Nutrition, Water quality, Sanitation and Hygiene Practices Associated with Children's Health Status in Nepal. A Cross-sectional Study on Intestinal Parasitic Infections, Diarrhoea and Undernutrition

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Abstract

Background: Providing universal access to safe water, sanitation and hygiene (WASH) in remote Nepal remains challenging. Efforts to improve WASH access in these areas are impeded by a dearth of information on the status of WASH conditions and its association with health and nutritional status of children in Nepal. Methods: We investigated nutritional status, WASH practices, and their association with intestinal parasitic infections, diarrhoea, undernutrition and clinical signs of nutritional deficiencies (hereafter health outcomes) during March to May 2018. Data was collected through a cross-sectional survey of 1427 households, including questionnaires, observations, stool analysis, anthropometry, water quality measurements and assessment of clinical signs of nutritional deficiencies. Results: We found that 55.5% had undernutrition, 63.9% had clinical signs of nutritional deficiencies, 51.1% of children were suffering from intestinal parasitic infections, and 52.2% had waterborne illnesses. Multivariate mixed logistic regression analysis revealed statistically significant associations ($p<0.05$) between aforementioned health outcomes and a better socioeconomic status (adjusted odds ratio (AOR)=0.43, 95% confidence intervals (CI)=0.25-0.75), caregivers who can read (AOR=4.07, 95% CI=1.00-16.5), own food production of food (AOR=0.67, 95% CI=0.46-0.97), providing food supplements to the children (AOR=0.57, 95% CI=0.38-0.84), intermittent water supply (AOR=2.72, 95% CI=1.18-6.31), source water quality (AOR=10.44, 95% CI=1.61-67.4), washing hands when they look dirty (AOR=0.47, 95% CI=0.32-0.71), no toilet at home (AOR=6.12, 95% CI=1.08-14.25), cleanliness of the available toilet (AOR=0.68, 95% CI=0.47-0.98), handwashing after going to toilet (AOR=0.37, 95% CI=0.13-1.02), cleanliness of caregivers hand (AOR=0.61, 95% CI=0.41-0.89), presence of earthen floor (AOR=2.29, 95% CI=1.20-4.37), animals inside the house overnight (AOR=1.71, 95% CI=1.17-2.51) and regular deworming of the children (AOR=0.44, 95% CI=0.20-0.94). Conclusions: Findings suggest improvements in WASH services, along with household hygiene and nutritional interventions, may together reduce child morbidity and mortality in Nepal. Keywords: Drinking Water Quality, Sanitation and Hygiene, Child Health, Diarrhoea, Undernutrition, Intestinal Parasitic Infections, Nepal.

Background

Children in low-income countries face a range of interrelated problems: poor nutrition, inadequate water, sanitation, and hygiene (WASH), consequent infections, and growth and development impairments [1]. Globally, a total of 297,000 WASH-attributable diarrhoea deaths occur per year among children under 5 years, every fifth child's growth is stunted, 1 in 13 is wasted, and every seventh child is underweight; nearly 90% of these cases occur in South Asia and Sub-Saharan Africa [2–4]. Furthermore, two billion people worldwide are infected with intestinal parasites, with the highest burden of disease among children in resource-poor settings [5–7]. Studies have shown that infections with intestinal parasites among children are associated with stunting, physical weakness, and low educational performance [6, 8, 9].

Nutrition is closely interlinked with multiple determinants [10, 11]. While malnutrition is directly associated with insufficient dietary intake, underlying contributing factors such as lack of access to safe water and sanitation result in recurrent infectious diseases such as diarrhoea and intestinal worms; these parasites interfere with the digestive process by competing with the host for nutrients and inhibiting absorption of nutrients, leading to compromised immunity [10, 11]. It is estimated that up to 45% of global malnutrition-related child deaths could be prevented by improving WASH conditions and practices [4, 12, 13].

