

〈共同研究〉

「途上国における乳幼児期の子どもの発達支援に関する実証研究」

Assessing the effects of water, sanitation, and hygiene (WASH) on undernutrition and diarrhea among children in Laos

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Abstract

Undernutrition and diarrhea among children remain a global health burden in the 21st century. We assessed the effect of access to basic water, sanitation, and hygiene (WASH) services at home had on reducing children's likelihood of being undernourished or having diarrhea in Laos. We pooled two rounds of nationally representative cross-sectional household surveys — Lao Social Indicator Surveys 2011/2021 and 2017. The study sample included 23,070 children under 5 years old. Multivariate multilevel logistic regression and propensity score matching (PSM) analysis were used as estimation methods. The PSM results showed that children's access to basic WASH (both drinking water and sanitation) at home had statistically significant effects on reducing the likelihood of being stunted (OR = 0.960, $p = 0.017$), underweight (OR = 0.936, $p = 0.005$) and having diarrhea (OR = 0.969, $p = 0.034$). We confirmed that there were socioeconomic disparities among children accessing basic WASH, and thus further efforts will be needed towards equitable access to WASH in Laos.

1. Introduction

Child undernutrition has been highly prevalent and remains a global health burden in the 21st century. An estimated 22.0% or 149.2 million and 6.7% or 45.4 million children under-five were stunted (height-for-age z-scores below -2) and wasted (weight-for-height z-scores below -2) worldwide in 2020, respectively¹⁾. Child undernutrition increases the risks of mortality, morbidity, illness, infection, developmental delay, and cognitive deficit in the early childhood period²⁾. Additionally, it causes detrimental effects on educational attainment and lower labor productivity in their later life^{3,4)}. Therefore, investment in child nutrition contributes not only to improving children's current welfare but also to enhancing human's capacity in the long run⁵⁾. The Sustainable Development Goals (SDGs) stipulates "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional

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needs of adolescent girls, pregnant and lactating women and older persons”⁶⁾. The UNICEF’s conceptual framework categorizes the main causes of child nutritional status into three factors: immediate, underlying, and basic⁷⁾. Among them, water, sanitation, and hygiene (WASH) are considered an important factor as the underlying causes. Children who have inadequate access to safe WASH services are susceptible to infections and thus likely to be undernourished⁸⁾.

In addition to undernutrition, reducing diarrheal cases among children is a global challenge because diarrhea has been known as one of the leading causes of child mortality in the world⁹⁾. According to the current estimate, diarrhea accounted for 8 percent of all deaths among children under the age of five, which was equivalent to approximately 525,000 deaths⁹⁾. Most diarrhea-induced child deaths were attributed to dehydration caused by the loss of a greater amount of water and electrolytes from the body in liquid stools⁹⁾. Therefore, the prevention of dehydration and malnutrition at the time of diarrhea as well as the widely recognized provision of safe WASH facilities is a key strategy for the prevention of diarrhea¹⁰⁾.

The Lao People’s Democratic Republic (Laos) is a land-locked country in mainland Southeast Asia and belongs to the least developed countries. Although Laos’s GDP per capita (2,629 USD) exceeded that of Cambodia (1,544 USD) and Myanmar (1,467 USD) in 2020¹¹⁾, the situation surrounding child health and nutrition was inferior to these neighboring countries. Laos reduced its under-five mortality rate from 107.2 per 1000 live births in 2000 to 44.1 deaths per 1000 live births in 2020, but the figure was worse compared to Cambodia (25.4 deaths per 1000 live births) and Myanmar (33.7 deaths per 1000 live births). Although several previous studies examined the determinants of child nutritional status in Laos¹²⁻¹⁵⁾, little has been known about the effects of WASH on child health outcomes. Therefore, the purpose of the present study is to investigate the effects of WASH on child undernutrition and diarrhea in Laos. The findings are expected to help policymakers improve child health by guiding effective WASH policies and programs.

