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Changes in water treatment, hygiene practices, household floors, and child health in times of Covid-19: A longitudinal cross-sectional survey in Surkhet District, Nepal

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ABSTRACT

Introduction: Consistent and effective practice of water treatment, sanitation, and hygiene (WASH) behaviour is an indispensable requisite for realizing health improvements among children living in low-income areas with challenging hygienic conditions. Sustainably achieving such a behaviour change is challenging but more likely to be realized during epidemics, when health threats are high and the dissemination of information on preventative measures is intense. Our study conducted cross-sectional surveys in Surkhet District Nepal, before and during the Covid-19 pandemic to assess the impact of water safety interventions and hygiene training implemented before and during the pandemic on WASH conditions and practices and to assess the association of these changes with child health.

Methods: Information on WASH infrastructure, WASH behaviour, nutrition, and child health, including on parasitic infections, was obtained before and during the Covid-19 pandemic in spring 2018 and spring 2021, from 589 children aged between 6 months and 10 years and their caregivers. Data was collected through quantitative, structured face-to-face interviews, observations, health examinations of children including anthropometric measurements, analysis of children's stool, and water quality analysis. The association of changes in WASH factors with changes in child health was analysed using multivariate generalized estimating equations for repeated measures.

Results: Water safety management was significantly improved by the introduction of chlorination to piped water supply systems, which served 40% of households. In addition, the percentage of households using a ceramic water filter increased from 12.2% to 34.8%. Large and significant changes were observed in handwashing behaviour (frequency, use of soap and washing at critical times) and infrastructure: 35% of households constructed a new handwashing station. Kitchen and household hygiene also improved. An additional 22% of households improved the cleanliness of the toilet. The number of houses with a cemented floor increased by 20%. WASH changes were significantly associated with improved child health: the chlorination of piped water supply reduced odds ratios for diarrhoea (OR = 0.36, 95% CI = 0.15–0.88, p = 0.025), respiratory difficulties (OR = 0.39, 95% CI = 0.16–0.92, p = 0.033), fever (OR = 0.42, 95% CI = 0.26–0.71, p = 0.001) and cough (OR = 0.58, 95% CI = 0.36–0.93, p = 0.024), and. The frequency of handwashing with soap was associated with significantly reduced odds ratios for infections with *Giardia lamblia* (OR = 0.68, 95% CI = 0.50–0.91, p = 0.011), stunting and wasting (OR = 0.75, 95% CI = 0.66–0.92, p = 0.003) and fever (OR = 0.85, 95% CI = 0.75–0.96, p = 0.008),. The presence of a handwashing station at baseline was associated with significantly reduced odds ratios for respiratory difficulties (OR = 0.45, 95% CI = 0.26–0.78, p = 0.004). The construction of a handwashing station between baseline and endline was significantly associated with reduced odds ratios for pale conjunctiva (OR = 0.32, 95% CI = 0.17–0.60, $p < 0.001$), which is a clinical sign of iron deficiency and anaemia, respiratory difficulties (OR = 0.39, 95% CI = 0.17–0.89, p = 0.026) and cough (OR = 0.44, 95% CI = 0.26–0.76, p = 0.003). Using a clean container for the transport of drinking water was significantly associated with reduced odds ratios for infections with *Giardia lamblia* (OR = 0.39, 95% CI = 0.16–0.93, p = 0.033) and diarrhoea (OR = 0.48, 95% CI = 0.24–0.96, p = 0.038). Similarly, a cemented floor in the household was significantly associated with

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reduced odd ratios for diarrhoea (OR = 0.38, 95% CI = 0.16–0.87, p = 0.022) and infections with *Giardia lamblia* (OR = 0.44, 95% CI = 0.19–1.02, p = 0.056).
Conclusion: WASH training and the promotion of preventative measures during the Covid-19 pandemic supported improved water safety management and hygiene behaviour, which resulted in a reduction in infectious diseases among children in the study area.

1. Introduction

Inadequate water, sanitation, and hygiene (WASH) are associated with infectious disease and impaired nutritional status (Freeman et al., 2017; Prüss-Ustün et al., 2019). Therefore, goals 6.1 and 6.2 of the Sustainable Development Goals aim at achieving universal and equitable access to safe and affordable drinking water and to adequate and equitable sanitation and hygiene for all by 2030 (UN, 2015). Although substantial progress has been made on improving access to basic services, 2 billion people globally did not have access to safe drinking water in 2020, 40% did not have a basic handwashing facility with water, and 3.6 billion lacked safely managed sanitation, including 1.7 billion without basic sanitation. A particular concern is the lack of progress in the global practice of handwashing (UN, 2021). Systematic reviews of handwashing practice indicated that handwashing after potential faecal contact was practiced in only about 19%–26% cases (Freeman et al., 2014; Wolf et al., 2019a).

Despite the clear associations between WASH and health (Prüss-Ustün et al., 2019; Wolf et al., 2018), WASH interventions do not always yield the expected results. Large randomized controlled trials of WASH interventions conducted in Kenya, Bangladesh, and Zimbabwe did not find an impact of single or combined WASH intervention on enhancing children's growth, and only the interventions conducted in Bangladesh reduced diarrhoea incidence by 30–40% (Humphrey and al, 2019; Luby et al., 2018; Null et al., 2018). The findings of these studies raise the question why the interventions did not yield the expected impacts and what kind of strategies are required to achieve better health outcomes. The authors concluded that elementary household-level WASH interventions were not sufficiently effective in reducing child exposure to diarrhoea-causing pathogens because 95% of children still had *E.coli* on their hands and more than 50% of stored drinking water was contaminated with *E.coli* (Pickering et al., 2019b). Experts concluded that more comprehensive WASH interventions are needed to achieve a major impact on child health (Cumming et al., 2019).

In addition to critical hygiene practices and the unsafe management of human faeces, the exposure to animal faeces in low-income settings is widespread and without safe management poses a threat to human health (Matilla et al., 2018; Penakalapati et al., 2017; Prendergast et al., 2019c). In particular, children below the age of 2 years living in household environments with dirt floors and domestic animals were observed to have constant exposure to dirt via the mouth (Vila-Guilera et al., 2021). About one third of deaths among children under 5 years can be attributed to pathogens found in animal faeces (Wang et al., 2016). The safe management of animal faeces therefore is an important contribution to improving environmental hygiene and reducing exposure to diarrhoea-causing pathogens.

Several studies have modelled the association between reduced exposure to diarrhoea-causing pathogens via sanitation or drinking water treatment interventions and expected health impact and find that health improvements can only be expected with high reductions of the pathogen load (Brown and Clasen, 2012; Enger et al., 2013; Wolf et al., 2019b). Pathogen load reductions depend upon the efficacy of treatment and containment technologies and the consistency in applying these technologies. Diminishing compliance, and subsequent exposure, even when minor, is likely to reduce the effect of the intervention (Brown et al., 2019; Enger et al., 2013). Decreasing compliance is likely to diminish previous health improvements as demonstrated by findings of a cross-sectional study repeated over 8 years that assessed the impact of a WASH intervention on diarrhoea reduction among 4775 children below the age of 5 years. The study documented a continuous reduction of diarrhoea prevalence between 2007 and 2011 but observed an increase in diarrhoea prevalence 4 years later when field staff had stopped monitoring and promoting WASH behaviours (Dey et al., 2019). Considering the spread of environmental faecal contamination, it may take widespread and sustained behaviour transformations and changes in service delivery models across a range of domains to reduce exposures and achieve a health impact via WASH interventions (Raj et al., 2020; Wolf et al., 2018).

However, establishing a consistent behaviour change through WASH interventions that address individual behaviours such as drinking water treatment and handwashing is challenging (Brown et al., 2019; Luby et al., 2008; Luoto et al., 2011; Martin et al., 2018; Parker Fiebelkorn et al., 2012; Shaheed et al., 2018). A higher adoption of behaviours that reduce health risks was observed during epidemics such as the current Covid-19 pandemic and the 2009 influenza A (H1N1) swine flu epidemic in Mexico; these behaviours included more frequent and rigorous handwashing, drinking water treatment and improved household hygiene (Agüero and Beleche, 2017; Bauza et al., 2021; Lim et al., 2021; Tripathy and Sahu, 2021). These studies indicate that the pending threat of an epidemic coupled with an intensified dissemination of WASH promotion messages might enhance risk awareness, impact social norms and thus be more effective in achieving WASH-related behaviour change than promotion activities during normal times. A recent study examined psychological predictors of preventative health behaviour during Covid-19 and found that greater perception of personal risk was strongly correlated with changes in handwashing (Schumpe et al., 2022).

In Nepal, 95% of the population had access to basic water supply services and 62% to basic sanitation facilities (DHS, 2016). However, efforts to provide safe water at the point of consumption and establish consistent hygiene practices remained challenging (Meierhofer et al., 2018). Also, efforts to combat health and nutritional problems among children in Nepal did not effectively incorporate WASH interventions (Shrestha et al., 2020). Diarrhoea remained one of the most common illnesses among children and was a major cause of childhood morbidity and mortality (DHS, 2016). One in 25 children in Nepal died before reaching the age of 5 years, and almost 3500 died yearly from preventable causes (DHS, 2016).