Even though 89% of the population in Nepal currently has access to at least basic water supply services and 62% to basic sanitation facilities, providing safe water quality at the point of consumption and ensuring adequate hygiene practices remain challenges [14, 15]. In a recent study, 31.5% of children in the Eastern region of Nepal were found to be infected with intestinal parasites. Parasitic infections were significantly associated with not using soap after defecation, the habit of thumb sucking, and not wearing sandals [16]. However, the health and nutritional status of children and their associations with nutrition and WASH have not been extensively investigated in remote hilly areas in Nepal. The Demographic and Health Survey (DHS) 2016 showed that 1 in 25 children in Nepal dies before reaching the age of 5 years, and almost 3,500 die yearly from preventable causes [17, 18]. Diarrhoea is one of the most common illnesses among children and continues to be a major cause of childhood morbidity and mortality [17]. However, efforts to combat health and nutritional problems among children in these settings do not effectively incorporate WASH interventions. Hence, the aim of this study is to assess the influence of nutrition and WASH infrastructure and practices on the health and nutritional status of children aged 6 months to 10 years of age in three districts in the rural hilly areas of Nepal. Findings from this study provide crucial support and information for delivering interventions that address water quality and improve hygiene and nutrition in the four study sites.

Methods

Study area

The four study sites are located in the districts of Surkhet, Achham, and Dailekh in the Karnali province of Nepal. These districts were selected for their combination of conditions: the region is mountainous, incomes are low, infrastructure is lacking, access is difficult and WASH conditions are challenging.

Study design, sample population, sample size and sampling methods

The study sites were located within Helvetas Swiss Intercooperation Nepal's Water Resources Management Programme (WARM-P) sites. The sites were selected according to the following criteria: (a) extremely remote location, (b) the availability of a piped water supply scheme that has not yet received the WARM-P training interventions, and (c) the population not having access to products for household water treatment. The cross-sectional study was conducted from March to May 2018 and involved 1427 households with children aged 6 months up to 10 years. Sample size and statistical power were calculated using G*Power 3.1. A sample size of 300 households was required at each of the four sites to detect an effect in Cohen's f2 at one-tailed alpha of 0.05 and a statistical power of 90% with multiple logistic regression and 15 predictor variables adjusting for clustering effect [19, 20]. We therefore randomly sampled a minimum of 345 households at each of the four sites (Surkhet A, Surkhet B, Dailekh, and Achham). If a household declined to participate, then the neighbouring household was included.

Questionnaire survey

A quantitative structured questionnaire was administered to the caregivers, whether male or female, in the households. When both caregivers were available, the interviews were conducted with the mother. The questionnaire contained both closed and open-ended multiple-choice questions with Likert-scale answer categories. The interviews took around 15 minutes on average and were complemented by structured observations. The questionnaire was coded in Open Data Kit software [21] on tablets (Samsung Galaxy note 10.1 N8010) and contained questions on the use of water sources, psychological factors concerning water handling and hygiene practices, observations of WASH infrastructure, information on WASH promotion activities received, nutrition provided to children, children's history of waterborne illnesses in the past 7 days, and potential confounders, such as sociodemographic and socioeconomic factors. The questionnaire was developed from standardized questions following international guidelines and incorporated amendments necessary to meet the conditions in our study areas [22, 23]. The questionnaire was developed in English and translated into Nepali with a back-translation. Interviewers were intensively trained for two days on data-collection procedures. The questionnaires were pretested and adapted to ascertain the reliability of the questions used in the final survey instrument [24].

Child diet and household food security

Child dietary information was assessed following the guidelines of the Food and Agricultural Organisation (FAO) [23]. The caregivers were asked to recall whether nine different food groups were consumed within the past 7 days and, if consumed, the frequency of consumption. The supervisors randomly re-interviewed a subset of 10% of the surveyed households to assess reproducibility. Household food security was assessed with questions relating to the availability of food during the entire year.

