BMJ Open

Association of both Water, Sanitation and Hygiene (WASH) and Infant and Young Child Feeding (IYCF) practices with childhood malnutrition in Lao PDR: a cross-sectional study of the 2017 Lao Social Indicator Survey II

Somphos Vicheth Som ,[1] Frank T Wieringa,[2] Maiza Campos Ponce,[1] Katja Polman,[1,3] Prosper Dakurah,[4] David Duncan,[4] Janneke Blomberg,[4] Sitthorot Rasphone,[5] Marinka van der Hoeven [1]

To cite: Som SV, Wieringa FT, Campos Ponce M, *et al*. Association of both Water, Sanitation and Hygiene (WASH) and Infant and Young Child Feeding (IYCF) practices with childhood malnutrition in Lao PDR: a cross-sectional study of the 2017 Lao Social Indicator Survey II. *BMJ Open* 2023;**13**:e073974. doi:10.1136/bmjopen-2023-073974

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2023-073974).

Received 23 March 2023
Accepted 11 September 2023

For numbered affiliations see end of article.

Correspondence to
Dr Somphos Vicheth Som; s.o.m.somphos@vu.nl

ABSTRACT

Objective We assessed whether Water, Sanitation and Hygiene (WASH) and Infant and Young Child Feeding (IYCF), either alone or combined, were associated with malnutrition among Lao People's Democratic Republic (Lao PDR) children aged 6 to <24 months.

Design This is a secondary analysis of the 2017 Lao Social Indicator Survey II (LSIS II), which used multistage probability proportional to size sampling. Logistic regression analyses were conducted with OR and its corresponding 95% CI.

Setting The LSIS II was conducted a nationwide household-based survey covering all 18 provinces in Lao PDR.

Participants We had a total of 3375 children (weighted sample 3345) and 357 households with data on drinking water.

Outcome measures The outcomes of this study were stunting and wasting.

Results The prevalence of stunting and wasting was 28.9% and 10.1%, respectively. Even though households with access to a basic or improved water source were high (82.5%), over 83% of drinking water was contaminated with *Escherichia coli*. Access to improved sanitation, basic hygiene and adequate IYCF gave a significant lower risk of becoming stunted. The combined effect of these practices on stunting was (adjusted OR (AOR)=0.54; 95% CI=0.41 to 0.73) greater than each practice alone (improved sanitation: AOR=0.75; 95% CI=0.61 to 0.93; basic hygiene: AOR=0.69; 95% CI=0.57 to 0.83; adequate IYCF: AOR=0.79; 95% CI=0.64 to 0.98). Access to improved sanitation and adequate IYCF was associated with a significant lower risk for being wasted, and again the combined effect of these practices was (AOR=0.64; 95% CI=0.44 to 0.92) greater than each practice alone (improved sanitation: AOR=0.68; 95% CI=0.49 to 0.93 and adequate IYCF: AOR=0.66; 95% CI=0.47 to 0.92).

Conclusion Given the strong associations with both stunting and wasting, and the added benefits when combining WASH and IYCF, there is a need of multisectoral interventions to reduce early childhood malnutrition in Lao PDR.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This is the first study in Lao People's Democratic Republic investing the association of Infants and Young Children Feeding practices and Water, Sanitation and Hygiene (WASH) practices (either alone or combined) with childhood malnutrition.
- ⇒ Our study used the most recent data of the Lao Social Indicator Survey, but these data were collected almost 6 years ago; thus, the situation might have changed.
- ⇒ This study was not intended to establish a causal relationship between childhood malnutrition and WASH, feeding practices and other factors since this was based on cross-sectional data.
- ⇒ The complex sampling design was taken into account by applying the sample weight during the analyses, assuring the findings to be represented at the national level.

INTRODUCTION

The prevalence of malnutrition in childhood, including acute and chronic malnutrition as well as micronutrient deficiencies, remains unacceptably high in many low-income and middle-income countries, with almost 50 million children being wasted, 150 million children being stunted and over 350 million preschool children having one or more micronutrient deficiencies.[1 2] Malnutrition increases the risk of morbidity and mortality and can also negatively affect child development.[3–5]

The WHO defines stunting as a height-for-age Z score (HAZ)< −2 SD of the WHO Child growth standards median, whereas wasting is defined as weight-for-height Z score (WHZ) < −2 SD of the WHO Child growth standards median and/or a mid-upper arm circumference<125 mm or presence of nutritional oedema.[6] Globally, the prevalence of stunting among children under 5 years has declined steadily from 33.1% to 22% between 2000 and 2020, even though the total number of stunted children is still far too high.[2] The prevalence of wasting has hardly changed during the past two decades and remains high at 6.7%.[2] Moreover, Asian and African countries have shown a much slower progression in reducing child malnutrition, and many countries are not expected to reach the Sustainable Development Goals (SDGs) by 2030.[2,7]