Limited knowledge is available on WASH related practices, behaviour change and associations between these changes and child health before and during a pandemic. The goal of our study was to contribute additional evidence to understanding WASH-related behaviour change during epidemics and the association of these changes with child health by analysing longitudinal data that had been collected before and during the Covid-19 pandemic in Surkhet District in Mid-Western Nepal in 2019. Baseline data had been collected in relation to a total sanitation campaign, about one year prior to the Covid-19 pandemic. During the pandemic, hygiene promotion messages were disseminated. The second survey was conducted as the pandemic receded in spring 2021 to assess changes in WASH conditions and practices and assess the association of these changes with changes in children's infectious diseases such as fever, respiratory infections, diarrhoea, parasitic infections, and child growth.

2. Method

2.1. Study design

Our study presents longitudinal data on changes in WASH conditions and WASH practices and changes in child health in Lekhbesi municipality in Surkhet District, Mid-Western Nepal before and during the Covid-19 pandemic. The study was conducted in an area with piped water supply schemes at community level. Surkhet district is located in the Karnali Province in the west of Nepal. Karnali Province has a human development index that is lower than the Nepalese average (0.47 vs 0.57) (Paudel et al., 2018).

Baseline data were collected during spring 2018 (Shrestha et al., 2020). WASH promotion activities in the Lekhbesi municipality were implemented during 2018 and 2019. Our study was originally designed as a randomized controlled trial with three intervention sites and a control area. The three interventions were (a) scheme-level chlorination and hygiene training; (b) establishing market channels for ceramic water filters and hygiene training; and (c) only hygiene training without a water safety intervention (neither scheme-level chlorination nor promotion of ceramic water filters). No interventions had been planned for the control area. The hygiene training consisted of female community health volunteers, members of a mother's groups in a particular village, conducting hygiene literacy classes and door to door visits to provide information on the hygienic use of the toilet, adequate handwashing, safe storage of food, management of safe water, and waste management. The female health volunteers work under the local health office and receive minimal technical and financial support. They were trained for 3–4 days and provided with a flip chart and other education materials. Afterwards, they conducted the hygiene literacy classes for members of the mother's group every month for a period of 6–12 months. During this period they visited each household three times to conduct training on site.

It was planned to collect endline data in spring 2020 and assess the impact of these interventions, but this was not possible due to the Covid-19 pandemic and consequent national lockdowns and travel restrictions. During the pandemic, hygiene promotion messages were disseminated through various media channels, community health workers, and government and non-government organizations (NGOs). In addition, the specific water safety interventions that had been designed for the intervention arms were implemented in the whole municipality. Irregular scheme-level chlorination was introduced in various water-supply schemes throughout the whole study area, and ceramic water filters were sold in all market centres. As a consequence, water safety management and hygiene practices improved throughout the study area including the control area, making it impossible to differentiate interventions and associate them with the three intervention sites. The original research questions that intended to compare the impact of water safety interventions with each other and hygiene training therefore had to be dropped. Instead, having cross-sectional data available on WASH conditions and practices and child health in Lekhbesi municipality, Surkhet District prior to the Covid-19 pandemic enabled us to conduct a longitudinal cross-sectional study to gain insight into the degree of uptake of WASH interventions during the pandemic and assess their impact on child health.

Endline data were collected during a recession of the pandemic in spring 2021, before high infections of the Delta variant of the SARS-CoV-2 virus led to new lockdowns. Data was collected from 589 households. Households were selected randomly if they had met the following inclusion criteria at baseline: households with at least one child between 6 months and 10 years present at the time of baseline data collection. In a household with several children, the youngest child was examined. The same households and children were interviewed and examined during endline data collection, three years after baseline data collection.

Written informed consent form was obtained from the children's caregivers, whether parents or legal guardians. The voluntary nature of participation in the research activities was emphasized. The study was conducted in accordance with the Declaration of Helsinki (WMA, 2001). The study protocol was approved by the Kantonale Ethikkommission, Zurich in Switzerland (KEK, reference no. 2018–00089) and the Nepal Health Research Council, Kathmandu in Nepal (NHRC, reference no. 2956). The sample size and statistical power were calculated using G*Power 3.1. A sample size of 560 households was required to detect a small to medium effect in Cohen's f2 of 0.07 at one-tailed alpha of 0.05 and a statistical power of 95% with multiple regression and 35 predictor variables (Faul et al., 2007, 2009).

2.2. Data collection procedures, variables, and measurements

Data was collected by trained interviewers during face-to-face interviews with children's caregivers using a quantitative, structured questionnaire with questions on WASH conditions and WASH practices, nutrition provided to children (24-h food recall), information received on protective measures against Covid-19 and corresponding awareness, and child health, including respiratory infections and diarrhoea. Diarrhoea was defined as three or more loose or watery stools passed by children younger than 10 years in a 24-hr period, as recommended by the WHO (Baqui et al., 1991). We used a recall period of 7 days to minimize the recall bias that can affect self-reported health outcomes. The interviews were complemented by structured observations. Most variables collected during the interviews, including health outcomes, were categorical (present or absent).

Certified medical assistants (CMAs) and/or health assistants (HAs) measured children's height or length and weight to evaluate deviations from linear growth. AnthroPlus (WHO, Geneva, Switzerland) was used to calculate three anthropometric indices: (a) weight for age (WAZ, underweight), (b) height for age (HAZ, stunting), and (c) body mass index for age (BAZ, wasting). Z-scores of ≥ -2 were regarded as normal, those between < -2 and ≥ -3 as moderate undernutrition, and those below $<$ -3 as severe undernutrition (de Onis et al., 2004, 2004d, 2007e Onis et al., 2007). A child that was stunted and wasted or stunted and underweight was coded as malnourished in the analysis.

CMAs/HAs also examined children for clinical signs of nutritional deficiencies such as pale conjunctiva (iron deficiency, anaemia), loss of hair pigments (protein deficiency), dermatitis (niacin (vitamin B3) deficiency), red inflamed tongue (riboflavin (vitamin B2) deficiency), oedema (thiamine (vitamin B1) deficiency), Bitot's spots (vitamin A deficiency), dry and infected cornea (vitamin A deficiency), bowed legs (vitamin D deficiency), spongy and bleeding gums (vitamin C deficiency), subdermal hemorrhage (vitamin C deficiency) and goitre (iodine deficiency). Signs of nutritional deficiencies were coded as present or absent.

Parasitic infections were assessed by analysing a fresh morning stool sample of the participating child following standard operating procedures. The stool samples were analysed each day by experienced laboratory technicians. First, stool samples were checked for consistency and the presence of blood and mucus; then, they were visually examined for the presence of adult worms. Second, a double Kato-Katz thick smear, using 41.7 mg templates, was prepared on a slide and examined under a microscope for the presence of eggs of hookworms, *Ascaris lumbricoides, Hymenolepsis nana*, and *Trichuris trichiura* (Katz et al., 1972; Yap et al., 2012). Third, a formal-ether concentration technique was used to enhance sensitivity for the diagnosis of helminths and to detect intestinal protozoa. Approximately 1–2 g of stool was placed in 15 ml Falcon tubes with 10 ml of 5% formalin and examined for the presence of helminths and intestinal protozoa (Utzinger et al., 2010). Additionally, 20 mg of stool was prepared with a saline wet mount concentration for the microscopic detection of the same intestinal helminths and protozoa (Endris et al., 2013; Koltas et al., 2014). The intensity of infection was calculated as the number of eggs per 1 g of stool (EPG). The infection intensity of parasites then was pooled into binary variables representing presence or absence of infection.

Drinking water quality was evaluated at the source and at the point of consumption by assessing colony-forming units of *E.coli* in 100 ml water samples using membrane filtration for water quality analysis. Details about the procedures and methods applied during data collection are presented elsewhere (Shrestha et al., 2020).

2.3. Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics Version 27. Frequency statistics were used to present information about household characteristics, the prevalence and change in prevalence of WASH indicators, hygiene practices, awareness of protective measures against Covid-19, and health outcomes. Numerical variables were described by means and standard deviations if normally distributed and by medians and interquartile range otherwise. Categorical variables were described by absolute and relative frequencies. The significance of difference between variables at baseline and endline was assessed with the McNemar Test for binary variables and the Wilcoxon signed rank test for continuous variables. The significance of difference between health outcomes at baseline and endline was also assessed with logistic regression. Associations were considered as statistically significant if p-values were $\leq$0.05. Chi-square test statistics were used to assess the correlation between having received WASH training and changes in WASH factors.

Principle component analysis (PCA) with orthogonal rotation (varimax) was used to calculate a wealth index for interviewees. The Kaiser Meyer Olkin (KMO) value was 0.66, which indicated good sampling adequacy. Bartlett's test of sphericity $\chi2$ (78) = 1836.6, $p < 0.001$, indicated that correlations between items were sufficiently large for PCA. The following items with KMO values above 0.5 were included in the analysis: possession of a radio, TV, mobile phone, bicycle, motor bike, car, and watch; the type of fuel mainly used for cooking; the number of rooms in the house; and the family's average monthly expenditure. The inflexions of the scree plot indicated retaining the first two components, which had eigenvalues over Kaiser's criterion of 1 and together explained 32% of the variance. The wealth index was calculated in accordance with previously described procedures (Krishnan, 2010; Rutstein, 2008).

We used generalized estimating equation (GEE) with binary logistic distribution, independent correlation, and robust variance estimation accounting for repeated measures with random intercepts at the individual level to assess the association of the following health outcomes with longitudinal changes in WASH-related risk factors: (a) fever, (b) cough, (c) respiratory difficulties, (d) diarrhoea, (e) infection with *Giardia lamblia*, and (f) undernutrition (stunting and wasting or stunting and underweight). To assess the association of health outcomes with the change of independent variables between baseline and endline, variables included in the model were controlled for their baseline values. All models were controlled for the age and sex of the children, socioeconomic status of the household, and access to a piped water supply in the household.