Anthropometric measurements

Certified medical assistants collected anthropometric measurements adhering to standard procedures [25]. Supine lengths were obtained for children younger than 2 years old using a Seca BabyMat 210. For children aged between 24 months and 10 years, a height-measuring board and a digital scale (Seca 877; Hamburg, Germany) were used with precisions of 0.1 cm and 0.1 kg, respectively. Before each measurement, scales were calibrated with a standardized weight, and the children were measured barefoot [24]. Anthropometric indices were calculated using AnthroPlus (WHO; Geneva, Switzerland) in accordance with the World Health Organisation (WHO) guidelines [25, 26]. Age in total months was recorded for each child and confirmed by an inspection of the birth certificate. Three anthropometric indices were expressed as z-scores (i.e. differences from the median in standard deviations): (a) weight for age (WAZ, underweight); (b) height for age (HAZ, stunting); and (c) body mass index for age (BMIZ, thinness) [4]. Z-scores of ≥ -2 were regarded as normal, those between < -2 and ≥ -3 as moderate undernutrition and those below < -3 as severe undernutrition [31,32]. Children were considered to be undernourished if at least one of the anthropometric indices indicated undernutrition.

Parasitological survey

On the day following the household survey visit, caregivers were asked to provide a fresh morning stool sample without urine contamination from the participating child. The samples were processed on the same day by two experienced laboratory technicians. Each stool sample was analysed using direct wet-mount and formalin-ether concentration techniques to detect intestinal protozoa and helminths following standard guidelines [27–29]. In addition, a duplicate Kato-Katz thick smear was prepared for the diagnosis of helminths [30]. The presence of infection by any worm species was defined by the detection of one or more eggs on either slide [7]. Children were considered positive if at least one of the diagnostic techniques revealed an infection. The infection intensity of helminths was calculated according to criteria defined by the WHO and multiplied by 24 to reach the total number of eggs per gram (EPG) of stool. Infection intensities were then classified as light, moderate, and heavy as per the thresholds set by the WHO [5, 31].

Signs and symptoms of nutritional deficiencies

During the household survey, the children were screened by the certified medical assistants using a standard checklist for clinical signs and symptoms of nutritional deficiencies: wasted appearance (protein deficiency), loss of hair pigment and easy pluckability (protein deficiency), Bitot's spots (vitamin A deficiency), dry and infected cornea (vitamin A deficiency), oedema (thiamine deficiency), several types of dermatitis (niacin deficiency), spongy bleeding gums (vitamin C deficiency), pale conjunctiva (iron-deficiency anaemia), red inflamed tongue (riboflavin deficiency), sub-dermal haemorrhage (vitamin C deficiency), bowed legs (vitamin D deficiency), and goitre (iodine deficiency) [32].

Drinking water quality examination

Water samples were collected from the household's main drinking water source and from the container used for drinking water transport and storage. The sample at the source was taken after letting the water run for 60 seconds from the tap, and then filling a sterile Nasco Whirl-Pak bag. The caregivers were requested to bring fresh drinking water from the point of collection to the household in the same container they usually use to fetch their drinking water [33]. A second water sample was taken by pouring water from the transport container into another sterile Nasco Whirl-Pak bag. All water samples were stored inside cooler bags and analysed at the field site using the membrane filtration technique: 100 ml water samples were passed through sterile 0.45 µm millipore cellulose membrane filters with sterilized filtration equipment. The filter pads were plated on Nissui Compact Dry Coli-scan plates and incubated for 24 hours at 35 +/- 2°C [15]. A solar-powered electrical system was set up to run a low-power incubator at the field site. Colony-forming units of total coliforms and *Escherichia coli* (*E. coli*) were counted after 24 hours of incubation.