The aetiology of malnutrition is multifactorial and interlinked at various (environmental, social and biological) levels.[8] WASH practices and Infant and Young Child Feeding (IYCF) practices are critical determinants of stunting and wasting.[9–12] There is growing evidence of an association between environmental enteric dysfunction (EED) and child growth.[13,14] EED characterised by abnormal morphology and physiology of the lining of the small intestine with inflammation resulting in impaired barrier function, increased permeability and reduced absorptive capacity of nutrients due to inadequate WASH.[15,16]

Hence, interventions such as improved nutrition intake and increasing access to improved WASH are usually implemented with the aim to reduce malnutrition rates, but results are mixed with some studies reporting no impact while others find strong effects on child growth. It has been estimated that even if standard nutritional interventions could be scaled up to 90% coverage, it would reduce the prevalence of stunting by only 20.3%.[17–20] A recent systematic review on the impact of improved water sources, sanitation and hygiene practices on growth in low and middle-income countries estimated that adequate access to WASH could decrease the risk of stunting by 13%.[21] However, it is plausible that combining interventions to improved WASH and received adequate IYCF could yield a greater positive impact on child growth.[19,22,23]

The current study focused on the Lao People's Democratic Republic (Lao PDR), because although this country has made progress in reducing the prevalence of stunting and underweight among children under 5 years of age from 2006 to 2017, the prevalence of stunting and wasting among these children remained high at 33% and 9%, respectively, in 2017.[24,25] To reach the SDGs by 2030, more efforts on reducing childhood malnutrition are needed. Little is known about an association of WASH and IYCF, either alone or combined, with child growth in Lao PDR. To fill this gap, we therefore investigated associations of WASH and IYCF, either alone or combined, with nutritional status among Lao PDR children, aged 6 to <24 months.

METHODS

Data and study population

This study is a secondary analysis, using data from the Lao Social Indicator Survey II (LSIS II) survey conducted in 2017. The LSIS II is a national representative household-based survey with a sample size of 23 400 households, 11 812 children aged <54 months and 3428 children aged 6 to <24 months. Information collected in the LSIS II included household characteristics, respondent's background characteristics, child anthropometric measurements, child anaemia status, WASH practices and IYCF practices. In addition, water quality testing was performed in a subset of households.

Sample size and sampling

The current study included 3375 children aged 6 to <24 months with complete data on anthropometric status. The 53 children who were excluded from this data analyses had missing data on anthropometric status. From these 3375 children, data was available for 537 of their households on drinking water quality, measured as *Escherichia coli* (*E. coli*) contamination in drinking water.

Outcome and measures

The outcome measures of this study were stunting and wasting, which were calculated according to the WHO Growth Child Standards.[6] Stunting defined as length-for-age Z score (LAZ)< −2 SD of the WHO Child growth standards median and wasting defined as weight-for-length Z score (WLZ)< −2 SD of the WHO Child growth standards median. To ensure the accuracy of the anthropometric variables, extreme values were checked and if LAZ< −6 or >5 or if WLZ< −5 or >5, they were excluded from the analysis. However, no extreme values were found in the database.

Child's age was grouped into three age groups: 6–8, 9–11 and 12–23 months. Child's diarrhoea status was recoded 'yes' if the children reported to have diarrhoea in the past 2 weeks prior to data collection. Maternal education was categorised as: no education, primary education, lower secondary and upper secondary/higher. Place of residence (regions) was used as categorical variable: urban, rural areas with access to road and rural areas with no access to roads. Wealth index was a composite measure of ownership of household assets, materials used for housing construction, types of water access and sanitation facilities. Wealth index was used for the analysis as a categorical variable: poorest, second, middle, fourth richer and richest households.

For water quality, *E. coli* was a measure of colony-forming units (CFUs) in drinking and source water was coded as: low (<1 per 100 mL), moderate (1–10 per 100 mL), high (10–100 per 100 mL) and very high (>100 per 100 mL). It was also coded as a binary variable: 'any contamination' if the *E. coli* CFUs was >1 per 100 mL.

WASH indicators such as access to improved drinking water source, improved sanitation and basic hygiene were collected according to the WHO Joint Monitoring

Programme guideline and coded as binary outcomes.[26] Access to improved drinking water source was coded as 'improved' for households with access to: piped into dwelling, piped into yard/plot, piped into neighbour, piped into public tap, tube well/borehole, protected dug well, protected spring, rainwater, bottled water, sachet water, tanker truck or cart with small tank. Basic drinking water was defined as drinking water from an improved source, with the additional condition that water collection time did not exceed 30 min (round trip), while access to unimproved drinking water source was coded as 'either unimproved or surface water' for households with access to unprotected dug well, unprotected spring, surface water (a river, stream, pound, lake, canal or dam) or others. An improved sanitation was coded 'improved' for households with flush/pour flush, piped sewer system, septic tanks, pit latrines, ventilated pit latrines, composting toilets or pit latrines with slab. An unimproved sanitation facility was coded 'unimproved' for households with no facility or the use of the bush or a field, a pit without a slab or an open pit, a bucket toilet, a hanging toilet. Access to basic hygiene was coded as 'yes' if handwashing facilities were located in the house, yard or plot with soap and water present and 'no' if the household had no handwashing facilities located in the house, yard or plot.

