.046)	−0.093 – 0.086
Year 2014 Ref: year 2007	−0.008 (0.006)	−0.020 – 0.004	−0.023 (0.006)***	−0.035 – −0.011
Constant	9.839 (12.07)	−13.81 – 33.49	43.783 (12.30)***	19.671 – 67.900
Observations	7,583		7,583	
Number of groups (community)	2,022		2,022	
Number of groups (household)	6,837		6,837	
LR test vs. linear model	46.30		63.62	
Prob > chi2	(0.000)		(0.000)	
LR test vs. null model	489.66		229.57	
Prob > chi2	(0.000)		(0.000)	

HAZ and WHZ scores are measured in β: regression coefficients; SE: standard error; Ref: reference category; WASH: water, sanitation, and hygiene; BMI: body mass index; ln: natural logarithm; and LR: likelihood ratio. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

violation of the assumption of data independence, which results in erroneous standard errors and significance tests.[22]

DISCUSSION

This study determines that some of the WASH variables are associated with children's health, specifically the HAZ score. Improved sanitation at the household level is significantly associated with higher HAZ scores, demonstrating its role in preventing diseases that impair nutritional growth. However, no significant association was identified between WASH variables and WHZ scores, implying that WASH impacts may manifest more in long-term than short-term health outcomes. implying that WASH impacts may manifest more in long-term than short-term health outcomes.

The findings align with previous observations, indicating a significant association between improved sanitation at the household level and children's HAZ.[10,23] Moreover, improved sanitation prevents diarrhea, active trachoma, certain soil-transmitted helminth infections, and schistosomiasis,[24] which are pathways that can lead to disturbed nutritional growth.[3] Prior research in the WASH-health domain often emphasized the impact of community-level sanitation on community-level water sources.[23,25,26]

However, our study reveals that improved water coverage, rather than improved sanitation coverage, is significantly positively correlated with children's height. This finding is consistent with other studies,[27,28] suggesting positive externalities generated by improved water sources. As improved water coverage increases, overall community pathogen levels may decrease, thus reducing contamination.[27] Study of Reese *et al*. in India determined that the influence of improved water coverage extends to children's anthropometry through household sanitation.[26]

TABLE 3. Association between access to water and sanitation and children's height-for-age (HAZ) and weight-for-height (WHZ) scores: Ordinary least squares regression analysis

Variables	HAZ β (SE)	WHZ β (SE)
Improved water^Ref: Unimproved	0.119 (0.134)	−0.092 (0.132)
Improved sanitation^Ref: Unimproved	0.168 (0.048)***	−0.045 (0.047)
Improved water coverage (%)	0.005 (0.002)**	0.002 (0.002)
Improved sanitation coverage (%)	0.000 (0.001)	0.001 (0.001)
Age (Years)	−0.010 (0.001)***	−0.007 (0.001)***
Girl^Ref: Boy	0.097 (0.034)***	0.004 (0.033)
Birth weight (Kilograms)	0.347 (0.028)***	0.217 (0.028)***
Full immunization^Ref: Not full	0.051 (0.037)	0.014 (0.036)
Boil water^Ref: Not boil	0.101 (0.038)***	0.007 (0.038)
Mother's education (Years)	0.031 (0.006)***	0.012 (0.006)**
Mother's BMI: underweight^Ref: Normal weight	−0.123 (0.063)**	−0.255 (0.062)***
Mother's BMI: overweight^Ref: Normal weight	−0.002 (0.041)	0.184 (0.040)***
Mother's BMI: obesity^Ref: Normal weight	0.049 (0.059)	0.337 (0.058)***
Per capita expenditure (ln)	0.148 (0.028)***	0.066 (0.028)**
Community education (Years)	0.020 (0.011)	0.011 (0.011)
Community per capita expenditure (ln)	0.022 (0.032)	0.024 (0.032)
Urban^Ref: Rural	0.078 (0.040)*	−0.002 (0.040)
Year 2014^Ref: year 2007	−0.009 (0.006)	−0.025 (0.005)***
Constant	11.584 (10.93)	47.244 (10.78)***
Observations	7,583	7,583
R-squared	0.069	0.029