Data management and statistical analysis

Data cleaning was performed daily during the survey, and if any values were missing or inconsistent, the respective household was consulted the following day. Readings of intestinal parasite and nutritional deficiency screenings were double entered into an Excel 2010 spread sheet (Microsoft; Redmond, USA) and cross-checked. 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. We employed χ^2 statistics to assess the differences in distribution for categorical variables between the study areas. Household socioeconomic status was characterized by factor analysis of reported household assets, such as the availability of electricity, radio, television, solar panel, mobile phone, bicycle, motorbike, fridge, watch, own house, and land ownership. Three factors reflecting three socioeconomic domains were retained and divided using the k-means procedure into three categories: (a) low, (b) medium, and (c) high [34]. The same procedure was applied to create one variable for the hygiene of containers used for transport and storage of drinking water, latrine hygiene, cleanliness of the household environment and kitchen, and personal hygiene. For each of these variables, three factors were retained and categorized, indicating (a) low, (b) medium, and (c) high status.

We assessed four health-related outcome variables: (a) intestinal parasitic infection; (b) diarrhoea; (c) undernutrition including stunting, underweight, and BMIZ (thinness); and (d) clinical signs and symptoms of nutritional deficiencies. The associations between the outcome variables and risk factors were first assessed by conducting univariate mixed logistic regression analyses with random intercepts of the study areas. Since only a few undernutrition cases were severe, the cases were pooled into a binary variable of stunted/non-stunted, and underweight/non-underweight for the subsequent analysis. Similarly, there was a low prevalence of parasites such as *T. trichiura*, *E. vermicularis* and *Ancylostoma duodenale*, so all reported intestinal parasitic infections were pooled into a binary variable of parasite infection/no infection to maximize statistical power. The clinical signs of nutritional deficiencies and diarrhoea outcomes were coded into binary variables for the subsequent comparative analysis.

We assessed associations between the binary outcome variables and hypothesized risk factors using logistic regression models with random study site intercepts and controlling for potential confounders with the demographic variables of age, sex, and socioeconomic status. First, the associations between outcome variables and risk factors were assessed using univariate models. Variables with p-values < 0.2 were retained for the maximal model. The final model was then obtained using backward selection with the same level of 0.2 [35]. Odds ratios were reported and the associations were considered as statistically significant if p-values were < 0.05. The statistical analysis was performed with STATA version 14 (STATA Corporation, College Station, TX, USA).

Results

Socio-demographic characteristics of the study participants

The sociodemographic and socioeconomic characteristics of the households interviewed are provided in Table A in supplementary materials. Caregivers aged 25–40 years of age constituted the largest group (57.9%) of interviewees, whereas those aged >40 years constituted the smallest group (13.9%). More than 80% of the caregivers could both read and write. Agriculture was the main (60.6%) occupation of the household heads. A total of 59.7% of the households kept animals inside the home overnight. A majority (84.1%) of the households had earthen floors. The majority of children (99.1%) included in the study were between 6 months and 5 years of age, while 0.9 % were age 6 to 10 years. Around 52.7% of the households across the study sites had access to electricity.

Water handling, water quality, sanitation, hygiene, and WASH promotion

Tables 1 and 2 and Table B in supplementary materials describe water handling, water quality, sanitation, and hygiene practices, WASH infrastructure, WASH promotion, and WASH-related psychological factors in the households in the four study sites. Some 75.5% of the respondents depend on a communal village tap for drinking purposes, 20.7% have access to piped water in the house or yard, and the remaining respondents use open water sources (2.0%) and unmanaged pipe systems (0.3%). More than half (54.4%) of the respondents were confident about the safety of their available drinking water. Just 16.5% of the households reported treating their water at the point of use. One third (33.7%) of the respondents reported disliking the taste of treated water (Table 2 & Table B in supplementary Materials).

We found that the vast majority of water samples from the point of collection and point of use were contaminated with *E. coli* (93.6% and 95.3%, respectively) and total coliform bacteria (99.4% and 98.8%, respectively). Five percent of water samples at the point of consumption met the WHO’s guidelines for microbial safety of drinking water (<1 CFU *E. coli*/100 mL), 16% were in the low risk category (1-10 CFU *E. coli*/100 mL), 51% in the intermediate risk category (10-100 CFU *E. coli*/100 mL), and 28% in the high or very high risk categories (>100 CFU *E. coli*/100 mL) [36]. Further details of the microbial water quality at the source and the point of use are presented in Table 2.