3. Results

3.1. Demographics

Frequency statistics on household characteristics revealed that the main occupation for most households was agriculture (90.2%). About one third of caregivers did not have a formal education, and another third had received a secondary or higher education. The socioeconomic status of 13% of households decreased between baseline and endline data collection from the third quintile of the wealth index to the first (poorest) or second quintiles. At baseline, none of the households was in the lowest quintile and 13.4% in the second quintile, whereas at endline, 2.8% of households were in the lowest quintile and 23.7% in the second quintile. Among the children involved in the study, 62.8% were between 0 and 5 years and 37.2% were above 5 years. Some 43.1% of the children involved were male and 56.9% were female. Details on household characteristics are presented in Table A in the supplementary materials.

3.2. Awareness and behaviour relating to Covid-19

Almost all households (95.1%) had received information on preventative measures against Covid-19. The most important sources of information were radio (58%), community members (57%), TV (54%), the internet (38%), family members (35%), newspapers (21%), health staff (14%), and public posters (9%). Transmission routes indicated by interviewees were by aerosols (84%), touching contaminated surfaces (50%), and drinking contaminated water (21%). The most frequently mentioned symptoms of Covid-19 were cough (90%), fever (84%), headache (57%), and difficulty in breathing (48%). Interviewees stated that they had taken the following hygiene measures to prevent Covid-19: social distancing (77%), wearing a face mask in public (74%), washing hands more often (62%), constructing a handwashing station (32%), disinfecting hands regularly (31%), and regularly disinfecting drinking water (22%).

Because endline data were collected before the wave of the Delta variant of the SARS-CoV-2 virus in the project area, incidence of Covid-19 in the community was quite low, with 7% reported having had a Covid-19 case in the household and no deaths reported. These results are substantially different from findings presented elsewhere on Covid-19-related awareness, behaviour, and incidence in the more remote sites in Accham and Dailekh District. The data in Accham and Dailekh had been collected after the Delta variant wave of the SARS-CoV-2 virus and found that more than half of the households surveyed had one or more Covid-19 cases in their family. Some 12% of households reported that family members had died of Covid-19 (Shrestha et al., 2022).

The five concerns mentioned as arising from the pandemic were the cost and availability of goods and social services, long-term economic decline, mental health, and lack of social interaction. The fear of contracting Covid-19 was mentioned by 23% of caregivers and ranked sixth in the position of concerns. Details on awareness and behaviour relating to Covid-19 are presented in Table B in the supplementary materials.

3.3. Water access, quality and treatment

At baseline, 40.6% of households had access to piped water in the house or yard. Between baseline and endline, an additional 12% of households obtained a household water connection. At the time of collecting endline data, measurements revealed that no chlorine was present in the water. However, about 40% of interviewees stated that their water source had been chlorinated during the past two years. Asked about the frequency of chlorination, 32% said that chlorination had been done sometimes. The number of households not using a method of treating drinking water decreased significantly from 81% to 53% ($p < 0.001$). The use of a ceramic water filter was the preferred method, with its use increasing from 12% to 35% ($p < 0.001$). Details of water access, quality, and treatment at baseline and endline are presented in Table 1.

Despite the introduction of irregular chlorination of the piped water and increased practice of household water treatment, water quality at the point of consumption was found to be only slightly and not significantly improved at endline data collection. Water quality at the source had significantly improved quality at endline. These findings indicate that although water was not chlorinated at the time of collecting endline data, the occasional disinfection of the water reservoirs, pipes, and outlets via chlorination may have contributed to improving water quality at the source. The use of ceramic filters also significantly contributed to improving drinking water quality between the source and the point of consumption in the 35% of households that used a filter at endline (B = −0.79, 95% CI = −1.1- −0.5, $p < 0.001$).

Table 1
Water access, quality, and treatment.

Variables	Categories	Baseline (n = 589)		Endline (n = 589)		Change between BL & EL	
						Δ pre-valence	p-value[a]
		n	%	*n*	%	%	
Water Quality							
E.coli at point of collection	0 CFU/100 mL	*24*	4.9	*18*	3.1	−1.8	**<0.001**
	1–10 CFU/100 mL	*189*	38.7	*141*	24.4	−14.3	
	11–100 CFU/100 mL	*240*	49.2	*339*	58.7	9.5	
	1001-1000 CFU/100 mL	*23*	4.7	*67*	11.6	6.9	
	>1000 CFU/100 mL	*12*	2.5	*13*	2.2	−0.3	
	Category [Mean (SD)]	*488*	1.61 (0.8)	*578*	1.85 (0.7)	0.2	
	Median (Q1-Q3) CFU/100 mL	*488*	14 (4–36)	*578*	23 (9–61)	9.0	
E.coli at point of consumption	0 CFU/100 mL	*40*	6.9	*34*	5.9	−1.0	0.253
	1–10 CFU/100 mL	*135*	23.2	*121*	20.9	−2.3	
	11–100 CFU/100 mL	*291*	49.9	*289*	49.9	0.0	
	1001-1000 CFU/100 mL	*92*	15.8	*119*	20.6	4.8	
	>1000 CFU/100 mL	*25*	4.3	*16*	2.8	−1.5	
	Category [Mean (SD)]	*488*	1.87 (0.9)	*579*	1.93 (0.9)	0.1	
	Median (Q1-Q3) CFU/100 mL	*488*	28 (8–74)	*579*	30 (9–92)	2.0	
Δ *E.coli* Point of consumption - source	Water quality improved (yes = 1, no = 0)	*150*	31.1	*248*	42.9	11.8	0.253
	Water quality deteriorated (yes = 1, no = 0)	*333*	68.9	*330*	57.1	−11.8	
Water Source							
Main drinking water source	Piped water in the house or yard (yes = 1, no = 0)	*239*	40.6	*310*	52.6	**12.0**	**<0.001**
	Piped water in the village (yes = 1, no = 0)	*319*	54.2	*204*	34.6	**−19.6**	**<0.001**
	Other source (yes = 1, no = 0)	*31*	5.3	*75*	12.7	**7.4**	**<0.001**
Functioning of main drinking water source	Source functions well	*63*	89.1	*508*	86.2	−2.9	0.108
	Source functions, but not well	*525*	10.7	*74*	12.6	1.9	
Water Treatment							
Water treatment	No treatment	*501*	85.1	*267*	45.3	**−39.8**	**<0.001**
	Treatment only at HH	*88*	14.9	*114*	19.4	4.5	
	Treatment only at scheme level	*0*	0.0	*64*	10.9	10.9	
	Treatment at HH & scheme level	*0*	0.0	*132*	22.4	22.4	
Source chlorinated during past 2 years	(yes = 1, no = 0)	*0*	0.0	*233*	39.6	**39.6**	**<0.001**
Could you taste chlorination?	never (0)	*0*	0.0	*363*	61.6	61.6	**<0.001**
	seldom (1)	*0*	0.0	*12*	2.0	2.0	
	sometimes (3)	*0*	0.0	*199*	33.8	**33.8**	
	often (4)	*0*	0.0	*14*	2.4	2.4	
	always (5)	*0*	0.0	*1*	0.2	0.2	
How regular was chlorination?	never (0)	*0*	0.0	*363*	61.7	61.7	**<0.001**
	seldom (1)	*0*	0.0	*18*	3.1	3.1	
	sometimes (3)	*0*	0.0	*190*	32.3	**32.3**	
	often (4)	*0*	0.0	*16*	2.7	2.7	
	always (5)	*0*	0.0	*1*	0.2	0.2	
Knowledge of water treatment methods	Boiling (yes = 1, no = 0)	*382*	64.9	*440*	74.7	9.8	**<0.001**
	Chlorination (yes = 1, no = 0)	*58*	9.8	*72*	12.2	2.4	0.198
	Sodis (yes = 1, no = 0)	*58*	9.8	*62*	10.5	0.7	0.743
	Filter (yes=1, no=0)	***411***	69.8	*512*	86.9	**17.1**	**<0.001**
	Do not know (yes=1, no=0)	***126***	21.4	*6*	1.0	**−20.4**	**<0.001**
Water treatments methods being available in the household	**Kettle for boiling (yes=1, no=0)**	*12*	2.0	*49*	8.3	**6.3**	**<0.001**
	Chlorine bottle (yes = 1, no = 0)	*0*	0.0	*1*	0.2	0.2	–
	Water filter (yes=1, no=0)	*72*	12.2	*205*	34.8	**22.6**	**<0.001**
	SODIS bottle (yes = 1, no = 0)	*0*	0.0	*1*	0.2	0.2	
	PUR[b] (yes = 1, no = 0)	*1*	0.2	*8*	1.4	1.2	0.039
	Cloth (yes = 1, no = 0)	*30*	5.1	*72*	12.2	**7.1**	**<0.001**
	No product available (yes=1, no=0)	*477*	81.0	*309*	52.5	**−28.5**	**<0.001**

BL = baseline, EL = endline.
[a] the significance of difference between variables at baseline and endline was assessed using the McNemar Test or Wilcoxon signed rank test.
[b] The PUR product is a small sachet containing powdered ferric sulfate (a flocculant) and calcium hypochlorite (a disinfectant) for water treatment.