2. Methods

2.1. Study context

Laos has 7.1 million population and has one of the youngest populations in Asia, with a median age of 22.8 years in 2015¹⁶⁾. People under the age of 5 and 18 constituted 11.6% and 44.2% of the population in 2015, respectively¹⁶⁾. The prevalence of child undernutrition was among the highest in the region. For instance, the prevalence of stunting among children of Laos (30.2%) was higher than that of Cambodia (29.9%) and Myanmar (25.2%) in 2020¹¹⁾. Laos recognized 49 ethnic groups, although most of the population was 54.6% Lao-Tai, 10.9% Khmu, and 8.0% Hmong; about 26.5% of the population was comprised of other ethnic groups in 2005¹⁷⁾. In 2008, the country promulgated the National Nutrition Policy to conform the national policy to its international obligations and focused on accelerating the decrease in undernutrition and the associated morbidity and mortality risks for all ethnic groups¹⁸⁾. Regarding WASH, the percentage of people who had ‘basic’ drinking water services in Laos increased from 77% in 2015 to 85% in 2020¹⁹⁾. Similarly, the percentage of people who had ‘basic’ sanitation in Laos increased from 70% in 2015 to 79% in 2020¹⁹⁾.

2.2. Data

We used two rounds of the latest nationally representative cross-sectional data: the LSIS-I (2011/2012) and the LSIS-II (2017). The LSIS applied the technical frameworks of Multiple Indicator Cluster Surveys and the Demographic and Health Surveys. The LSIS-I provided baseline data for the 7th National Socio-Economic Development Plan (NSED) of the Government of Laos and the Millennium Development Goals^{20, 21)}. Following the LSIS-I, the LSIS-II was conducted to monitor the 8th NSED and SDGs. LSIS-I data were collected from 18,843 households from October 2011 to February 2012²⁰⁾, while 22,287 households were interviewed for the LSIS-II from July 2017 to November 2017²¹⁾. Among them, we used the data of 23,070 children under 5 years old (11,258 from LSIS-I and 11,812 from LSIS-II) as the study sample. Ethical protocols of the surveys were approved by Lao Statistics Bureau, Government of Laos. Prior to the questionnaire survey, verbal consent was obtained from all adult respondents or from parents/guardian for minors. They were informed of the voluntary nature of participation and the confidentiality and anonymity of information^{20, 21)}.

2.3. Water, sanitation, and hygiene (WASH)

Access to WASH has been one of the key components of maintaining good health, welfare and productivity and was recognized as a human right by the UN General Assembly and Human Rights Council in 2010 and in 2015²²⁾. Inadequate WASH can cause many diseases such as diarrhea, respiratory infections, malaria, schistosomiasis, trachoma, and cholera, as well as neglected tropical diseases²³⁾. The most vulnerable groups to inadequate WASH are newborns, infants, and young children. While 3.3% of global deaths were attributed to inadequate WASH in 2016, 13% of deaths in children under 5 years of age were related to inadequate WASH²³⁾. In 2020 worldwide, an estimated 1.2 billion people lacked basic drinking water services and 1.9 billion people lacked basic sanitation services, and 494 million people practiced open defecation¹⁹⁾.

According to the WHO and UNICEF as well as the LSIS report, 'basic' sources of drinking water refer to "piped water (located into dwelling, compound, yard, or plot to neighbor, public tap/standpipe), tube well/ borehole, protected dug well, protected spring, rainwater collection, and packaged or delivered water"^{19, 20)}. Regarding sanitation, 'basic' sanitation (latrine) facilities include "dwelling has piped sewer systems with (pour) flush, septic tanks, or (ventilated improved) pit latrines, pit latrines with slabs, and composting toilets"^{19, 20)}.

In Laos, the percentage of households using basic drinking water was 83.9% (96.7% in the urban and 78.3% in the rural regions) in 2017²⁰⁾. However, less than 10% of the households used piped water as the main source of drinking water, but rather relies on bottled water (48.1% in whole nation, 81.9% in the urban, 33.1% in the rural regions)²⁰⁾. Moreover, 73.8% of the households used basic sanitation facility, with 94.1% in the urban 64.9% in the rural regions²⁰⁾. One of the remarkable and crucial differences between regions was the practice of open defecation. Although only 4.2% of the households practiced open defecation in the urban area, did 32.6% of the households in the rural area²⁰⁾.