We found that 6.3% of the households did not have latrines, and 93.7% of the households had traditional pit latrines. Almost half of the latrines (48.7%) were in a poor hygienic state. Three quarters (76.0%) of the respondents reported having washed their hands with soap less than five times per day prior to the day of survey. The overall hygiene conditions were very low or low in 64.0% of the surveyed households. Only 10.9% of the respondents reported having received information on water treatment and hygiene. Among those, 89.7% reported that this information changed their WASH behaviour, such as using soap more often for washing hands (Table 3).

Child health, health-seeking behaviours, and KAP survey

Table C in the supplementary materials shows the percentage distribution of child health records, health-seeking behaviours, and risk awareness of the causes of diarrhoea and of perceived vulnerability by study site. A total of 49.9% of the children from under age 6 months to 5 years were reported to have been sick within 7 days prior to the survey. Respiratory illnesses and fevers were most common (both 40.4%) followed by diarrhoea (16.5%). For respondents not seeking health care services, the main reason was a feeling of non-requirement (61.9%), followed by financial constraints (21.2%), preference for self-treatment (7.1%), and lack of accessibility (1.8%) (Table C in supplementary materials).

A majority (82.7%) of the respondents knew that contaminated water can cause diarrhoea and that children are particularly vulnerable (74.4%). However, a majority (78.9%) of the respondents had never heard about intestinal parasites. The proportions of caregivers who were aware that handwashing with soap (11.1%), wearing shoes (5%), drinking clean water (16.6%), and undergoing regular deworming treatment (11.1%) might prevent intestinal parasitic infections were low (Table C, Supplementary materials).

Prevalence of diarrhoea and associated risk factors

Table 3 presents the association of risk factors with diarrhoea. A total of 16.5% of children less than 5 years suffered from diarrhoea within 7 days prior to the survey. The results from the multivariate regression analysis indicated that children above the age of 5 years showed significantly lower odds of diarrhoea (AOR = 0.39; 95% CI: 0.26-0.57; $p = 0.01$) than their younger counterparts. The children from the households experiencing a service interruption of more than 1 week to their main drinking water source at the time of visit had 2.87 higher odds of diarrhoea (AOR = 2.87; 95% CI: 1.24-6.61; $p = 0.01$) than children from households not experiencing an interruption. The children of caregivers who were aware of the need for handwashing during critical times, such as after using the latrine, were significantly better protected against diarrhoea (AOR = 0.37; 95% CI: 0.14-1.10; $p = 0.05$) than were children whose caregivers were unaware. Households with clean latrines were significantly better protected against diarrhoea (AOR = 0.66; 95% CI: 0.45-0.95; $p = 0.03$) than were households with dirty latrines. Similarly, the children with visually clean hands without spots of dirt were significantly better protected against diarrhoea than were children with dirty hands (AOR = 0.63; 95% CI: 0.41-0.98; $p = 0.04$). Children living in households with a floor made of earth painted with animal dung had 2.29 times higher odds of suffering from diarrhoea than children living in households with a cement floor (AOR = 2.29; 95% CI: 1.20-4.37; $p = 0.01$).

Prevalence of intestinal parasites and associated risk factors

Tables 4 and 5 show the prevalence of intestinal parasitic infections in the study population and the associated risk factors. The overall prevalence of intestinal parasitic infection is 51.1%. The prevalence of intestinal parasitic infections, stratified by sex, age group, and study site, are summarized in Table 4. The predominant helminth species infecting the children was *Ascaris lumbricoides* (21.1%), followed by *Hymenolepsis nana* (4.6%), *Ancylostoma duodenale* (3.2%), *Enterobius vermicularis* (2.7%), and *Trichuris trichiura* (0.7%). Polyparasitism and co-infection were not common. Infections with all types of helminths were of light intensity. About 23.4% of the children were infected with *Giardia intestinalis* (Table 4).