For IYCF indicators included minimum dietary diversity (MDD), minimum meal frequency (MMF) and minimum acceptable diet (MAD) using the WHO classification.[27] Receiving adequate MDD was coded as 'yes' if a child received foods from at least five of eight food groups in the past 24 hours, otherwise 'no'. These eight food groups included: (1) breastmilk, (2) grains, roots and tubers, (3) legumes and nuts, (4) dairy products (milk, infant formula, yoghurt, cheese), (5) flesh foods (meat, fish, poultry and liver/organ meats), (6) eggs, (7) fruits and vegetables that are rich in vitamin A and (8) other fruits and vegetables. Receiving adequate MMF was defined as 'yes' if breastfed infants aged 6–8 months received two mealtimes, aged 9–23 months received three mealtimes and for non-breastfed infants aged 6–23 months received four mealtimes in the past 24 hours, otherwise 'no'. Receiving adequate MAD was coded as 'yes' if children received both appropriate MDD and MMF, otherwise 'no'. For this study, adequate MAD was used to define adequate IYCF, since it included both quality (MDD) and quantity (MMF) of IYCF.

Statistical analysis

Data analysis was done using STATA software V.14 (Stata Corp, College Station, Texas, USA). All analyses were adjusted the sampling weight to make the estimates representative at the population level. Sampling weight (SW), primary sampling unit (PSU) and strata were used to consider for a complex survey design to control the error term due to the survey design. All analyses were used SVY command in STATA. Weighted frequency distribution was used to describe the study population taking into consideration the clustering due to survey study design.

To identify the association between child growth status (stunting and wasting) and WASH and IYCF practices, either alone or combined, determinants, forward logistic regression (LR) section was used. First, unadjusted LR was performed to identify factors of stunting and wasting. Then, only factors that showed statistical significance at p value<0.05 with the outcomes in the unadjusted logistic model were added into the adjusted LR model (forward LR). Crude OR and adjusted OR (AOR) and 95% CI were used to describe the strength of the association between child growth status and its factors. Multicollinearity between independent variables was checked based on the variance inflation factor (VIF). VIF>5 was used as an indication of the presence of multicollinearity.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our secondary analysis.

RESULTS

Study sample characteristics

Table 1 summarises the weighted frequency and percentage of general characteristics of the study population. In total, we had 3375 children with weighted sample of 3345 children aged 6 to <24 months in our analysis. The majority (71.8%) of these children lived in rural areas with 59.7% living in rural areas with access to roads and 12.1% living in rural areas without access to roads. The percentage of boys (53%) was a little higher than girls (47%) and the largest proportion of children (64.9%) was found in 12 to <24 months aged group. Among their mothers, around 19% had no education and 43.2% had lower or higher secondary education level. Moreover, 10% of these children were reported by their mothers to have diarrhoea in the 2 weeks prior to the data collection.

Child's nutritional status, WASH practices, water quality and IYCF practices among children aged 6–23 months

Table 2 summarises the distribution of child's nutritional status, household's WASH practices and feeding practices among our study population. The prevalence of stunted children was 28.9% and the prevalence of wasted children was 10.1%, among children aged 6–23 months in Lao PDR. The prevalence of children that received MMF was 69.2%. Children who met the MDD (≥5 food groups) and MAD were 35.6% and 28.5%, respectively.

Most children in our study population lived in households with access to an improved drinking water source (82.5%). However, as can be seen in table 2, the prevalence of children at risk of faecal contamination measured by number of *E. coli* CFU in their drinking water and source water was very high (86.5% and 83.6%, respectively). Moreover, nearly 30% of these children had no access to an improved sanitation facility and among those 27.7%

Table 1 General characteristics of children age between 6 and 23 months (weighted sample=3345)

Demography and socioeconomic status	Frequency (weighted)	Percentage (weighted)
Regions	n=3345	
Urban	944	28.2
Rural with road	1995	59.7
Rural without road	406	12.1
Sex	n=3345	
Female	1572	47.0
Male	1773	53.0
Child's age in months	n=3345	
6–8 months	583	17.4
9–11 months	592	17.7
12–23 months	2170	64.9
Maternal education	n=3345	
None	638	19.1
Primary	1260	37.7
Lower secondary	760	22.7
Upper secondary	687	20.5
Wealth index	n=3345	
Poorest	809	23.8
Second	748	22.0
Middle	651	19.2
Fourth	614	18.1
Richest	571	16.8
Diarrhoea in past 2 weeks	n=3343	
No	3007	90.0
Yes	335	10.0

had no access to a toilet and practised open defecation. Even though the majority (89.8%) of these children lived in households with access to a handwashing place in their premise (limited hygiene), nearly half of them (48.2%) had no access to a handwashing place with soap and water (basic hygiene).