In our study, we defined a variable "Basic drinking water" takes 1 if the household of a child has basic drinking water facility, or 0 otherwise. In the same way, we defined a variable "Basic sanitation" takes 1 if the household has basic sanitation facility, or 0 otherwise. Based on these variables, we created a main explanatory variable "Basic WASH" that takes 1 if the household has

both basic drinking water (“Basic drinking water” =1) and basic sanitation (“Basics sanitation” = 1) facilities, or 0 otherwise.

2.4. Children’s nutritional status

As outcome variables of child undernutrition, we used three anthropometric measures, height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and weight-for-height z-score (WHZ), that correspond to standard deviations from the median of the reference population²⁴⁾. HAZ is a longer-term index that represents linear growth of a child and often used as an index of chronic undernutrition or ‘stunting’. WAZ is an index of both acute and chronic undernutrition which provides the information about ‘underweight’. WHZ is a shorter-time index which indicates acute undernutrition or ‘wasting’. Wasting is usually caused by a recent nutritional deficiency and manifests seasonal variations according to a change in the availability of food or disease prevalence. A child whose HAZ, WAZ, or WHZ is more than two standard deviations below the median of the reference population is classified as moderately ‘stunted’, ‘underweight’, or ‘wasted’, respectively.

2.5. Diarrheal disease

There are various causes of diarrheal symptoms, yet previous studies showed some methods for preventing diarrhea. Approximately 88% of global deaths from diarrhea were caused by unsafe water, unhygienic environment, and inappropriate toilet⁹⁾, and therefore improving water quality is one of the measures of preventing diarrhea. Although there are many ways to improve its quality, most of them are inexpensive. In the LSIS, an incidence of diarrhea of a child was defined if their mothers or caretakers answered that the child had a symptom of diarrhea in the two weeks preceding the survey²⁰⁾. As an outcome variable of our study, we defined a variable “Diarrhea” takes 1 if a child had a diarrheal symptom in the two weeks prior to the survey, or 0 otherwise.

2.6. Control variables

As control variables, we used child-, mother-, household-, and community-level characteristics. Child-level variables included sex and age (0–4 years old). Mother-level variables consisted of their age and educational achievement (none, primary, secondary, and higher). Household-level variables included the ethnicity of the household head (Lao-Tai, Mon-Khmer, Hmong-Mien, and others) and wealth quintiles. The community-level variables include province dummies (Vientiane Capital, Phongsaly, Luangnamtha, Oudomxay, Bokeo, Luangprabang, Huaphanh, Xayabury, Xiengkhuang, Vientiane, Borikhamxay, Khammuane, Savannakhet, Saravane, Sekong, Champasack, Attapeu, and Xaysomboune). In addition, we used a round dummy variable (LSIS-I [2011–2021] and LSIS-II [2017]). Selection of the covariates was based on the UNICEF’s analytical framework on the causes of child nutrition⁷⁾ and empirical studies on child nutrition^{12–15)} and diarrhea²⁵⁾ in Laos.

2.7. Statistical analysis

To evaluate the impact of children’s access to WASH services on their nutrition and diarrheal symptom, we conducted multivariate multilevel logistic regressions. Nevertheless, the assumption that children’s access to WASH is exogenous may not be realistic. To solve this endogeneity problem, we applied the propensity score matching (PSM) method to obtain robust estimates. The PSM

attempts to estimate the effects of a treatment in observational studies by reducing the bias arising from confounding factors that might predict outcomes. The PSM matches treated and untreated units based on a set of basic characteristics and attempts to balance covariates of both groups. In our study, we created the following groups: children with access to basic WASH and children without access to basic WASH. Stata version 16 was used for statistical analysis.

3. Results

3.1. Sample characteristics

Table 1 reports the sample characteristics. With respect to the main predictors, 74.9% and 57.2% of the total children had access to basic drinking water and basic sanitation services at home, respectively. Accordingly, around half (50.3%) of the children had access to basic WASH (both basic drinking water and basic sanitation services) at home. In addition to the mean values of the total sample, we report the mean values of children by whether they had access to basic WASH (“Basic WASH”) or not (“Without basic WASH”).