Multivariate analysis showed that the odds of infection with intestinal parasites among children in households where the caregivers could only read were four times higher than the odds among children whose caregivers could both read and write (AOR = 4.07; 95% CI: 1.00-16.55; $p = 0.05$). Children in households relying on a simple pit latrine for defecation had six times higher odds of being infected with intestinal parasites than those in households with a pour flush pit latrine (AOR = 6.12; 95% CI:1.57-23.9; $p = 0.01$). Children with caregivers having clean hands were significantly better protected from intestinal parasitic infection (AOR = 0.61; 95% CI: 0.41-0.89; $p = 0.01$) than were children of caregivers with dirty hands (Table 5).

Child-feeding practices and household food security

Almost all caregivers (99.6%) reported having breastfed the participating child until the age of 6 months. Complementary feeding in addition to breastfeeding before the age of 6 months was only provided to 3.0% of children. The dietary diversity scores were low, with only 11.2% of the households having consumed all nine listed food groups in the previous 7 days (Table 6 and Table D, supplementary materials). The consumption of milk or milk products and eggs at least once per week was low (9.2% and 5.3%, respectively; Table D, supplementary materials). About 60% of the households do not produce their own food. Among those producing their own food, 20.8% reported self-sufficiency throughout the entire year.

Prevalence of undernutrition and associated risk factors

Table 7 shows the percentage distribution of undernutrition in the study sample by sex, age group, and study area. The prevalence of undernutrition was 55.5%, while the prevalence of stunting was 44.5%, thinness (BMIZ) 11.2%, and underweight 29.9%.

Table 8 provides an overview of the association between undernutrition and the caregiver's socioeconomic status, nutrition and health awareness, intestinal parasitic infections, hygiene status, and water quality of the households in univariate and multivariate regression analyses. Children living in a household of higher socioeconomic status showed lower odds of undernutrition (AOR = 0.43; 95% CI: 0.25-0.75; $p = 0.01$) than in households with lower socioeconomic status. Children of caregivers with sound knowledge about the importance of regular deworming had lower odds of undernutrition (AOR = 0.44; 95% CI = 0.20-0.94; $p = 0.03$) than did children whose caregivers had no such knowledge. Children receiving supplementary food were at significantly lower odds of being undernourished (AOR = 0.57; 95% CI: 0.38-0.84; $p = 0.01$) than were the children without supplementary food. Similarly, households producing their own food were at significantly lower risk of being undernourished (AOR = 0.67; 95% CI: 0.46-0.97; $p = 0.03$) than were households without agricultural production.

Prevalence of nutritional deficiencies and associated risk factors

A total of 63.9% of the children in the study suffered from at least one sign of a nutritional deficiency. About one third (35.9%) of the children suffered from pale conjunctiva, followed by Bitot's spots (19.8%), red inflamed tongue (18.3%), spongy bleeding gums (16.3%), wasted appearance (13.8%), dry and infected cornea (13.2%), loss of hair pigment (10.7%), sub-dermal haemorrhage (4.6%), oedema (2.7%), bowed legs (2.6%), and goitre (0.6%) (Table 9).

The children >5 years had twice the odds of having nutritional deficiencies compared to their younger counterparts (AOR = 1.84; 95% CI: 1.30-2.62; $p = 0.01$). Children whose caregivers washed their hands after cleaning a baby's bottom were at lower odds of having nutritional deficiencies (AOR = 0.60; 95% CI = 0.40-0.92; $p = 0.02$) compared to children whose caregivers did not follow this practice. Children from households producing their own food were significantly better protected against nutritional deficiencies (AOR = 0.51; 95% CI: 0.35-0.76; $p = 0.01$) than were children from households without their own food production. Children from households in the higher category of latrine hygiene were at lower odds of nutritional deficiencies than those living in households with low latrine hygiene (AOR = 0.61; 95% CI: 0.41-0.91; $p = 0.01$). Children living in houses where animals were kept inside overnight had 1.71 times higher odds of having signs of nutritional deficiencies (AOR = 1.71; 95% CI = 1.17-2.51; $p = 0.01$) than children from households not keeping animals inside the home overnight. Being in the lower category of personal hygiene increased a child's odds for clinical signs of nutritional deficiencies by 1.84 (AOR = 1.90; 95% CI: 1.17-3.10; $p = 0.01$) over being in the higher category. Children from households with coliform bacteria in their drinking water sources had 10.4 times higher odds of having signs and symptoms of nutritional deficiencies (AOR = 10.4; 95% CI: 1.61-67.42; $p = 0.01$) than children from households with an uncontaminated water source (Table 9).