Association between access to either alone or combined WASH and IYCF practices and child growth

Multicollinearity was found between wealth index and each of WASH practices (VIF>5); hence, wealth index was not included in the adjusted model.

Table 3 shows the unadjusted and adjusted LR of the association between WASH and IYCF practices, either alone or combined, and stunting. Each WASH and IYCF were significantly associated with stunting in the unadjusted analysis. However, access to improved drinking water sources was not statistically significant associated with stunting when adjusted for improved sanitation, basic hygiene, regions, child's sex, child's age and maternal education. Replacing 'improved drinking water sources' with 'basic water sources' as determinant for stunting did not change the findings. Children living in households with access to improved sanitation and at least access to basic hygiene had a lower risk of becoming stunting (improved sanitation; AOR=0.75, 95% CI=0.61 to 0.93 and basic hygiene; AOR=0.69, 95% CI=0.57 to 0.83) than children living in households with access to unimproved sanitation and no access to basic hygiene in the adjusted model. Children receiving adequate IYCF had a lower risk of becoming stunting compared with children received inadequate IYCF (AOR=0.79; 95% CI=0.64 to 0.98) adjusted for region, child's sex, child's age and maternal education. A combination of access to improved sanitation, basic hygiene and adequate IYCF had a stronger effect on stunting (AOR=0.54, 95% CI=0.41 to 0.73) than each of these practices separately.

Table 4 shows the unadjusted and adjusted LR of the association between WASH and IYCF practices, either alone or combined, and wasting. In the unadjusted model, access to improved drinking water sources, access to improved sanitation and adequate IYCF were significantly associated with wasting but access to basic hygiene was not significantly associated with wasting. Access to improved drinking water sources was not significantly associated with wasting after adjusted for improved sanitation, regions and maternal education. Households with access to improved sanitation decreased the risk of becoming wasting by 32% (AOR=0.68, 95% CI=0.49 to 0.93) when adjusted for improved drinking water sources, regions and maternal education and children who had adequate IYCF decreased the risk of wasting by 34% (AOR=0.66, 95% CI=0.47 to 0.92) after adjusted for regions and maternal education. A combination of both access to improved sanitation and adequate IYCF decreased greater risk of wasting more (AOR=0.64, 95% CI=0.44 to 0.92) than these practices alone. Rerunning the analyses with 'basic drinking water source' instead of 'improved drinking water source' yielded similar results. Additional analyses of each specific and combined WASH and feeding practices with stunting and wasting are shown in online supplemental tables.

DISCUSSION

To our knowledge, this is the first study investigating associations between WASH, IYCF and nutritional status of children, aged 6 to <24 months, in the Lao PDR, using the most recent available national data. In our dataset, children from households with access to improved WASH or adequate IYCF practices were at a lower risk to be stunted than children who had no access to these conditions. This is in line with several other studies from the region, with, for example, Dearden *et al* showing that access to improved water sources and sanitation was associated with less stunting in Vietnam.[28] A systematic review of randomised controlled trials in low-income and middle-income countries and a study from multiple countries also reported that access to improved sanitation was significantly associated with child linear growth.[21 29] And in Ethiopia, poor sanitation was associated with poor

Table 2 Nutritional status, WASH practices, water quality and IYCF practices among children aged 6–23 months

	Total (weighted)	Frequency (weighted)	Percentage (weighted)
Nutritional status			
Stunted (LAZ< −2SD)	3286	949	28.9
Wasted (WHZ<2 SD)	3314	336	10.1
WASH practices			
Access to improved water source	3344	2760	82.5
Access to improved sanitation	3344	2384	71.3
Access to basic hygiene	3345	1733	51.8
Open defecation	3344	926	27.7
Safely disposal child's stool	3344	830	24.8
Water quality			
Escherichia coli (*E. coli*) contamination in source water			
Low (<1 per 100 mL)	508	83	16.4
Moderate (1–10 per 100 mL)	508	98	19.3
High (11–100 per 100 mL)	508	152	30.0
Very high (>100 per mL)	508	174	34.3
E. coli contamination in drinking water			
Low (<1 per 100 mL)	512	69	13.5
Moderate (1–10 per 100 mL)	512	92	17.9
High (11–100 per 100 mL)	512	160	31.2
Very high (>100 per mL)	512	191	37.4
Feeding practices			
Initial breast fed	3036	2158	71.1
Received MDD	3213	1144	35.6
Received MMF	3217	2227	69.2
Received MAD	3213	916	28.5
Combined interventions			
Access to improved WASH (improved drinking water source+improved sanitation+basic hygiene)	3344	1387	41.5
Access to improved WASH and adequate IYCF (improved drinking water source+improved sanitation+basic hygiene+adequate IYCF)	3211	555	17.3