3.4. *Hygiene behaviour and infrastructure*

Significant and large differences between baseline and endline conditions were observed in handwashing behaviour and infrastructure, kitchen hygiene, waste management, and cleanliness of the toilet. An additional 35% of households constructed a handwashing station, and the frequency of handwashing increased, especially before cooking (24%) and before eating (11%). Details of hygiene infrastructure and behaviour are presented in Table 2.

The number of houses with a cemented floor had increased by 20% in our study area. This is surprising, especially as the socioeconomic conditions of 13% of households decreased during the pandemic due to lockdowns and restrictions on income-generating activities. Inquiries revealed that in 2019, a Chinese company had financially compensated households living in the area for capturing the water of Bheri River for production of electricity and irrigation in Bardiya. The Chinese company also purchased land to construct roads and a hydropower plant. Several families living in the project area had used this compensation or income from land sales for household-related construction activities.

Not much change was observed in sanitation infrastructure between baseline and endline data collection as the majority of households (88%) had private latrines at baseline. The percentage of households without a latrine decreased from 3.2% to 0.3% at endline ($p < 0.001$). The number of toilets rated as clean increased by 21.6% ($p < 0.001$).

Roughly, 40% of households involved in the study said that they had received training on WASH improvements from several organizations

Table 2
Hygiene infrastructure and behaviour.

Variables	Categories	Baseline (n = 589)		Endline (n = 589)		Change between BL & EL	
						Δ prevalence	p-value[a]
		n	%	*n*	%	%	
Received information on water treatment and hygiene from an organization [n(%)]	(yes = 1/no = 0)	*100*	17.0	*318*	54.0	37.0	
Handwashing							
Frequency of handwashing [Mean (SD)]	continuous	*589*	6.11 (2.9)	*589*	6.86 (2.7)	**0.75 (3.9)**	**<0.001**
Frequency of handwashing with soap [Mean (SD)]	continuous	*589*	3.81 (1.5)	*589*	4.16 (1.9)	**0.35 (2.3)**	**<0.001**
During which occasions do you wash hands?	When they look dirty (yes = 1/no = 0)	*399*	67.7	*395*	67.1	−0.6	0.856
	After going to toilet (yes = 1/no = 0)	*577*	98.0	*560*	95.1	**−2.9**	**0.012**
	After cleaning baby's bottom (yes = 1/no = 0)	*319*	54.2	*161*	27.3	**−26.9**	**<0.001**
	Before eating (yes = 1/no = 0)	*463*	78.6	*527*	89.5	**10.9**	**<0.001**
	Before cooking (yes = 1/no = 0)	*262*	44.5	*402*	68.3	**23.8**	**<0.001**
Presence of handwashing facility	(yes = 1/no = 0)	*370*	62.8	*578*	98.1	**35.3**	**<0.001**
Handwashing facility in good condition	(yes = 1/no = 0)	*279*	75.4	*452*	78.2	**2.8**	**0.024**
Handwashing facility clean	(yes = 1/no = 0)	*248*	67.0	*434*	75.1	**8.1**	**0.001**
Presence of soap at handwashing facility	(yes = 1/no = 0)	*272*	73.5	*441*	76.3	2.8	0.070
Presence of water at the handwashing facility	(yes = 1/no = 0)	*345*	93.2	*555*	96.0	2.8	0.100
Cleanliness of children hands	(yes = 1/no = 0)	*347*	58.9	*400*	69.2	**10.3**	**<0.001**
Handling of water containers							
Water transport container is clean	(yes = 1/no = 0)	*478*	81.3	*523*	90.8	**9.5**	**<0.001**
Using same container for drinking water storage and transport	(yes = 1/no = 0)	*524*	89.0	*455*	77.2	**−11.8**	**<0.001**
Water storage container is clean	(yes = 1/no = 0)	*475*	80.8	*438*	75.9	**−4.9**	**0.035**
Sanitation							
Type of latrine	No latrine	*19*	3.2	*2*	0.3	**−2.9**	**<0.001**
	Shared latrine	*53*	9.0	*48*	8.1	−0.9	0.678
	Private latrine	*517*	87.8	*539*	91.5	**3.7**	**0.039**
Cleanliness of the toilet	(clean = 1/not clean = 0)	*318*	56.3	*450*	77.9	**21.6**	**<0.001**
Presence of cleaning materials in the toilet	Sandles (yes = 1, no = 0)	*42*	7.1	*156*	26.5	**19.4**	**<0.001**
	Drum of water (yes = 1, no = 0)	*520*	88.3	*540*	91.7	3.4	0.065
	Brush (yes = 1, no = 0)	*204*	34.6	*72*	12.2	**−22.4**	**<0.001**
	None of these (yes = 1, no = 0)	*40*	6.8	*0*	0.0	**−6.8**	**<0.001**
Household hygiene							
Type of floor in the house	Earth	*428*	72.7	*332*	50.8	**−21.9**	**<0.001**
	Cement	*161*	27.3	*246*	47.4	**20.1**	
Keeping animals in the house overnight	(yes = 1/no = 0)	*274*	46.6				
Animals observed in the house	(yes = 1/no = 0)			*128*	22.1		
Quantification of animal faeces around the house	no faeces visible			*465*	80.4		
	very little animal faeces (1–3 piles)			*57*	9.9		
	some animal faeces (4–7 piles)			*54*	9.3		
	a lot of animal faeces (more than 7 piles)			*2*	0.3		
Presence of trash outside the house	(yes = 1/no = 0)	*334*	56.7	*328*	55.7	−1.0	1.000
Presence of trash inside the household	(yes = 1/no = 0)	*230*	39	*191*	33	**−6.0**	**0.035**
Presence of garbage inside trash-garbage pit	(yes = 1/no = 0)	*57*	9.7	*134*	23.2	**13.5**	**<0.001**
Kitchen hygiene							
Clean dishes are kept high	(yes = 1/no = 0)	*410*	69.6	*420*	72.7	3.1	0.256
All food is covered	(yes = 1/no = 0)	*451*	76.6	*489*	84.6	**8.0**	**<0.001**
Drying rack for dishes available	(yes = 1/no = 0)	*355*	60.3	*401*	69.4	**9.1**	**0.001**
Parents wearing shoes	(yes = 1/no = 0)	*424*	72.0	*441*	76.3	4.3	0.076

BL = baseline, EL = endline.
[a] the significance of difference between variables at baseline and endline was assessed using the McNemar Test or Wilcoxon signed rank test.

working in the area. Having received WASH training was significantly or marginally significantly correlated with the following changes: chlorination of the piped water supply (χ^2 (1) = 12.4, p < 0.001), keeping food in the kitchen covered (χ^2 (2) = 28.7, p < 0.001), construction of a drying rack for dishes (χ^2 (2) = 15.1, p < 0.001), higher consumption of leafy green vegetables (χ^2 (12) = 39.5, p < 0.001), handwashing after cleaning baby's bottom (χ^2 (2) = 11.1, p = 0.004), covering the floor in the house with cement (χ^2 (1) = 7.0, p = 0.008), cleanliness of the container for water storage (χ^2 (2) = 8.1, p = 0.017), presence of water in the toilet (χ^2 (2) = 6.6, p = 0.036), handwashing before cooking (χ^2 (3) = 8.3, p = 0.040), construction of a handwashing facility (χ^2 (1) = 5.9, p = 0.052).

3.5. Nutrition

The average number of meals provided per day increased slightly, by 0.2%, and an additional 9% of children received food supplements at endline. The frequency of consumption of the following foods decreased significantly: starchy food, beans, peas, lentils, meat and fish, vegetables; in contrast, the frequency of consuming nuts, eggs, and fruits increased. Details on nutrition provided to children are presented in Table 3.

3.6. Prevalence of health disorders among children

Our data revealed a decrease in various indicators of malnutrition. Despite a slightly reduced reported intake of meat, fish, beans, peas, and lentils, the clinical signs of iron deficiency, anaemia, and protein deficiency (pale conjunctiva and loss of hair pigments) significantly decreased by about 9%. Iron intake may have been compensated by the increased intake of nuts and seeds, and the protein intake might have been raised by the increased intake of eggs. This hypothesis is supported by a significant association between the frequency of eggs provided to children and a 16% reduced odds ratio for pale conjunctiva (OR = 0.84, 95% CI = 0.73–0.98, p = 0.023) in multivariate repeated measures GEE. Stunting among children in the study area decreased, but the change was not significant. In contrast to this, wasting significantly increased by 4.6% (p < 0.001). The percentage of children stunted and underweight or stunted and wasted increased by 0.8% (p < 0.001). Because an increase of wasting alone could indicate a short-term reduction of nutrition provided to children during the Covid-19 lockdowns, we used the combined variable of children being stunted and wasted or stunted and underweight to capture the impact of longer-term changes in WASH and nutrition on child health.

The incidence of parasitic infections including soil transmitted helminths (*Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale*), tapeworm (*Hymenolepsis nana*), and intestinal protozoa (*Giardia lamblia*) decreased significantly.

We observed a strong and significant reduction in the incidence of infectious diseases, including fever, cough, respiratory difficulties, and diarrhoea. Details on the prevalence of health disorders among children are presented in Table 4.

3.7. Association of changes in water treatment and hygiene with child health

Multivariate repeated-measures GEEs were calculated to understand the association of changes in water treatment and hygiene-related risk factors during the pandemic with fever, cough, respiratory difficulties, diarrhoea, stunting and wasting, infections with *Giardia lamblia*, and pale conjunctiva among children.