Regarding outcome variables, the proportions of children who were stunted, underweight, and wasted were 33.9%, 29.6%, and 6.8%, respectively. 8.3% of the children had an episode of diarrhea in the two weeks prior to the survey. The proportions of undernutrition and diarrhea were significantly lower among children with basic WASH than for those without. Regarding the covariates, educational attainment of the mothers of a child with basic WASH were significantly higher than that of those without. The household wealth level was higher for children with basic WASH than for those without.

Table 1. Sample characteristics

Variables	Total Obs	Mean	Basic WASH Mean	Without basic WASH Mean	Gap	
Outcome variables						
Stunted	21,981	0.339	0.247	0.432	-0.185	***
Underweight	22,370	0.296	0.225	0.368	-0.143	***
Wasted	22,045	0.068	0.062	0.074	-0.012	**
Diarrhea	22,770	0.083	0.062	0.104	-0.042	***
Main predictors						
Basic WASH: Both (1) & (2)	23,064	0.503	1.000	0.000	1.000	***
(1) Basic drinking water	23,070	0.749	1.000	0.495	0.505	***
(2) Basic sanitation	23,064	0.572	1.000	0.139	0.861	***
Covariates						
Girl	23,070	0.491	0.495	0.486	0.009	
Child age						
0 year	22,787	0.201	0.204	0.197	0.008	
1 year	22,787	0.192	0.197	0.186	0.010	***
2 years	22,787	0.199	0.196	0.201	-0.004	
3 years	22,787	0.213	0.210	0.216	-0.006	
4 years	22,787	0.196	0.193	0.200	-0.008	

Mother's age	23,070	28.4	28.5	28.3	0.2	***
Educational attainment of mother						
None	22,976	0.283	0.113	0.455	-0.342	***
Primary	22,976	0.397	0.372	0.422	-0.050	***
Secondary	22,976	0.242	0.371	0.112	0.259	***
Higher	22,976	0.078	0.144	0.012	0.132	***
Ethnicity						
Lao-Tai	23,070	0.486	0.652	0.318	0.334	***
Mon-Khmer	23,070	0.197	0.137	0.258	-0.121	***
Hmong-Mien	23,070	0.150	0.123	0.177	-0.054	***
Other	23,070	0.167	0.088	0.247	-0.159	***
Wealth quintile						
Lowest	22,787	0.297	0.079	0.517	-0.438	***
Lower middle	22,787	0.220	0.155	0.287	-0.132	***
Middle	22,787	0.178	0.211	0.144	0.066	***
Upper middle	22,787	0.156	0.264	0.048	0.215	***
Highest	22,787	0.148	0.292	0.004	0.288	***
Province						
Vientiane capital	23,070	0.089	0.166	0.011	0.155	***
Phongsaly	23,070	0.032	0.019	0.044	-0.025	***
Luangnamtha	23,070	0.028	0.038	0.018	0.019	**
Oudomxay	23,070	0.066	0.062	0.070	-0.008	***
Bokeo	23,070	0.032	0.032	0.033	-0.001	
Luangprabang	23,070	0.072	0.069	0.076	-0.008	
Huaphanh	23,070	0.054	0.051	0.058	-0.007	
Xayabury	23,070	0.047	0.064	0.031	0.033	***
Xiengkhuang	23,070	0.054	0.064	0.043	0.021	***
Vientiane	23,070	0.068	0.093	0.043	0.050	***
Borikhamxay	23,070	0.041	0.059	0.023	0.036	***
Khammuane	23,070	0.054	0.043	0.065	-0.022	***
Savannakhet	23,070	0.146	0.096	0.197	-0.101	***
Saravane	23,070	0.077	0.026	0.129	-0.102	***
Sekong	23,070	0.024	0.018	0.030	-0.012	***
Champasack	23,070	0.082	0.073	0.092	-0.018	
Attapeu	23,070	0.022	0.016	0.027	-0.012	***
Xaysomboun	23,070	0.011	0.011	0.010	0.001	*
Round						
LSIS-I (2011-2012)	23,070	0.496	0.402	0.592	-0.190	***
LSIS-II (2017)	23,070	0.504	0.598	0.408	0.190	***