IYCF, Infant and Young Child Feeding; MAD, minimal acceptable diet; MDD, minimal dietary diversity; MMF, minimal meal frequency; WASH, Water, Sanitation and Hygiene.

linear growth in children aged 6 to <12 months and no access to a latrine was significantly associated with stunting among children aged 6 to <24 months.[30 31] In our earlier study, we showed that stunting in Cambodian children was associated with poor IYCF practices.[10]

But the impact of WASH on child nutritional status is not equivocal and appears to be dependent on the type of intervention. Perhaps surprisingly, we found no association between access to improved drinking water sources and child growth. However, these findings are in line with recent studies from South Africa and Kenya that found that households with access to improved drinking water sources were not having lower rates of wasting or stunting, and similar to findings from Dearden *et al* for India, Ethiopia and Peru.[23 28 32] Another study in India also found that access to improved drinking water sources was not a predictor of stunting.[17] These studies, however, did not include any water quality analysis. In our study, we found that even in households with access to improved drinking water sources, drinking water was heavily contaminated with *E. coli*. This indicates that access to improved drinking water sources cannot be equated with access to safe drinking water. Our study suggests that *E. coli* contamination primarily occurs at the source of drinking water, rather than during collection and/or storage as there was no difference in contamination between drinking water source itself and the point of use (83.6% and 86.5% contaminated water samples, respectively). The distance to the water source also appears not to be a major factor in causing the contamination, as the analyses with 'basic drinking water source' gave similar results. Hence, programmes should focus not only on providing

Table 3 Unadjusted and adjusted logistic regression of stunting with either alone or combined WASH and IYCF practices and other factors among children aged 6–23 months

	Model 1	Model 2	Model 3	Model 4	Model 5
	COR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Accessed to improved water (no)	Reference	Reference		Reference	
Yes	0.59 (0.47 to 0.74)***	0.87 (0.69 to 1.10)			
Accessed to improved sanitation (no)	Reference	Reference			
Yes	0.51 (0.42 to 0.62)***	0.75 (0.61 to 0.93)**			
Accessed to basic hygiene (no)	Reference	Reference			
Yes	0.52 (0.43 to 0.62)***	0.69 (0.57 to 0.83)***			
Received adequate IYCF (no)	Reference		Reference		
Yes	0.69 (0.56 to 0.84)***		079 (0.64 to 0.98)*		
Accessed to improved WASH and adequate IYCF (improved water+improved sanitation+basic hygiene+adequate IYCF) (no)	Reference			Reference	
Yes	0.43 (0.33 to 0.57)***			0.56 (0.41 to 0.75)***	
Accessed to improved sanitation, basic hygiene and adequate IYCF (no)					Reference
Yes					0.54 (0.41 to 0.73)***

Model 1: unadjusted model or univariate analysis.
Model 2: adjusted logistic regression of the association between stunting and each WASH practices by controlled for regions, child's sex, child's age and maternal education.
Model 3: adjusted logistic regression of the association between stunting and IYCF by controlled for regions, child's sex, child's age and maternal education.
Model 4: adjusted logistic regression of the association between stunting and combination of all WASH practices (water, sanitation and basic hygiene) and IYCF practices by controlled for regions, child's sex, child's age and maternal education.
Model 5: adjusted logistic regression of the association between stunting and combined access to improved sanitation, basic hygiene and IYCF practices by controlled for drinking water source, regions, child's sex, child's age and maternal education.
*P value<0.05, **p value<0.01, ***p value<0.001.
AOR, adjusted OR; COR, crude OR; IYCF, Infant and Young Child Feeding; WASH, Water, Sanitation and Hygiene.

improved drinking water sources, but also make sure that pathogens are eliminated from the source.

Beyond the associations of individual interventions with stunting, we also found that a combination of adequate WASH and adequate IYCF resulted in lower risk for stunting and wasting than either WASH alone or IYCF alone. A systematic review study on the effects of WASH alone or combined with improved nutrition on children's nutritional status found similar results as our study, in that although WASH alone improved HAZ, the combined WASH and improved nutrition intervention showed a stronger effect on HAZ and weight-for-age Z score, with a borderline effect on WHZ.[22] Moreover, a study in Ghana found that a combined effect of unimproved water sources and inappropriate IYCF on stunting was greater than either unimproved water sources only or inappropriate IYCF only.[19] Our analysis suggests that 44% of stunting could have been prevented by providing households with combined access to improved sanitation, basic hygiene and adequate IYCF. Similarly, a combination of access to improved sanitation and receiving adequate IYCF could have been prevented 36% of wasting in Lao children. This indicates that a combination of nutrition-sensitive WASH interventions alongside nutritional interventions could significantly improve both linear and ponderal growth in young children in Lao PDR.