Discussion

Our findings highlight that the alarming health conditions of children in remote areas of rural Nepal are associated with insufficient nutrition, with unhygienic conditions in the household environment and inappropriate personal hygiene, including inadequate handwashing, inappropriate sanitation, and lack of access to regular and safely managed drinking water supply. While more than half of the surveyed children were infected with parasites and suffered from undernutrition or nutritional deficiencies, the prevalence of diarrhoea of 16.5% was slightly lower. Our analysis identified specific risk factors for each of these health outcomes.

Diarrhoea

In line with previously reported findings, the prevalence of diarrhoea was highly associated with the age of the children, with older children being less susceptible [37, 38]. Surprisingly, water quality was not associated with diarrhoea prevalence, but we found significant associations with factors relating to handwashing, personal hygiene, kitchen hygiene, and the type of toilet. A very strong association was observed between diarrhoea incidence and the family living in a house with a floor made of mud [39, 40]. This risk factor needs further attention, because people living in the surveyed area have the practice of painting the mud floors in houses with animal dung. We hypothesize that this practice leads to a high load of diarrhoea-causing pathogens in the household environment, orders of magnitude higher than concentrations found in drinking water, thus masking the impact of clean drinking water on children's health. Children playing on the floor inside or around their houses are at high risk of ingesting pathogens [41, 42]. This assumption is confirmed by several studies that associate the contamination of the floor with *E. coli* with the disposal of faeces and the presence of animals close to the households. Kwong et al. reported that 35% of children put their hands in their mouths after touching soil particles, putting them at risk of contamination [40]. Additionally, we observed that animals were often kept in or near the home and brought indoors overnight. Such practices have been shown to increase exposure to faecal contamination in the household environment in other rural settings [15]. Other studies conducted in India and Bangladesh highlighted the importance of faecal contamination of animal origin in the domestic environment, including source and stored drinking water, hands, and soil [43, 44]. A strong association was also found between diarrhoea and interruptions of the water supply. Caregivers who reported their water supply system being interrupted for more than 7 days had 2.7 times higher odds of having children with diarrhoea. Underlying reasons might be the subsequent lack of water for hygienic practices or that intermittent water services present an increased risk of bacterial contamination in the system, or it might be that the risk of pathogen infiltration is greater during such low-pressure events in the piped network [45, 46]. Similar results were reported in a study conducted in low- and middle-income countries, which reported that the provision of high-quality piped water, sewer connections, and the use of water filters were associated with considerable reductions in diarrhoea [47].

Intestinal parasitic infections

The high prevalence of intestinal parasitic infections among children in our study is similar to or higher than the rate reported in studies conducted in other parts of Nepal [16, 18, 48]. The higher infection rates may be explained by the fact that our study areas were located in extremely remote rural and hilly areas with difficult access and a lack of infrastructure, which together result in a low level of access to basic health and WASH services [16, 18, 48]. Our analysis showed that children from households without latrines had a four times higher odds ratio for developing an intestinal parasitic infection than did those without latrines. This indicates that the poor hygienic status observed in the pit latrines used by more than 94% of the households and the lack of water for flushing toilets is a major risk factor in the transmission of intestinal parasites. The effect of inadequate sanitary conditions on intestinal parasitic infections was also documented in a systematic review and meta-analysis [49].