Children's age, sex, and socioeconomic status were included as confounding factors in the analysis. Age was significantly associated with a slightly reduced odds ratio for fever, cough, respiratory difficulties, and diarrhoea. Girls had a 36% lower odds ratio for respiratory difficulties (OR = 0.64, 95% CI = 0.43–0.97, *p* = 0.033), and children with a lower socioeconomic status had a 44 times higher odds ratio for infection with *Giardia lamblia* (OR = 44.18, 95% CI = 5.5–354.4, *p* < 0.001).

Changes in water treatment and hygiene behaviour had a significant impact on improving child health.

The introduction of **chlorination of the piped water supply** was significantly associated with a 40–60% reduced odds ratio for diarrhoea (OR = 0.36, 95% CI = 0.15–0.88, *p* = 0.025), respiratory difficulties (OR = 0.39, 95% CI = 0.16–0.92, p = 0.033), fever (OR = 0.42, 95% CI = 0.26–0.71, p = 0.001) and cough (OR = 0.58, 95% CI = 0.36–0.93, p = 0.024),.

The frequency of handwashing with soap and the presence of a handwashing station were other factors that had a significant impact on child health. The presence of a handwashing facility at baseline was

Table 3
Nutrition provided to children.

Variables	Categories	Baseline (n = 589)		Endline (n = 589)		Change between BL & EL	
		n	%/mean (SD)	*n*	%/mean (SD)	Δ pre-valence	p-*value*[b]
Meals							
Number of meals/day for children	mean (SD)	*589*	3.72 (0.6)	*588*	3.88 (0.7)	**0.16 (0.9)**	**<0.001**
Additional snacks provided	(yes = 1/no = 0)	*589*	73.3%	*588*	72.2%	−1.10%	0.739
Food supplements provided	(yes = 1/no = 0)	*589*	49.2%	*578*	58.4%	**9.2%**	**<0.001**
Type & frequency of food children consumed in past week[a]							
Starchy food (rice, grain, potatoes, etc.)	mean (SD)	*589*	6.96 (0.6)	*578*	5.8 (1.0)	**−1.16 (1.2)**	**<0.001**
Beans, peas or lentils	mean (SD)	*589*	6.27 (1.1)	*578*	5.35 (0.9)	**−0.92 (1.5)**	**<0.001**
Nuts or seed	mean (SD)	*589*	0.98 (0.8)	*578*	1.33 (1.2)	**0.35 (1.5)**	**<0.001**
Dairy products	mean (SD)	*589*	2.88 (2.3)	*578*	2.77 (1.8)	−0.13 (2.5)	0.372
Meat or fish	mean (SD)	*589*	3.23 (1.2)	*578*	2.59 (1.0)	**−0.65 (1.6)**	**<0.001**
Eggs	mean (SD)	*589*	1.93 (1.7)	*578*	2.30 (1.2)	**0.35 (2.0)**	**<0.001**
Leafy green vegetables	mean (SD)	*589*	4.27 (2.2)	*578*	2.57 (1.5)	**−1.7 (2.7)**	**<0.001**
Other vegetables	mean (SD)	*589*	4.94 (2.2)	*578*	4.21 (1.8)	**−0.73 (2.9)**	**<0.001**
Fruits	mean (SD)	*589*	1.22 (0.9)	*578*	1.94 (1.1)	**0.72 (1.4)**	**<0.001**
Date of last deworming	never (0)			*267*	51.4		
	>6 months ago (1)			*147*	28.3		
	<6 months ago (2)			*105*	20.2		

BL = baseline, EL = endline.
[a] Categories: three times per day (7), twice per day (6), once per day (5), every 2nd day (4), two times per week (3), once per week (2), less than once per week (1), not at all (0).
[b] the significance of difference between variables at baseline and endline was assessed using the McNemar Test or Wilcoxon signed rank test.

Table 4
Prevalence of health disorders among children.

Variables	Categories	Baseline (n = 589)		Endline (n = 589)		Change between BL & EL		Change between BL & EL	
						Δ pre-valence	p-value[a]	*Odds ratio (95% CI)*[b]	p-value[b]
		n	%	*n*	%	%			
Growth HAZ, WAZ, BAZ scores									
Stunting	severly stunted (−3)	*66*	11.8	*57*	10.4	−1.4	0.150		
	stunted (−2)	*137*	24.5	*115*	20.9	−3.6			
	normal (0)	*356*	63.7	*377*	68.7	5.0			
Underweight	severly underweight (−3)	*35*	6.3	*27*	6.2	−0.1	0.095		
	underweight (−2)	*80*	14.4	*85*	19.5	5.1			
	normal (0)	*442*	79.4	*323*	74.3	−5.1			
Wasting	severly wasted (−3)	*34*	6.1	*41*	7.5	1.4	**<0.001**		
	wasted (−2)	*29*	5.2	*46*	8.4	3.2			
	normal (0)	*374*	67.4	*408*	74.9	7.5			
	possible risk of overweight (1)	*63*	11.4	*25*	4.6	−6.8			
	overweight (2)	*24*	4.3	*8*	1.5	−2.8			
	obese (3)	*31*	5.6	*17*	3.1	−2.5			
Wasted or stunted or underweight	(yes = 1/no = 0)	*266*	45.2	*249*	42.3	−2.9	0.528	0.92 (0.73–1.17)	0.491
Stunting and underweight or stunting and wasting	(yes = 1/no = 0)	*75*	13.5	*78*	14.3	**0.8**	**<0.001**	1.06 (0.75–1.49)	0.749
Clinical signs of malnutrition (yes=1/no=0)									
Pale conjunctiva	**Iron deficiency, anaemia (1/0)**	***146***	24.8	*80*	15.3	**−9.5**	**<0.001**	**0.55 (0.41–0.74)**	**<0.001**
Loss of hair pigments	**Protein deficit (1/0)**	***56***	9.5	*2*	0.4	**−9.1**	**<0.001**	**0.04 (0.01–0.15)**	**<0.001**
Dermatitis	**Niacin (Vitamin B3) deficit (1/0)**	*295*	50.1	*217*	41.5	−8.6	0.683	**0.71 (0.56–0.90)**	**0.004**
Red inflamed tongue	Riboflavin (Vitamin B2) deficit (1/0)	*66*	11.2	*65*	12.4	**1.2**	**<0.001**	1.13 (0.78–1.62)	0.528
Oedema	Thiamine (Vitamin B1) deficit (1/0)	*6*	1.0	*2*	0.3	−0.7	–	0.37 (0.08–1.86)	0.228
Bitots spots	**Vitamin A deficit (1/0)**	*77*	13.1	*98*	18.7	**5.6**	**<0.001**	**1.57 (1.14–2.17)**	**0.006**
Dry and infected cornea	Vitamin A deficit (1/0)	*43*	7.3	*33*	6.3	**−1.0**	**<0.001**	0.86 (0.54–1.37)	0.514
Bowed legs	**Vitamin D deficit (1/0)**	*7*	1.2	*2*	0.4	**−0.8**	**<0.001**	**0.31 (0.07–1.54)**	**0.156**
Spongy bleeding gums	Vitamin C deficit (1/0)	*84*	14.3	*97*	18.5	**4.2**	**<0.001**	1.37 (0.99–1.88)	0.054
Subdermal hemorrhage	Vitamin C deficit (1/0)	*20*	3.4	*25*	4.8	**1.4**	**<0.001**	1.43 (0.78–2.60)	0.244
Goiter	Iodine deficit (1/0)	*2*	0.3	*4*	0.8	**0.5**	**<0.001**	2.26 (0.41–12.4)	0.347
Parasitic infections									
Soil transmitted helminths	(yes = 1/no = 0)	***119***	26.4	*73*	21.2	**−5.2**	**<0.001**	0.75 (0.54–1.05)	0.089
Hymenolepsis nana	(yes = 1/no = 0)	*7*	1.6	*0*	0.0	**−1.6**	**<0.001**	0.00 (0.00–0.00)	0.994
Giardia lamblia	**(yes=1/no=0)**	***61***	13.6	*10*	2.9	**−10.7**	**<0.001**	**0.19 (0.10–0.38)**	**<0.001**
Infectious diseases in past 7 days									
Fever	**(yes=1/no=0)**	***223***	37.9	*94*	16.0	**−21.9**	**<0.001**	**0.31 (0.24–0.41)**	**<0.001**
Cough	**(yes=1/no=0)**	***237***	40.2	*115*	19.6	**−20.6**	**<0.001**	**0.36 (0.28–0.47)**	**<0.001**
Respiratory difficulties	**(yes=1/no=0)**	***95***	16.1	*34*	5.8	**−10.3**	**<0.001**	**0.32 (0.21–0.48)**	**<0.001**
Diarrhoea	**(yes=1/no=0)**	***81***	13.8	*26*	4.4	**−9.4**	**<0.001**	**0.29 (0.18–0.46)**	**<0.001**
Blood in stool	**(yes=1/no=0)**	*18*	3.1	*1*	0.2	**−2.9**	**<0.001**	**0.05 (0.01–0.41)**	**0.005**
Mucus in stool	**(yes=1/no=0)**	*22*	3.7	*3*	0.5	**−3.2**	**<0.001**	**0.13 (0.04–0.44)**	**<0.001**

BL = baseline, EL = endline, CI=Confidence Interval.

[a] the significance of difference between health outcomes at baseline and endline was assessed using the McNemar Test for binary outcomes and Wilcoxon signed rank test for continuous variables.