Interestingly, access to basic hygiene (soap and water) was found to reduce risk of being stunted but not of being wasted. It should be noted that this variable signifies only whether water and soap for handwashing was present in the household and does not capture actual handwashing behaviour. However, other studies which did measure handwashing behaviour reported similar findings. A cross-sectional study in India found that children of caregivers who reported washing their hands with soap had lower odds of being stunted.[17] Another study in rural Ethiopia found that handwashing was significantly associated with less stunting.[33] The findings suggest that caregiver hygiene practices can help prevent growth retardation perhaps through less diarrhoea and other infections, or through reduced EED in children.

Almost a third of the children in our study did not receive food at appropriate times (MMF=69.2%), while the quality of food intake among children was low

Table 4 Unadjusted and adjusted logistic regression of wasting with either alone or combined WASH and IYCF practices and other factors among children aged 6–23 months

	Model 1	Model 2	Model 3	Model 4	Model 5
	COR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Access to improved water (no)	Reference				
Yes	0.62 (0.45 to 0.86)**	0.76 (0.54 to 1.07)			
Access to improved sanitation (no)	Reference				
Yes	0.59 (0.44 to 0.80)**	0.68 (0.49 to 0.93)*			
Access to basic hygiene (no)	Reference				
Yes	0.98 (0.74 to 1.29)				
Received adequate IYCF (no)	Reference		Reference		
Yes	0.61 (0.45 to 0.85)**		0.66 (0.47 to 0.92)*		
Access to improved drinking water sources, improved sanitation and adequate IYCF (no)				Reference	
Yes				0.67 (0.46, 0.98)*	
Access to improved sanitation and adequate IYCF (no)					Reference
Yes					0.64 (0.44 to 0.92)**

Model 1: unadjusted model or univariate analysis.
Model 2: adjusted logistic regression of the association between wasting and each WASH practices by controlled for, regions and maternal education.
Model 3: adjusted logistic regression of the association between wasting and IYCF practices by controlled for regions and maternal education.
Model 4: adjusted logistic regression of the association between wasting and combined access to improved drinking water source, improved sanitation and IYCF by controlled for regions and maternal education.
Model 5: adjusted logistic regression of the association between wasting and combined access to improved sanitation and IYCF practices by controlled for regions, child's sex, child's age and maternal education.
*P value<0.05, **p value<0.01, ***p value<0.001.
AOR, adjusted OR; COR, crude OR; IYCF, Infant and Young Child Feeding; WASH, Water, Sanitation and Hygiene.

(MDD=35.6%). In combination, considering both quantity and quality, only 28% of children were adequately fed, which in our study was associated with significantly associated with a better nutritional status in the children. A recent mixed-method study in Lao PDR also reported results that were similar to our findings. They found that traditional feeding practices were prevalent among young children, with diets being insufficient in terms of both nutritional quality and quantity.[34] Similar findings of poor IYCF practices have been reported in many other places in the region, including Cambodia and Myanmar.[35–37] According to The Global Nutrition Report in 2021, children aged 6–23 months often do not receive enough variety of food and their diets are often lacking essential micronutrients and fatty acid, while containing excessive amounts of sugar.[38]

The analyses were done by accounting for the complex survey design using sample weight during the analyses assuring the findings to be represented at the national level. This study was not intended to establish a causal relationship between childhood malnutrition and WASH, feeding practices and other factors since this was based on cross-sectional data. Even though our study used the most recent data of the LSIS but these data were collected almost 6 years ago; thus, the situation might have changed.

Conclusion

Stunting and wasting among children aged 6 to <24 months remains a serious public health issue in the Lao PDR. Our study shows not only that WASH and IYCF practices were associated with both forms of malnutrition, but also that combining interventions to improve both WASH and IYCF simultaneously are likely to have a greater impact. Moreover, access to improved drinking water was not sufficient in our study to provide access to safe drinking water, as most drinking water was still contaminated with *E. coli*. Thus, there is a need of multifactorial interventions such as increasing access to improved WASH and nutrition to reduce child malnutrition in Lao PDR.

Author affiliations
[1]Section of Infectious Diseases, Department of Health Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
[2]UMR QualiSud, French National Research Institute for Sustainable Development, Montpellier, France
[3]Biomedical Sciences, Institute of Tropical Medicine, Antwerp, Belgium
[4]United Nations Children's Emergency Fund Lao PDR, Vientiane, Lao People's Democratic Republic
[5]The Ministry of Planning and Investment's National Economic Research Institute, Vientiane, Lao People's Democratic Republic

Acknowledgements The authors are very grateful to UNICEF Loa People's Democratic Republic for providing us the fund for this study. We also extend our thanks to UNICEF Multiple Indicator Cluster Surveys for providing us the data.

Contributors FTW, MvdH, MCP, KP, DD, PD, JB and SR developed study, designed study, advised on data interpretation and edited the manuscript. SVS developed study, designed study, analysed the data, interpreted the data and wrote the article. FTW, MvdH, MCP, KP, SVS, DD, PD, JB and SR have read and approved the submitted version of the manuscript. SVS is responsible for the overall content as guarantor.