HAZ and WHZ scores are measured in β: regression coefficients; SE: standard error; Ref: reference category; WASH: water, sanitation, and hygiene; BMI: body mass index; and ln: natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

By contrast, none of the WASH variables are significantly related to WHZ. This result aligns with previous studies[29,30] and might indicate that WASH variables affect children's health more on the long-term [31] rather than a short-term basis, as reflected by WHZ.[32] However, caution is warranted, as research in sub-Saharan Africa[33] and Cambodia[34] identified a significant relation between WHZ and WASH interventions. This discrepancy implies that our study might be overlooking certain confounding variables, such as children's dietary intake or personal hygiene, or that the outcome result might be underestimated.

According to Richard and others, decreases in HAZ and WHZ overall distribution among children as they get older suggests that they are not growing to their full capability, as is often the case for children in developing countries.[35] Furthermore, the study underscores the strong association between birth weight and children's anthropometrics (i.e, HAZ and WHZ), echoing earlier findings.[36] The prenatal environment, as represented by birth weight, emerges as a pivotal predictor of children's nutrition.[36] Another significant individual factor is the child's gender, as girls are generally taller than boys. This finding supports Thurstan and others' claim that boys are relatively more vulnerable to undernutrition than girls.[37] Moreover, children who reside in urban areas are reportedly taller than those who live in rural areas. Similarly, as the average educational attainment in the community increases, so does the children's height.

The household practice of boiling water to treat contaminated water is significantly related to HAZ, which aligns with findings from Cousens' study of Sri Lanka.[38] The mother's education also is crucial to children's anthropometry. This supports Glewwe's work and suggests that education contributes to the mother's knowledge of health and indirectly influences the child's nutritional status. The effect of the mother's BMI on the child's health, expected because of its representation of genetic factors and household lifestyle, is significant for WHZ. This association is highly linked to dietary intake and recurrent disease episodes.[35] The relationship indicates that when the mother is underweight, the WHZ of her children is lower than that of children whose mothers have a healthy weight. The coefficient increases as the mother's weight category inclines toward overweight and obese. However, the year 2014 variable shows that children's WHZ in 2014 were lower than children's WHZ in 2007. While it might indicate possible infectious diseases and a persistent lack of nutritional intake,[40] the variable also suggests that there are differences between the two-time frames of the data, which might be a result of natural changes in the circumstances over time.

However, this study encountered some limitations. First, one of the WASH components, personal hygiene, had to be left out because of the limitation of the IFLS. Including it would have further substantiated the association between WASH and nutrition. Second, apart from personal hygiene, this research might be overlooking some noteworthy determinants of children's anthropometrics, for instance, dietary intake, which might result in an underestimated outcome. Third, this study is cross-sectional, so a causal relationship between the outcome and the explanatory variables cannot be inferred. Finally, the datasets were constructed in 2007 and 2014, which might reflect a circumstance different from the current situation, especially after the COVID-19 pandemic.

Multilevel interventions targeting specific audiences are crucial, and promoting education, especially for women, fosters better child nutrition practices. Future research could use panel data to explore the causal relationships between WASH variables and children's anthropometry to enhance the understanding of their causality. Comprehensive inclusion of WASH variables, such as hygiene practices, is essential for a comprehensive exploration of this subject.

CONCLUSIONS

This study contributes to explaining the urgency of access to improved water and sanitation, especially at different levels (individual, household, and community) in Indonesia. The findings of this study fill a research gap in children's anthropometrics by adjusting the individual, household, and community-level factors in Indonesia, which might open new avenues for future research. Moreover, this study underscores the need for governments to prioritize improving water sources and sanitation facilities to alleviate the health burden of inadequate drinking water and sanitation. Furthermore, exploring the implications of our findings in the current situation, particularly in the post-COVID-19 era, is essential for informing policy decisions and interventions to address the health challenges that children face.

CONFLICT OF INTEREST

None declared.

FUNDING

This article received no external funding.