*p<0.1 **p<0.05 ***p<0.01

3.2. Regression analysis

Table 2 presents the results of the multivariate multilevel logistic regressions on the effects of basic WASH on undernutrition and diarrhea among children. The magnitude of the effects was assessed by odds ratios (ORs), which are interpreted as increasing the likelihood of undernourished or having diarrhea (if OR > 1) or reducing that likelihood (if OR < 1). Regarding the main predictor, whether the child had access to basic WASH — both drinking water and sanitation — at home (Model 1), there was a statistically significant effect. The estimated ORs for stunting (OR = 0.843, p = 0.001) indicates that if the child has access to basic WASH, the odds of a child being stunted decreased by

0.157. Similarly, favorable effects of basic WASH were confirmed for underweight (OR = 0.855, $p = 0.002$) and diarrhea (OR = 0.875, $p = 0.081$). On the other hand, there was no significant effect of basic WASH for wasting at the less than 10% significance level (OR = 0.871, $p = 0.124$). Model 2 and Model 3 report the estimated effect of basic drinking water and basic sanitation services, respectively. Children with access to basic drinking water services (Model 2) were less likely to be undernourished at the less than 5% significance levels, albeit with no statistical significance for diarrheal episode. Children with access to basic sanitation services (Model 3) were less likely to be stunted (OR = 0.875, $p = 0.011$), underweight (OR = 0.824, $p < 0.001$), wasted (OR = 0.849, $p = 0.078$), and have diarrhea (OR = 0.862, $p = 0.063$).

Regarding the estimated results of the covariates, higher educational levels of the mother were associated with reduced likelihood of stunting and underweight among children, but not for wasting and diarrhea. Regarding ethnicity, children from Mon-Khmer, Hmong-Mien, and other ethnic groups were more likely to be undernourished and have diarrhea than those from Lao-Tai group. Children from wealthier households were less likely to be undernourished or have diarrhea.

Table 2. Results of multilevel logistic regressions for the effect of WASH

	Stunted	Underweight	Wasted	Diarrhea
Model 1				
Basic WASH	0.843 (0.001)***	0.855 (0.002)***	0.871 (0.124)	0.875 (0.081)*
Covariates				
Girl	0.979 (0.560)	1.040 (0.284)	0.934 (0.280)	0.860 (0.007)***
Child's age				
0 year †				
1 year	5.256 (0.000)***	6.568 (0.000)***	3.212 (0.000)***	1.357 (0.000)***
2 years	4.418 (0.000)***	5.989 (0.000)***	1.912 (0.000)***	0.781 (0.003)***
3 years	5.790 (0.000)***	5.267 (0.000)***	1.451 (0.001)***	0.517 (0.000)***
4 years	6.629 (0.000)***	4.923 (0.000)***	1.220 (0.083)*	0.465 (0.000)***
Mother's age	0.990 (0.000)***	0.989 (0.000)***	0.999 (0.816)	1.001 (0.854)
Mother's education				
None †				
Primary	0.865 (0.004)***	0.887 (0.019)**	0.992 (0.932)	0.970 (0.679)
Secondary	0.799 (0.001)***	0.864 (0.030)**	1.092 (0.440)	0.916 (0.380)
Higher	0.783 (0.017)**	0.646 (0.000)***	0.897 (0.516)	0.790 (0.146)
Ethnicity				
Lao-Tai †				
Mon-Khmer	1.445 (0.000)***	1.214 (0.004)***	0.727 (0.004)***	1.812 (0.000)***