Funding This study is supported by UNICEF Lao People's Democratic Republic. The grant number is not applicable.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. This study was used a data from the Lao Social Indicator Survey II (LSIS II), which was conducted in 2017. The protocol for the LSIS II was approved by Lao Statistics Bureau in May 2016. Informed consent was obtained by the LSIS II from individuals who participated in the survey. The datasets did not include variables that identify individuals and was used for the purpose of secondary data analyses. The access to the dataset was requested and approved through online. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

ORCID iDs

Somphos Vicheth Som http://orcid.org/0000-0003-3336-3652
Marinka van der Hoeven http://orcid.org/0000-0003-0566-6592

REFERENCES

1 Stevens GA, Beal T, Mbuya MNN, *et al*. Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: A pooled analysis of individual-level data from population-representative surveys. *Lancet Glob Health* 2022;10:e1590–9. 10.1016/S2214-109X(22)00367-9 Available: https://doi.org/10.1016/S2214-109X(22)00367-9
2 UNICEF, WHO, WORLD BANK. Levels and trends in child malnutrition UNICEF / WHO / World Bank group joint child malnutrition estimates key findings of the 2021 edition. *World Heal Organ* 2021:1–32.
3 Blössner M, Onis MD, World Health Organization. Malnutrition, Quantifying the health impact at national and local levels. *Environ Burd Dis Ser* 2005;12.
4 Khandelwal N, Mandliya J, Nigam K, *et al*. Determinants of motor, language, cognitive, and global developmental delay in children with complicated severe acute malnutrition at the time of discharge: an observational study from central India. *PLoS One* 2020;15:e0233949. 10.1371/journal.pone.0233949 Available: https://doi.org/10.1371/journal.pone.0233949
5 Martins VJB, Toledo Florêncio TMM, Grillo LP, *et al*. Long-lasting effects of Undernutrition. *Int J Environ Res Public Health* 2011;8:1817–46. 10.3390/ijerph8061817 Available: https://doi.org/10.3390/ijerph8061817
6 de Onis M, Onyango AW, Borghi E, *et al*. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007;85:660–7. 10.2471/blt.07.043497 Available: https://doi.org/10.2471/BLT.07.043497
7 UNICEF, WHO, World Bank. UNICEF-WHO-World Bank: joint child malnutrition estimates 2020 edition – interactive dashboard. n.d. Available: https://data.unicef.org/resources/joint-child-malnutrition-estimates-interactive-dashboard-2020/
8 UNICEF. Conceptual framework on maternal and child nutrition. 2021.
9 Hondru G, Laillou A, Wieringa FT, *et al*. Age-appropriate feeding practices in Cambodia and the possible influence on the growth of the children: A longitudinal study. *Nutrients* 2019;12:12. 10.3390/nu12010012 Available: https://doi.org/10.3390/nu12010012
10 Som SV, Van Der Hoeven M, Laillou A, *et al*. Adherence to child feeding practices and child growth: A retrospective cohort analysis in Cambodia. *Nutrients* 2021;13:137. 10.3390/nu13010137 Available: https://doi.org/10.3390/nu13010137
11 Manzoni G, Laillou A, Samnang C, *et al*. Child-sensitive WASH composite score and the nutritional status in Cambodian children. *Nutrients* 2019;11:2142. 10.3390/nu11092142 Available: https://doi.org/10.3390/nu11092142
12 Jubayer A, Islam MH, Nayan MMC-SW. Child-sensitive water, sanitation, and hygiene composite score and its association with child nutritional outcomes in St. Martin's Island, Bangladesh. *SAGE Open Medicine* 2022;10:205031212210959. 10.1177/20503121221095966 Available: https://doi.org/10.1177/20503121221095966
13 Kosek M, Haque R, Lima A, *et al*. Fecal markers of intestinal inflammation and permeability associated with the subsequent acquisition of linear growth deficits in infants. *Am J Trop Med Hyg* 2013;88:390–6. 10.4269/ajtmh.2012.12-0549 Available: https://doi.org/10.4269/ajtmh.2012.12-0549
14 Budge S, Parker AH, Hutchings PT, *et al*. Environmental Enteric dysfunction and child Stunting. *Nutr Rev* 2019;77:240–53. 10.1093/nutrit/nuy068 Available: https://doi.org/10.1093/nutrit/nuy068
15 Ngure FM, Reid BM, Humphrey JH, *et al*. Environmental Enteropathy, nutrition, and early child development: making the links. *Ann N Y Acad Sci* 2014;1308:118–28. 10.1111/nyas.12330 Available: https://nyaspubs.onlinelibrary.wiley.com/toc/17496632/1308/1
16 Wirth JP, Kitilya B, Petry N, *et al*. Growth status, inflammation, and Enteropathy in young children in northern Tanzania. *Am J Trop Med Hyg* 2019;100:192–201. 10.4269/ajtmh.17-0720 Available: https://doi.org/10.4269/ajtmh.17-0720
17 Rah JH, Cronin AA, Badgaiyan B, *et al*. Household sanitation and personal hygiene practices are associated with child Stunting in rural India: a cross-sectional analysis of surveys. *BMJ Open* 2015;5:e005180.
18 Billah SM, Ferdous TE, Karim MA, *et al*. A community-based cluster randomised controlled trial to evaluate the effectiveness of different bundles of nutrition-specific interventions in improving mean length-for-age Z score among children at 24 months of age in rural Bangladesh: study protocol. *BMC Public Health* 2017;17:375.
19 Saaka M, Saapiire FN, Dogoli RN. Independent and joint contribution of inappropriate complementary feeding and poor water, sanitation and hygiene (WASH) practices to stunted child growth. *J Nutr Sci* 2021;10:e109.
20 Bhutta ZA, Das JK, Rizvi A, *et al*. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet* 2013;382:452–77.
21 Gera T, Shah D, Sachdev HS. Impact of water, sanitation and hygiene interventions on growth, non-Diarrheal morbidity and mortality in children residing in Low- and middle-income countries: A systematic review. *Indian Pediatr* 2018;55:381–93.
22 Bekele T, Rawstorne P, Rahman B. Effect of water, sanitation and hygiene interventions alone and combined with nutrition on child growth in low and middle income countries: a systematic review and meta-analysis. *BMJ Open* 2020;10:e034812.
23 Thakkar RN, Kioutchoukova IP, Griffin I, *et al*. Mapping the Glymphatic pathway using imaging advances. *J (Basel)* 2023;6:477–91. 10.3390/j6030031 Available: https://doi.org/10.1016/S2214-109X(18)30005-6
24 Ministry of Health and Lao Statistics Bureau 2018. Lao social indicator survey II. 2018.
25 Ministry of Health and Lao Statistics Bureau 2012. Lao social indicator study (LSIS) 2011-2012, Ministry of health and Lao Statistics Bureau. *Lao Soc Indic Study* 2012:1–496.
26 WHO. Core questions on water, sanitation and hygiene for household surveys 2018 UPDATE, New York United Nations child fund. *World Heal Organ* 2018:1–24.