[b] Odds ratios and p-values were calculated using logistic regression.

associated with a 55% reduced odds ratio for respiratory difficulties (OR = 0.45, 95% CI = 0.26–0.78, p = 0.004). The installation of a handwashing facility during the pandemic reduced odds ratios for cough (OR = 0.44, 95% CI = 0.26–0.76, p = 0.003), respiratory difficulties (OR = 0.39, 95% CI = 0.17–0.89, p = 0.026) and pale conjunctiva (OR = 0.32, 95% CI = 0.17–0.60, $p < 0.001$). The frequency of handwashing at baseline was associated with reduced odd ratios for fever (OR = 0.85, 95% CI = 0.75–0.96, p = 0.008), stunting and wasting (OR = 0.75, 95% CI = 0.66–0.92, p = 0.003) and infections with Giardia lamblia (OR = 0.68, 95% CI = 0.50–0.91, p = 0.011). An increased frequency of handwashing during the pandemic was associated with a reduced odds ratio for children being both stunted and wasted (OR = 0.83, 95% CI = 0.72–0.96, p = 0.012). Children's hands being clean was associated with a 40% lower odds ratio for pale conjunctiva (OR = 0.57, 95% CI = 0.36–0.90, p = 0.016).

The cleanliness of the container used for the transport of drinking water was associated with a 61% reduced odds ratio for infections with Giardia lamblia (OR = 0.39, 95% CI = 0.16–0.93, p = 0.033) and a 52% reduced odds ratio for diarrhoea (OR = 0.48, 95% CI = 0.24–0.96, p = 0.038).

Similarly, the type of floor in the household was associated with child health. Children living in a home with a cement floor had a 62% reduced odds ratio for diarrhoea (OR = 0.38, 95% CI = 0.16–0.87, p = 0.022) and a 56% reduced odds ratio for infections with Giardia lamblia (OR = 0.44, 95% CI = 0.19–1.02, p = 0.056). Our study found that children in households that had received a newly cemented floor instead of a dirt floor had a 28% lower odds ratio for stunting and wasting (OR = 0.72, 95% CI = 0.30–1.71, *p* = 0.458); however, the effect was not significant.

The model indicated several associations between the **frequency of selected food items** provided to children and the health outcomes. High frequency of meat provided was associated with a 15% reduced odds ratio for cough (OR = 0.85, 95% CI = 0.74–0.98, $p = 0.022$), but was not significantly associated with stunting and wasting or with pale conjunctiva. However, high frequency of eggs provided to children was significantly associated with a 16% reduced odds ratio for pale conjunctiva (OR = 0.84, 95% CI = 0.73–0.98, $p = 0.023$). High frequency of leafy green vegetables at baseline and increased consumption by children were both associated with a 13–18% reduced odds ratio for pale conjunctiva (OR = 0.82, 95% CI = 0.74–0.92, $p < 0.001$), diarrhoea (OR = 0.86, 95% CI = 0.74–0.99, $p = 0.036$), respiratory difficulties (OR = 0.87, 95% CI = 0.78–0.98, $p = 0.017$), and also with an increased odds ratio for infections with *Giardia lamblia* (OR = 1.41, 95% CI = 1.11–1.79, $p = 0.005$).

Sanitation infrastructure and the cleanliness of the toilet was not significantly associated with any health improvements between baseline and endline among the children in the study area. Similarly, changes in kitchen hygiene were not significantly associated with child health.

Details on the association of water treatment, hygiene, and nutrition-related risk factors with child health are presented in Table 5.

4. Discussion

The information dissemination campaigns targeting Covid-19 prevention through hygiene improvements had reached the population in the study area effectively, mainly via mass media such as radio, TV, internet, and newspapers and via social networks of community members, family members and to a lower extent health staff. During the pandemic, significant changes occurred in hygiene behaviour, including kitchen hygiene, waste management, water treatment, and handwashing.

Particularly remarkable was the increased frequency of handwashing in the study area and the construction of handwashing stations. We hypothesize that households were particularly motivated to improve their hygiene and handwashing practice by the intensity of hygiene promotion messages received during the Covid-19 prevention campaigns and the threat of contracting Covid-19 if hygiene measures were not followed. This hypothesis is supported by the findings of a cross-sectional survey conducted in Singapore, China, and Italy during the Covid-19 pandemic, in spring 2020. That study found that high levels of information on Covid-19 and preventative measures were associated with increased willingness to comply with restrictive measures and with consequent behaviour change (Lim et al., 2021). Increased compliance with handwashing as a measure to prevent the spread of Covid-19 in similar settings in lower-income countries was documented in South Africa during the first wave of the pandemic (Kollamparambil and Oyenubi, 2021) and in India, where interviewees reported an increase in handwashing frequency and more thorough washing with soap (Bauza et al., 2021). A cross-sectional study across six high-income countries found that the uptake of handwashing was related to how handwashing was promoted during Covid-19 promotion campaigns and the subsequent perception of its effectiveness as a preventative measure. In two thirds of these countries, compliance was highest if handwashing had been recommended by doctors or public health officals (Fujii et al., 2021). Despite the various demographic and socio-economic characteristics of the interviewees assessed in these studies, the reported practice of handwashing or increase in its frequency was 86–99.9%.

Our study documented improved water management at the community and household level: 12% of households had gained piped water access to the household, 40% of the interviewees said that their water sometimes had been chlorinated, and 23% had purchased a water filter. We cannot relate these changes to hygiene promotion efforts that had taken place during the pandemic as local NGOs had worked on improving water supply before the start of the pandemic. However, increased hygiene awareness during the pandemic might have supported efforts to improve water quality at both community and household levels. Improved water management during the pandemic, including the cleaning of water tanks, treatment of piped water, and increased practice of household water treatment, was also observed during the Covid-19 pandemic in Odisha, India (Bauza et al., 2021).

The multivariate repeated-measures GEE analysis of risk factors and child health revealed that four main WASH-related risk factors were associated with a reduction of several infectious diseases among children: (a) the chlorination of piped water supply schemes, (b) handwashing with soap, (c) the cleanliness of the container used for the transport of drinking water, and (d) the type of floor in the household.

The effect of **chlorination of the piped water supply** was observed even though the water had not always been chlorinated by the scheme operators. We hypothesize that the scheme-level chlorination, although not provided regularly, had an impact on reducing contamination risks in the water schemes by irregularly disinfecting pipes, reservoirs, water collection points, and water storage containers, thereby reducing drinking-water-related infection risks. The impact of system-level chlorination on reducing diarrhoea among children had previously been documented by Pickering et al. (2019a). Endline data collection indicated that water quality at the point of consumption had been improved only slightly. The reason for this could be that water in the schemes had not been chlorinated at the time of data collection in spring 2021. Other chlorination trials in Nepal confirmed that regular scheme-level chlorination led to a significant improvement of water quality at the point of consumption (Bänziger et al., 2022). Regular provision of scheme-level chlorination in the study area should be implemented to assess whether further health improvements among children can be achieved. In contrast to this, the purchase of a ceramic water filter was not associated with any of the health improvements among children in our study site. A previous study conducted in the same region had found that the locally produced ceramic filters did not perform very well at household level with a low average log reduction value for *E.coli* of 0.4 and that a majority of users did not maintain the filters adequately. This led to microbiological recontamination of drinking water stored in the filter (Meierhofer et al., 2018). Subsequently, the training strategy for filter handling was improved by the implementing NGO, but no information is available about whether filter handling improved afterwards. In addition, qualitative microbiological risk assessments revealed that water quality related health improvements can be realized only if people consistently consume safe drinking water (Brown and Clasen, 2012; Enger et al., 2013). Thus, it is possible that households in the project area did not consistently treat their drinking water despite having purchased a ceramic water filter.

The frequency of **handwashing with soap** and the **presence of a handwashing station** was associated with reduced odd ratios for fever, cough, respiratory difficulties, stunting and wasting, and infections with *Giardia lamblia* and pale conjunctiva. These findings are in line with a previous study that highlighted the association between the cleanliness of children's hands and frequent or chronic diarrhoea, subsequent anaemia, and stunting and wasting (Howard et al., 2007). However, our study did not find a significant association between handwashing and reduced odds ratios for diarrhoea. This is surprising because a large body of evidence supports the association of handwashing with reduction in diarrhoeal diseases. Several systematic reviews have confirmed that handwashing reduces the risk of diarrhoea by 25%–40% (Ejemot-Nwadiaro et al., 2015; Freeman et al., 2014). The results of our study were in line with previous findings that revealed an association of improved handwashing with a 6%–44% lower risk of respiratory illnesses (Aiello et al., 2008; Rabie and Curtis, 2006), 50% lower incidence of pneumonia (Luby et al., 2005), and 28.2% lower prevalence ratio for *Giardia* infections in Bangladesh (Lin et al., 2018).

Previous studies have indicated that the **cleanliness of the container used for the transport and storage of drinking water** is important for reducing the risk of contaminating water that is put in the containers (Gärtner et al., 2021; Meierhofer et al., 2019; Wright et al., 2004). Our study contributes to the very limited evidence available on the association between safe storage and health. One study conducted in a refugee camp in Sudan attributed an outbreak of shigellosis to

Table 5
Association of water treatment, hygiene and nutrition related risk factors with child health using GEE for repeated measures.