Hmong-Mien	2.191 (0.000)***	0.966 (0.653)	0.498 (0.000)***	1.698 (0.000)***
Other	1.558 (0.000)***	1.486 (0.000)***	0.777 (0.039)**	1.357 (0.004)***
Wealth quintile				
Lowest †				
Lower middle	0.789 (0.000)***	0.800 (0.000)***	0.808 (0.025)**	0.975 (0.748)
Middle	0.560 (0.000)***	0.659 (0.000)***	0.805 (0.061)*	0.794 (0.021)**
Upper middle	0.420 (0.000)***	0.474 (0.000)***	0.590 (0.000)***	0.722 (0.009)***
Highest	0.256 (0.000)***	0.298 (0.000)***	0.607 (0.003)***	0.653 (0.007)***
Province				
Vientiane capital †				
Phongsaly	2.652 (0.000)***	1.125 (0.460)	0.751 (0.276)	1.616 (0.041)**
Luangnamtha	1.720 (0.001)***	1.443 (0.019)**	1.861 (0.010)***	1.317 (0.243)
Oudomxay	1.904 (0.000)***	1.211 (0.200)	0.622 (0.056)*	1.478 (0.077)*
Bokeo	1.447 (0.017)**	1.006 (0.971)	0.566 (0.031)**	2.332 (0.000)***
Luangprabang	1.557 (0.003)***	1.045 (0.766)	0.836 (0.450)	1.288 (0.251)
Huaphanh	1.847 (0.000)***	1.136 (0.392)	1.170 (0.504)	0.804 (0.345)
Xayabury	1.383 (0.039)**	1.264 (0.125)	1.989 (0.002)***	0.977 (0.923)
Xiengkhuang	2.186 (0.000)***	1.191 (0.245)	0.406 (0.001)***	1.349 (0.183)
Vientiane	1.819 (0.000)***	1.326 (0.050)*	0.764 (0.246)	0.882 (0.578)
Borikhamxay	1.820 (0.000)***	1.062 (0.691)	0.775 (0.287)	1.067 (0.778)
Khammuane	1.606 (0.001)***	1.424 (0.015)**	0.974 (0.906)	0.691 (0.119)
Savannakhet	1.304 (0.066)*	1.145 (0.337)	0.895 (0.614)	1.124 (0.585)
Saravane	2.494 (0.000)***	1.814 (0.000)***	0.930 (0.745)	0.730 (0.163)
Sekong	2.786 (0.000)***	2.090 (0.000)***	0.919 (0.714)	1.219 (0.372)
Champasack	1.375 (0.033)**	1.356 (0.036)**	0.941 (0.788)	0.702 (0.135)
Attapeu	1.144 (0.390)	1.500 (0.008)***	2.073 (0.001)***	0.468 (0.003)***
Xaysomboune	1.690 (0.002)***	1.153 (0.407)	0.596 (0.078)*	1.720 (0.031)**

Round				
LSIS-I (2011/2012) †				
LSIS-II (2017)	0.627 (0.000)***	0.859 (0.001)***	1.770 (0.000)***	0.611 (0.000)***
Observation	21977	22366	22041	22765
Model 2				
Basic drinking water	0.862 (0.002)***	0.901 (0.036)**	0.836 (0.035)**	0.956 (0.536)
Observation	21977	22366	22041	22765
Model 3				
Basic sanitation	0.875 (0.011)**	0.824 (0.000)***	0.849 (0.078)*	0.862 (0.063)*
Observation	21977	22366	22041	22765

Odds ratios (ORs) are reported, *p<0.1 **p<0.05 ***p<0.01, † : Reference
Estimates of covariates for Model 2 and Model 3 are omitted from the table.

Table 3 presents the results of the logistic regression analysis to identify factors that are associated with the child's access to basic WASH services at home. It shows higher educational levels of the mother and household's wealth level were strongly associated with a higher likelihood of preschool attendance and home stimulation. Regarding ethnicity, children from Mon-Khmer, Hmong-Mien, and other ethnic groups were less likely to have access to basic WASH services.