Received: *March 12, 2024* | *Accepted: August 20, 2024*

REFERENCES

1. United Nations Children's Fund (UNICEF) and World Health Organization (WHO*). Progress on Household Drinking Water, Sanitation and Hygiene 2000-2022: Special Focus on Gender*. New York: United Nations Children's Fund (UNICEF) and World Health Organization (WHO); 2023.
2. Statistics Indonesia. *Indikator Perumahan dan Kesehatan Lingkungan 2022*. Jakarta: Statistics Indonesia; 2023.
3. Bery R, Rosenbaum J, Annis J. *Horizontal challenges: WASH and nutrition integration*. United Kingdom: 38th WEDC International Conference, Loughborough University; 2015. Briefing Paper 2196.
4. World Health Organization (WHO), United Nations Children's Fund (UNICEF) and World Bank. *State of the world's drinking: An urgent call to action to accelerate progress on ensuring safe drinking water for all*. New York: World Health Organization; 2022.
5. Alam MA, Richard SA, Fahim SM, Mahfuz M, Nahar B, Das S, *et al*. Impact of early-onset persistent stunting on cognitive development at 5 years of age: Results from a multi-country cohort study. *PLoS One*. 2020;15:e0227839.
6. Dewey KG, Begum K. Long-term consequences of stunting in early life. *Matern Child Nutr*. 2011;7 Suppl 3:518.
7. McDowell MA, Fryar CD, Ogden CL, Flegal KM. Anthropometric reference data for children and adults: United States, 2003–2006. *Natl Health Stat Report*. 2008;(10):1–48.
8. Ministry of Health of the Republic of Indonesia. B*uku saku: Hasil Survei Status Gizi Indonesia (SSGI) 2022*. Jakarta: Ministry of Health of the Republic of Indonesia; 2022.
9. Ayuningtyas D, Hapsari D, Rachmalina R, Amir V, Rachmawati R, Kusuma D. Geographic and Socioeconomic disparity in child undernutrition across 514 districts in Indonesia. *Nutrients*. 2022;14:843.
10. Cameron L, Chase C, Haque S, Joseph G, Pinto R, Wang Q. Childhood stunting and cognitive effects of water and sanitation in Indonesia. *Econ Hum Biol*. 2021;40:100944.
11. Gelli A, Headey D, Becquey E, Ganaba R, Huybregts L, Pedehombga A, *et al*. Poultry husbandry, water, sanitation, and hygiene practices, and child anthropometry in rural Burkina Faso. *Matern Child Nutr*. 2019;15:e12818.
12. Lauer JM, Duggan CP, Ausman LM, Griffiths JK, Webb P, Bashaasha B, *et al*. Unsafe drinking water is associated with environmental enteric dysfunction and poor growth outcomes in young children in rural Southwestern Uganda. *Am J Trop Med Hyg*. 2018;99:1606–12.
13. Pickering AJ, Djebbari H, Lopez C, Coulibaly M, Alzua ML. Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: A cluster-randomised controlled trial. *Lancet Glob Health*. 2015;3:e701–11.
14. Komarulzaman A, Smits J, de Jong E. Clean water, sanitation and diarrhoea in Indonesia: Effects of household and community factors. *Glob Public Health*. 2017;12:1141–55.
15. Goldstein H. *Multilevel Statistical Model*. London, UK: Institute of Education, Multilevel Models Project; 1999.

16. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B; International Child Development Steering Group. Developmental potential in the first 5 years for children in developing countries. *Lancet*. 2007;369:60–70.
17. RAND. *The Indonesian Family Life Survey (IFLS)*. Santa Monica, CA: RAND; c1994-2024.
18. World Health Organization. *Training course on child growth assessment: WHO child growth standards*. Geneva: World Health Organization; 2008.
19. Ministry of Health of the Republic of Indonesia. *National Basic Health Research 2007*. Jakarta: Ministry of Health Republic of Indonesia; 2008.
20. Ministry of Health of the Republic of Indonesia. *National Basic Health Research 2013*. Jakarta: Ministry of Health Republic of Indonesia; 2013.
21. Leyland AH, Groenewegen PP. What is multilevel modelling? In: Leyland AH, Groenewegen PP. Eds. *Multilevel Modelling for Public Health and Health Services Research*. Cham: Springer Cham; 2020. p.29–48.
22. Garson GD. *Multilevel Modeling: Applications in STATA®, IBM® SPSS®, SAS®, R, & HLM™*. Thousand Oaks, CA: SAGE Publications, Inc., 2023.
23. Fuller JA, Villamor E, Cevallos W, Trostle J, Eisenberg JN. I get height with a little help from my friends: Herd protection from sanitation on child growth in rural Ecuador. *Int J Epidemiol*. 2016;45:460–9.
24. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, *et al*. The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017;220:928–49.
25. Alemu ZA, Ahmed AA, Yalew AW, Birhanu BS, Zaitchik BF. Individual and community level factors with a significant role in determining child height-for-age Z score in East Gojjam Zone, Amhara Regional State, Ethiopia: A multilevel analysis. *Arch Public Health*. 2017;75:27.
26. Reese H, Sinharoy SS, Clasen T. Using structural equation modelling to untangle sanitation, water and hygiene pathways for intervention improvements in height-for-age in children <5 years old. *Int J Epidemiol*. 2019;48:1992–2000.
27. Fuller JA, Eisenberg JN. Herd protection from drinking water, sanitation, and hygiene interventions. *Am J Trop Med Hyg*. 2016;95:1201–10.
28. Zhang J. The impact of water quality on health: Evidence from the drinking water infrastructure program in rural China. *J Health Econ*. 2012;31:122–34.
29. Bekele T, Rahman B, Rawstorne P. The effect of access to water, sanitation and handwashing facilities on child growth indicators: Evidence from the Ethiopia Demographic and Health Survey 2016. *PLoS One*. 2020;15:e0239313.
30. Dangour AD, Watson L, Cumming O, Boisson S, Che Y, Velleman Y, *et al*. Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. *Cochrane Database Syst Rev*. 2013;(8):CD009382.
31. World Health Organization. *Burden of Disease Attributable to Unsafe Drinking-Water, Sanitation and Hygiene, 2019 Update*. Geneva: World Health Organization; 2023.
32. Getu BD, Azanaw KA, Zimamu LY, Adal GM, Tibebu NS, Emiru TD, *et al*. Wasting and its associated factors among children aged from 6 to 59 months in Debre Tabor town, Amhara region of Ethiopia, 2019: A multicentre community-based cross-sectional study. *BMJ Open*. 2023;13:e071679.
33. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho AMN, Merom D. Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review. *Int J Environ Res Public Health*. 2017;14:863.
34. Manzoni G, Laillou A, Samnang C, Hong R, Wieringa FT, Berger J, *et al*. Child-sensitive WASH composite score and the nutritional status in Cambodian children. *Nutrients*. 2019;11:2142.
35. Richard SA, Black RE, Checkley W. Revisiting the relationship of weight and height in early childhood. *Adv Nutr*. 2012;3:250–4.
36. Schmidt MK, Muslimatun S, West CE, Schultink W, Gross R, Hautvast JG. Nutritional status and linear growth of Indonesian infants in West Java are determined more by prenatal environment than by postnatal factors. *J Nutr*. 2002;132:2202–7.
37. Thurstans S, Opondo C, Seal A, Wells JC, Khara T, Dolan C, *et al*. Understanding Sex differences in childhood undernutrition: A narrative review. *Nutrients*. 2022;14:948.
38. Cousens SN, Mertens TE, Fernando MA. The anthropometric status of children in Kurunegala district in Sri Lanka: Its relation to water supply, sanitation and hygiene practice. *Trop Med Parasitol*. 1990;41:105–14.
39. Glewwe P. Why Does mother's schooling raise child health in developing countries? Evidence from Morocco. *J Hum Resour*. 1999;34:124–59.
40. Putri DSK, Wahyono TYM. Direct and indirect factors of wasting in children aged 6 ± 59 months in Indonesia, 2010 [Faktor langsung dan tidak langsung yang berhubungan dengan kejadian wasting pada anak umur 6 ± 59 bulan di Indonesia tahun 2010]. *Media Litbangkes*. 2013;23:110–21. Indonesian.