Variables (n=589)	Fever				Cough				Respiratory difficulties				Diarrhoea				Stunting and wasting				*Giardia lamblia*			
	p	OR	95% CI		p	OR	95% CI		p	OR	95% CI		p	OR	95% CI		p	OR	95% CI		p	OR	95% CI	
			Lr	Up			Lr	Up			Lr	Up			Lr	Up			Lr	Up			Lr	Up
Intercept	0.123	2.24	0.80	6.21	0.001	4.72	1.84	12.12	0.207	2.38	0.62	9.15	0.387	0.51	0.11	2.35	0.031	0.24	0.063	0.88	0.035	0.157	0.028	0.876
Age[a]	**<0.001**	**0.99**	**0.98**	**0.99**	**<0.001**	**0.99**	**0.98**	**0.99**	**<0.001**	**0.99**	**0.98**	**0.99**	**0.003**	**0.99**	**0.98**	**1.00**	0.870	1.00	1.00	1.01	0.244	1.00	0.99	1.00
Sex[b]	0.694	0.94	0.70	1.26	0.775	0.96	0.73	1.27	**0.033**	**0.64**	**0.43**	**0.97**	0.309	0.79	0.51	1.24	0.981	1.01	0.69	1.47	0.079	1.65	0.94	2.88
Socio-economic index[c]	0.752	0.80	0.21	3.14	0.140	0.40	0.12	1.35	0.695	0.69	0.10	4.52	0.059	8.67	0.93	81.20	0.992	1.01	0.20	5.17	**<0.001**	**44.18**	**5.51**	**354.43**
Piped water at home at baseline (@BL)[d]	0.179	1.25	0.90	1.74	0.196	1.23	0.90	1.70	**0.017**	**1.79**	**1.11**	**2.89**	0.360	1.30	0.74	2.26	0.202	0.77	0.51	1.15	**<0.001**	**0.14**	**0.06**	**0.35**
Water filter available (@BL)[d]	0.156	1.39	0.88	2.18	0.611	1.12	0.72	1.74	0.534	1.25	0.62	2.53	0.154	0.46	0.16	1.34	**0.004**	**2.27**	**1.29**	**3.97**	0.379	1.36	0.69	2.66
Δ Water filter available[e]	0.851	0.96	0.60	1.52	0.217	1.29	0.86	1.93	0.300	1.42	0.73	2.76	0.260	1.61	0.70	3.68	0.670	1.12	0.68	1.84	0.487	0.70	0.26	1.90
Source chlorinated self-report (@BL)[d]	.	1.00	.	.	.	1.00	.	.	.	1.00	.	.	.	1.00	.	.	.	1.00	.	.	.	1.00	.	.
Δ Source chlorinated self-report[d]	**0.001**	**0.43**	**0.26**	**0.71**	**0.024**	**0.58**	**0.36**	**0.93**	**0.033**	**0.38**	**0.16**	**0.92**	**0.025**	**0.36**	**0.15**	**0.88**	0.480	0.82	0.47	1.43	0.091	0.14	0.01	1.38
Presence handwashing facility (@BL)[d]	0.139	0.75	0.51	1.10	0.056	0.68	0.46	1.01	**0.004**	**0.45**	**0.26**	**0.78**	0.408	0.80	0.46	1.37	0.847	0.95	0.55	1.64	0.294	1.47	0.72	3.01
Δ Presence handwashing facility[f]	0.212	0.71	0.41	1.22	**0.003**	**0.44**	**0.26**	**0.76**	**0.026**	**0.39**	**0.17**	**0.89**	0.133	0.53	0.23	1.21	0.626	1.20	0.58	2.45	0.228	2.08	0.63	6.85
Frequency handwashing with soap (@BL)[a]	**0.008**	**0.85**	**0.75**	**0.96**	0.062	0.89	0.79	1.01	0.641	0.96	0.80	1.15	0.503	1.09	0.85	1.39	**0.003**	**0.78**	**0.66**	**0.92**	**0.011**	**0.68**	**0.50**	**0.91**
Δ Frequency handwashing with soap[a]	0.117	0.91	0.81	1.02	0.347	0.95	0.84	1.06	0.686	0.97	0.86	1.11	0.458	1.05	0.92	1.20	**0.012**	**0.83**	**0.72**	**0.96**	0.023	0.71	0.52	0.95
Cleanliness of child's hands (@BL)[d]	0.940	0.99	0.68	1.44	0.586	1.11	0.76	1.62	0.296	0.76	0.45	1.27	0.181	0.68	0.38	1.20	0.144	1.51	0.87	2.61	0.553	1.24	0.61	2.51
Δ Cleanliness of child's hands[f]	0.570	0.90	0.61	1.31	0.260	1.24	0.85	1.80	0.072	1.66	0.96	2.88	0.063	0.55	0.29	1.03	0.140	1.47	0.88	2.45	0.842	0.93	0.45	1.91
Transport container for drinking water is clean (@BL)[d]	0.112	0.66	0.40	1.10	0.195	0.72	0.44	1.18	0.602	0.84	0.43	1.63	**0.038**	**0.48**	**0.24**	**0.96**	0.517	0.80	0.40	1.59	**0.033**	**0.39**	**0.16**	**0.93**
Δ Transport container for drinking water is clean[f]	0.382	0.76	0.42	1.40	0.703	0.89	0.50	1.59	0.069	0.50	0.24	1.05	0.392	0.66	0.25	1.72	0.851	1.07	0.51	2.26	0.238	0.51	0.16	1.57
Toilet water present (@BL)[d]	0.353	1.36	0.71	2.61	0.690	0.89	0.50	1.58	0.798	0.91	0.44	1.88	0.391	0.70	0.30	1.60	0.470	0.75	0.34	1.65	0.244	0.53	0.18	1.54
Δ Toilet water present[f]	0.593	0.81	0.37	1.76	0.072	0.54	0.27	1.06	0.895	0.94	0.35	2.53	0.865	1.10	0.36	3.36	0.903	0.96	0.45	2.01	0.907	1.09	0.27	4.41
Toilet is clean (@BL)[d]	0.238	1.24	0.87	1.79	0.153	1.31	0.91	1.89	0.091	1.56	0.93	2.61	0.666	0.89	0.52	1.53	0.847	0.96	0.60	1.52	0.719	1.13	0.57	2.24
Δ Toilet cleanliness[f]	0.729	1.07	0.72	1.61	0.296	1.23	0.84	1.81	0.765	1.10	0.60	2.02	0.363	1.38	0.69	2.74	0.201	1.36	0.85	2.19	0.261	0.54	0.18	1.59
Kitchen clean dishes stored high (@BL)[d]	0.792	1.07	0.65	1.77	0.900	0.97	0.61	1.55	0.802	0.92	0.48	1.76	0.580	1.25	0.57	2.70	0.270	0.70	0.38	1.32	0.776	1.17	0.39	3.53
Δ Kitchen clean dishes stored high[f]	0.933	0.98	0.65	1.49	0.815	0.95	0.62	1.46	0.792	1.09	0.59	2.01	0.251	1.57	0.73	3.37	0.658	0.88	0.51	1.53	0.444	1.49	0.54	4.13
Kitchen drying rack available (@BL)[d]	0.080	0.68	0.44	1.05	0.268	0.79	0.52	1.20	0.702	0.88	0.47	1.67	0.971	1.01	0.49	2.12	0.690	0.90	0.52	1.53	0.626	0.80	0.33	1.95
Δ Kitchen drying rack available[f]	0.854	0.96	0.63	1.46	0.721	1.08	0.71	1.65	0.821	1.08	0.57	2.02	0.309	0.70	0.36	1.39	0.557	0.87	0.53	1.40	0.573	1.25	0.58	2.70
Type of floor in the house (cement vs earth) (@BL)[g]	0.480	1.20	0.73	1.97	0.437	1.20	0.76	1.87	0.848	1.08	0.50	2.32	**0.022**	**0.38**	**0.16**	**0.87**	0.588	1.19	0.64	2.22	**0.056**	**0.44**	**0.19**	**1.02**
Δ Type of floor in the house (cement vs earth)[g]	0.476	0.78	0.39	1.55	0.146	0.61	0.32	1.19	0.624	0.76	0.26	2.25	0.076	0.29	0.07	1.14	0.458	0.72	0.30	1.71	0.279	0.43	0.09	1.98
Parent wears shoes (@BL)[d]	0.197	1.30	0.87	1.95	0.054	1.47	0.99	2.17	0.964	1.01	0.61	1.67	0.294	0.75	0.44	1.28	0.176	1.39	0.86	2.22	0.757	0.89	0.44	1.81
Δ Parent wears shoes[f]	0.277	0.78	0.50	1.22	0.749	0.93	0.61	1.42	0.684	0.88	0.46	1.67	0.608	0.77	0.29	2.08	0.308	1.37	0.75	2.52	0.371	0.69	0.30	1.56
Frequency meat, fish (@BL)[h]	0.131	0.90	0.78	1.03	**0.022**	**0.85**	**0.74**	**0.98**	0.148	0.86	0.70	1.06	0.350	0.90	0.73	1.12	0.058	1.19	0.99	1.43	0.558	0.93	0.72	1.20
Δ Frequency meat, fish[i]	0.889	1.01	0.84	1.22	0.715	0.968	0.811	1.154	0.401	0.88	0.657	1.183	0.873	1.03	0.73	1.46	0.743	1.03	0.85	1.25	0.959	1.01	0.73	1.40
Frequency eggs (@BL)[h]	0.527	1.03	0.93	1.15	0.462	1.039	0.939	1.149	0.622	1.04	0.894	1.206	0.504	1.06	0.90	1.24	0.598	0.96	0.84	1.11	0.427	1.10	0.88	1.37
Δ Frequency eggs[i]	0.786	1.02	0.88	1.18	0.382	1.061	0.929	1.213	0.709	0.97	0.798	1.166	0.305	0.86	0.64	1.15	0.305	1.08	0.93	1.25	0.276	1.14	0.90	1.46
Frequency leafy green vegetables (@BL)[h]	0.159	1.06	0.98	1.15	0.495	1.027	0.952	1.108	**0.017**	**0.87**	**0.777**	**0.975**	0.415	0.95	0.84	1.08	0.269	1.06	0.96	1.18	**0.005**	**1.25**	**1.07**	**1.46**
Δ Frequency leafy green vegetables[i]	0.259	1.05	0.96	1.15	0.083	1.08	0.99	1.179	0.393	0.94	0.824	1.079	**0.036**	**0.86**	**0.74**	**0.99**	0.787	0.98	0.87	1.11	**0.005**	**1.41**	**1.11**	**1.79**