Table 3. Results of logistic regressions for children's access to basic WASH

	Basic WASH	Basic drinking water	Basic sanitation
Girl	1.065 (0.083)*	1.031 (0.377)	1.045 (0.247)
Child's age			
0 year †			
1 year	1.033 (0.577)	1.012 (0.828)	0.982 (0.770)
2 years	1.006 (0.922)	0.999 (0.992)	0.996 (0.949)
3 years	1.020 (0.729)	0.982 (0.744)	1.003 (0.963)
4 years	0.973 (0.641)	0.999 (0.980)	0.976 (0.691)
Mother's age	1.015 (0.000)***	1.008 (0.000)***	1.013 (0.000)***
Mother's education			
None †			
Primary	1.587 (0.000)***	1.207 (0.000)***	1.496 (0.000)***
Secondary	2.167 (0.000)***	1.536 (0.000)***	2.087 (0.000)***
Higher	2.462 (0.000)***	1.740 (0.000)***	2.287 (0.000)***
Ethnicity			
Lao-Tai †			
Mon-Khmer	0.906 (0.106)	0.748 (0.000)***	0.965 (0.588)
Hmong-Mien	0.599 (0.000)***	0.604 (0.000)***	0.558 (0.000)***

Other	0.787 (0.000)***	0.828 (0.001)***	0.777 (0.000)***
Wealth quintile			
Lowest †			
Lower middle	3.937 (0.000)***	1.539 (0.000)***	4.985 (0.000)***
Middle	10.681 (0.000)***	2.291 (0.000)***	18.148 (0.000)***
Upper middle	41.447 (0.000)***	5.557 (0.000)***	98.287 (0.000)***
Highest	417.013 (0.000)***	49.869 (0.000)***	1077.349 (0.000)***
Province			
Vientiane capital †			
Phongsaly	0.667 (0.029)**	1.156 (0.436)	0.334 (0.000)***
Luangnamtha	2.450 (0.000)***	7.034 (0.000)***	1.062 (0.847)
Oudomxay	1.392 (0.065)*	1.475 (0.035)**	0.683 (0.213)
Bokeo	0.818 (0.291)	0.599 (0.006)***	1.049 (0.878)
Luangprabang	0.854 (0.385)	0.662 (0.023)**	0.599 (0.097)*
Huaphanh	1.660 (0.005)***	2.253 (0.000)***	1.058 (0.853)
Xayabury	1.010 (0.960)	0.774 (0.191)	1.610 (0.137)
Xiengkhuang	1.710 (0.003)***	1.738 (0.004)***	0.880 (0.678)
Vientiane	0.902 (0.570)	0.773 (0.165)	0.927 (0.810)
Borikhamxay	0.922 (0.665)	0.652 (0.023)**	1.052 (0.874)
Khammuane	0.230 (0.000)***	0.321 (0.000)***	0.114 (0.000)***
Savannakhet	0.199 (0.000)***	0.260 (0.000)***	0.093 (0.000)***
Saravane	0.123 (0.000)***	0.426 (0.000)***	0.062 (0.000)***
Sekong	0.791 (0.187)	0.968 (0.856)	0.440 (0.007)***
Champasack	0.213 (0.000)***	0.642 (0.015)**	0.088 (0.000)***
Attapeu	0.233 (0.000)***	0.486 (0.000)***	0.136 (0.000)***
Xaysomboune	0.682 (0.052)*	0.715 (0.087)*	0.632 (0.152)
Round			
LSIS-I (2011/2012) †			
LSIS-II (2017)	3.058 (0.000)***	1.629 (0.000)***	3.521 (0.000)***
Observation	22782	22786	22782

Odds ratios (ORs) are reported, *p<0.1 **p<0.05 ***p<0.01, † : Reference

3.3. Propensity score matching analysis

Table 4 reports the results of the PSM analysis. As a main predictor, children's access to basic WASH (both drinking water and sanitation services) at home had statistically significant effects on reducing the likelihood of being stunted (OR = 0.960, $p = 0.017$), underweight (OR = 0.936, $p = 0.005$) and having diarrhea (OR = 0.969, $p = 0.034$).

Children with access to basic drinking water services were less likely to be stunted and underweight. Children with access to basic sanitation services were less likely to be underweight, wasted, and have diarrhea. These results confirm the robust and favorable effect of WASH services on reduction in undernutrition and diarrheal episode among Laotian children.