27 WHO, UNICEF. Indicators for assessing infant and young child feeding practices part 2: measurement. *World Heal Organ* 2010.
28 Dearden KA, Schott W, Crookston BT, *et al*. Children with access to improved sanitation but not improved water are at lower risk of Stunting compared to children without access: a cohort study in Ethiopia, India, Peru, and Vietnam. *BMC Public Health* 2017;17:110. 10.1186/s12889-017-4033-1 Available: https://doi.org/10.1186/s12889-017-4033-1
29 Esrey SAW. Waste, and well-being: A Multicountry study. *Am J Epidemiol* 1996;143:608–23.
30 Medhin G, Hanlon C, Dewey M, *et al*. Prevalence and predictors of Undernutrition among infants aged six and twelve months in Butajira, Ethiopia: the P-Mamie birth cohort. *BMC Public Health* 2010;10:27. 10.1186/1471-2458-10-27 Available: https://doi.org/10.1186/1471-2458-10-27
31 Derso T, Tariku A, Biks GA, *et al*. Stunting, wasting and associated factors among children aged 6-24 months in Dabat health and demographic surveillance system site: A community based cross-sectional study in Ethiopia. *BMC Pediatr* 2017;17:96.
32 Momberg DJ, Voth-Gaeddert LE, Ngandu BC, *et al*. Factors associated with growth between birth and 1 year of age in children in Soweto, South Africa: results from the Soweto baby WASH study. *J Water Health* 2020;18:798–819. 10.2166/wh.2020.085 Available: https://doi.org/10.2166/wh.2020.085
33 Kwami CS, Godfrey S, Gavilan H, *et al*. Water, sanitation, and hygiene: linkages with Stunting in rural Ethiopia. *Int J Environ Res Public Health* 2019;16:3793.
34 Boulom S, Bon DM, Essink D, *et al*. Understanding discrepancies in nutritional outcomes among under-fives in Laos: A mixed-methods study using the positive deviance approach. *Food Nutr Bull* 2022;43:303–22. 10.1177/03795721221096187 Available: https://doi.org/10.1177/03795721221096187
35 Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 demographic and health survey. *PLoS One* 2019;14:e0209044.
36 Som SV, Prak S, Laillou A, *et al*. Diets and feeding practices during the first 1000 days window in the Phnom Penh and North Eastern districts of Cambodia. *Nutrients* 2018;10:500. 10.3390/nu10040500 Available: https://doi.org/10.3390/nu10040500
37 Areja A, Yohannes D, Yohannis M. Determinants of appropriate complementary feeding practice among mothers having children 6-23 months of age in rural Damot sore district, Southern Ethiopia; a community based cross sectional study. *BMC Nutr* 2017;3:82.
38 WHO. Global nutrition report. 2021.