Categories of variables: [a]continuous, [b](1=girl/ 0=boy), [c](continous (0<x<1)), [d](1=yes/ 0=no), [e](-1=water filter lost/ 0=no change/ 1=new water filter), [f](-1=deterioration/ 0=no change/ 1=improvement), [g](1=cement/ 0=earth),

Categories of variables: [h](three times per day (7)/ twice per day (6)/ once per day (5)/ every 2nd day (4)/ two times per week (3)/ once per week (2)/ less than once per week (1)/ not at all (0)), [i](Δ([h]@EL-[h]@BL)

@BL=at baseline; @EL=at endline; OR=odd ratio; CI=confidence interval; *p*= *p*-value; Lr=lower CI; Up=upper CI
Cells marked in green indicate a significantly reduced odds ratio (at alpha ≤ 0.05) between a risk factor and a child health outcome. Cells marked in red indicate a significantly increased odds ratio (at alpha ≤ 0.05) between a risk factor and a child health outcome.

postcollection contamination in water containers (Walden et al., 2005), and a trial in another refugee camp in Malawi found a 69% reduction of faecal coliforms at the point of consumption and a 31% reduction of diarrhoea among children of households following the introduction of improved water collection containers (Roberts et al., 2001).

Having a **cemented floor** was associated with a reduced odds ratio for diarrhoea and infections with *Giardia lamblia* in our study site. This finding is in line with a study conducted in Bangladesh and Kenya that found that children living in households with cemented floors had a lower prevalence of *Giardia duodenalis* and soil-transmitted helminths (Benjamin-Chung et al., 2021). An assessment in Tanzania documented that soils and surfaces in households with low-cost sanitation facilities are a reservoir for diarrhoea-causing pathogens: soil collected from household floors had higher concentrations of *E.coli* and enterococci than samples collected from the floor of latrines (Pickering et al., 2012). The risk of transmission of diarrhoea-causing pathogens from dirt floors in the house therefore seems very high. The association of cemented floors with a reduced risk for parasitic infections, diarrhoea, and anaemia was similarly documented by studies in Mexico and Zimbabwe (Cattaneo et al., 2009; Koyuncu et al., 2020). A review conducted by Vilcins et al. (2018) found strong evidence of dirt floors in the house being associated with stunting. This association was not confirmed in our study.

The changes observed in **sanitation infrastructure** and **kitchen hygiene** between baseline and endline data collection were relatively small, and it is likely that they may not have contributed to a large reduction of pathogens in the household environment. This might explain why our study did not find a statistically significant association between these factors and health improvements among children in the study area even though previous studies have indicated that improving sanitation is protective against diarrhoea, some parasitic infections and stunting (Freeman et al., 2017; Wolf et al., 2022).

Our findings indicate that people are more likely to improve their hygiene behaviour and WASH infrastructure during epidemics. This confirms results from an earlier study implemented during the H1N1 swine flu outbreak in Mexico and a study, that was conduced in India during the Covid-19 pandemic that showed that health threats facilitated the adoption of health behaviours like proper handwashing, using hand sanitizers, improving water safety management and wearing face masks (Agüero and Beleche, 2017; Bauza et al., 2021). The behaviour changes in Mexico were sustained over 3 years and resulted in significant reductions in severe diarrhoea among children below the age of 5 years (Agüero and Beleche, 2017). It seems that the perception of increased risk and higher vulnerability during an epidemic supports the process of changing behaviour to improved hygiene practices and more consistent safe water management. The perceived personal risk of being infected, social norms, trust in the government and vulnerability and fear have been identified by an international survey and a large study in Turkey as important psychological drivers for assuming protective health behaviours during the Covid-19 pandemic (Schumpe et al., 2022; Yıldırım et al., 2021). However, using strong fear as a motivator has been found to achieve a significant behaviour change only when people feel a sense of self-efficacy (Witte and Allen, 2000).

Our data were collected in Surkhet District in spring 2021 before the Delta variant wave of the SARS-CoV-2 virus. They did not indicate any association between the pandemic and reduced household incomes due to recurrent lockdowns, nor did we observe any negative impact on the nutrition provided to children. These results stand in sharp contrast to insights gained from data that were collected in November and December 2021 in the remote hilly districts of Accham and Dailekh after the wave of the Delta variant of the SARS-CoV-2 virus. The findings from Accham and Dailekh revealed similar changes in hygiene behaviour but also showed a significant decline in household income due to lockdowns, migrant workers returning during the pandemic, deterioration in the nutrition provided to children, and an increase in clinical signs of malnutrition among children (Shrestha et al., 2022). This clearly shows that mitigation measures for the prevention of epidemics carefully have to be evaluated; while some interventions have been very effective and contributed to improving child health beyond the prevention of the pandemic, other measures have produced substantial social, financial, and health-related harm. Also, it has yet to be seen whether the improvements in hygiene behaviour and the health gains realized through the reduction in infectious diseases can be sustained (Michie and West, 2021). In addition to needing to understand whether the changes in healthy behaviour achieved during the pandemic can be maintained, more socio-psychological research is required to gain insight into how the mechanisms that come in play during epidemics could be used to achieve similar behaviour changes during normal times.

Our study has some limitations: First, exposure to animal faeces previously has been identified as an important risk factor for human health, particularly for children below the age of 2 years (Matilla et al., 2018; Penakalapati et al., 2017; Prendergast et al., 2019c; Wang et al., 2016). At the time of the cross-sectional survey in 2018, 59.7% of households in the study areas kept their animals inside the home overnight. Children living in these households had a 1.7 higher odds ratio (95% CI = 1.17–2.51, $p = 0.01$) for nutritional deficiencies than children from households that kept animals in separate stables (Shrestha et al., 2020). For the endline survey, the variable assessing the presence of animal faeces was changed to be able to better quantify animal faeces in and around the household. This change precluded the assessment of longitudinal changes in this variable and its association with changes in child health. Second, the responses during the interviews were self-reported. This could have introduced a social desirability bias, as respondents might sometimes have over-reported hygiene behaviours. Furthermore, self-reports of more frequent handwashing do not indicate whether handwashing was performed correctly. Third, this study's design does not allow causal associations to be inferred between WASH practices and child health outcomes.

Despite the limitations, our study has several strengths. First, we used mixed methods to triangulate between the WASH practices and problems before and during the COVID-19 pandemic and changes in the children's health and nutritional status. Second, baseline data were available from the pre-COVID-19 period. This gave us the unique opportunity to use a longitudinal dataset to assess changes in the health status of children, WASH practices, and nutrition before and during the pandemic. Thus our study contributes insights to WASH related behaviour changes that can be achieved during epidemics and their associations with child health.

5. Conclusions

Our study evaluated changes in water treatment at community and household levels, hygiene practices and infrastructure, and the association of risk factors with changes in child health before and during the Covid-19 pandemic in an area where some households had received a water safety and hygiene education intervention prior to the pandemic. During the pandemic, all households had received messages on preventative measures against Covid-19, including handwashing and the importance of drinking water safety.

We found significant changes in WASH conditions and behaviour in the study area, including the introduction of chlorination of piped water supply to 40% of households, uptake of ceramic water filtration in 23% of households, increased frequency of handwashing with soap, particularly at critical times, improved cleanliness of containers for the transport of drinking water, and the introduction of cemented floors in the homes. The chlorination of the piped water supply and hygiene improvements were significantly associated with reduced odd ratios for fever, cough, respiratory difficulties, diarrhoea, and infections with *Giardia lamblia*, and handwashing was associated with a reduced odds ratio for children being stunted and wasted.

The increased health threat during the pandemic, together with potentially increased perception of risk and vulnerability and intensified

WASH promotion activities during the Covid-19 pandemic seems to have contributed to improving hygiene behaviour and hygiene infrastructure in the study area. These improvements were significantly associated with reductions in infectious diseases among the children studied. Further studies are necessary to assess whether and how the changes in hygiene and improvements in child health achieved can be sustained in the future and to learn how the mechanisms that drive effective behaviour change during epidemics can be used to achieve similar impacts during non-epidemic times.

Author contributions

All authors, RM, AS, and BK, contributed to the study design. AS coordinated the field and laboratory work and supervised the research assistants. RM and AS performed the statistical analysis. RM wrote the manuscript with inputs from AS and BK. All authors read and approved the final manuscript.

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Availability of data and material

The dataset and the questionnaire supporting the conclusions are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijheh.2023.114138.

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