Table 4. Results of of propensity score matching analysis

	Stunted	Underweight	Wasted	Diarrhea
Basic WASH	0.960 (0.017)**	0.936 (0.005)***	0.981 (0.269)	0.969 (0.034)**
Observation	21977	22366	22041	22765
Basic drinking water	0.957 (0.004)***	0.976 (0.051)*	0.990 (0.302)	0.966 (0.109)
Observation	21977	22366	22041	22765
Basic sanitation	0.997 (0.810)	0.943 (0.005)***	0.947 (0.034)**	0.953 (0.069)*
Observation	21977	22366	22041	22765

Odds ratios (ORs) are reported, * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$, p-values in brackets

4. Discussion

This study investigated the effect of WASH on undernutrition and diarrhea among children in Laos by analyzing a nationally representative sample from two rounds of household surveys — LSIS-I (2011/2012) and LSIS-II (2017) — . We confirmed that children's access to basic WASH services at home, after controlling for potential confounders, had significant effects on reducing children's likelihoods of being undernourished and having diarrhea by conducting both multivariate multilevel logistic regressions and PSM analysis.

This favorable effect of access to WASH on child health status is consistent with the results of several previous studies in LMICs. Despite the importance of WASH on for improving child health in LMICs, results from the previous empirical studies were mixed²⁶⁾. Many experimental studies exerted no significant effects of WASH. For instance, studies using experimental methods have documented that intervention of providing safe water, sanitation, and handwashing reduced child diarrhea, but the single treatment of water had no positive effect on diarrhea in rural Bangladesh²⁷⁾, while in rural Kenya these interventions had small and insignificant effects on diarrhea and growth²⁸⁾. On the other hand, several observational studies found more optimistic results on the relationship between WASH and child health outcomes. For instance, using subnational data from 59 countries, an

empirical study found the negative correlation between the access to piped water in their dwelling and child stunting²⁹⁾. In addition, a systematic review found that point-of-use water treatments such as water filtration and disinfection as well as hygiene education and soap provision can mitigate the risk of diarrhea. In the public health literature, WASH has been recognized as a crucial component to reduce stunting, but WASH alone was not sufficient³⁰⁾. Our study adds the new findings of the effects of WASH in Laos to the literature.

We also confirmed that there were significant socioeconomic inequalities in terms of educational attainment of the parents, ethnicities, and wealth of the household among Laotian children accessing WASH. To ensure better health and well-being of all people in Laos, the 9th NSEDP primarily aims to improving hygiene and preventing diseases. Their WASH-related targets include increasing the percentage of basic drinking water from 83.9% in 2017 to 95% in 2025 and that of sanitation from 73.8% in 2017 to 85% in 2025, respectively³¹⁾. As the 9th NSEDP emphasizes the importance of achieving the goals for the development of the nation with ensured fair and equitable improvements, policymakers should work toward eliminating disparities in children's access to basic WASH in Laos.

This study has several limitations. We could not investigate the detailed mechanism behind the linkage between children's access to WASH and their nutritional status due to the nature of cross-sectional datasets. Further research will be preferable to clarify this point.

Despite these limitations, this study is the first empirical study to investigate the effects of WASH on child nutrition and diarrhea by analyzing two rounds of nationally representative cross-sectional datasets in Laos, and it will thus serve as a reference and foundation for future research. From policy point of view, since the dissemination of WASH is still low, the further expansion of preschool will be critical for the improvement of child health in Laos.

5. Conclusions

This study confirms the importance of WASH for child nutrition and health in Laos. The further expansion of WASH services at home will be critical for the achievement of health- and WASH-related SDGs in Laos.

List of abbreviations

1. Height-for-age z-score (HAZ)
2. Lao People's Democratic Republic (Laos)
3. Lao Social Indicator Surveys (LSIS)
4. Low- and middle- income countries (LMICs)
5. National Socio-Economic Development Plan (NSEDP)
6. Odds ratios (ORs)
7. Propensity score matching (PSM)
8. Sustainable Development Goals (SDGs)
9. Water, sanitation, and hygiene (WASH)
10. Weight-for-age z-score (WAZ)
11. Weight-for-height z-score (WHZ)

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