The cleanliness of caregivers' hands was identified as a significant risk factor for children's parasitic infections, suggesting that caregivers' hands play a critical role in transferring parasites from the household environment to their children. We observed poor handwashing conditions, with 59.9% of households not having adequate infrastructure for washing their hands and a limited presence of soap and water at the handwashing stations. The importance of clean hands to preventing parasitic infections is in agreement with previous studies conducted in eastern Nepal, which found not using soap after defecation to be significantly associated with intestinal parasitic infection [16, 50]. There is strong evidence a high load of pathogens in the household environment and inadequate handwashing increase the numbers of pathogens on caregivers' hands [42]. The association between critical sanitation, hygiene factors and infections with intestinal parasites was also documented by studies conducted in other parts of Nepal [16, 48, 51] .

Surprisingly, despite the low quality of the water consumed, we did not find any association between drinking water quality and parasitic infections in the study households. We hypothesize that the transmission of pathogens through drinking water was minor compared to the high load of pathogens existing in the household environment. In contrast to this, two other studies recently conducted in Nepal identified the consumption of untreated water as a risk factor for infection with *Giardia* species [18, 48]. However, these studies may well have been conducted in different, hygienically less challenging contexts.

Undernutrition

One reason for the high prevalence of undernutrition in our study sites could be high poverty rates and their location in food-scarce regions where agricultural activity has been affected by such impacts of climate change as untimely heavy rainfall, droughts, and hailstorms. Against expectations, undernutrition was linked less to hygiene-related risk factors and more to a low socioeconomic status of the household and poor nutrition. These findings are in line with the results of recent evaluations of WASH and nutrition interventions that found an effect of nutrition on reducing child stunting or thinness but no effect of improved WASH [52–54]. An indirect link to the importance of hygienic conditions in reducing undernutrition could be observed through the significant association with a lack of regular deworming activities. Although the relation between undernutrition and parasitic infections is not well understood, undernutrition may be caused by recurring infections in the gut, which limit the proper absorption of calories and nutrients [55, 56]. Our findings on the association between undernutrition and intestinal parasitic infection are in agreement with studies conducted elsewhere [56, 57]. However, in contrast to findings from a study conducted in Bangladesh, our study did not identify recent diarrhoea infection as a risk factor for undernutrition [58]. Because we collected data during a cross-sectional survey, we do not have any longitudinal information on the frequency and severity of diarrhoea cases occurring in the study population. We think that there is a high chance that chronic diarrhoea and environmental enteropathy are linked with undernutrition at our study sites, but our data only refers to one point in time and, thus, cannot be confirmed [54, 59, 60].

We observed that unsafe water was used to wash feeding and storage containers, unhygienic kitchen cloths were used to dry children's utensils, caregivers did not wash their hands with soap while preparing food and feeding children and food was not hygienically stored. In addition, 76.8% of the households had flies indoors and in their surroundings. The recurrent food-borne infections are likely to have resulted in nutritional deficiency, environmental enteropathy, and consequent undernutrition [54, 56, 61, 62]. Similar observations of unsafe WASH practices and inadequate food hygiene were reported in a study conducted in other parts of Nepal [63].

Clinical signs of nutritional deficiencies

The prevalence of having at least one clinical sign for a nutritional deficiency was high. Because of the dearth of studies conducted on children with clinical signs of nutritional deficiencies in Nepal and other similar contexts, our results cannot be compared with other studies. The most frequently encountered nutritional deficiency, pale conjunctiva, which was found in 36.0% of children, can be related to the lack of animal proteins in diets.

In contrast to our findings on risk factors associated with undernutrition, clinical signs of nutritional deficiencies were significantly associated with water quality and various hygiene factors. Our analysis identified a significant protective association with handwashing, improved latrine cleanliness, better hygiene in the kitchen, and the household's own production of food. A higher risk for a nutritional deficiency was associated with poor water quality, keeping animals inside the house overnight, and the low personal hygiene of caregivers and of children. Further in-depth research is required to provide more insight into these issues.

Our study has several limitations. First, the findings presented in our study cannot be generalized to all other rural areas of Nepal, as the study was conducted in an extremely remote setting characterized by exceptionally low access to basic services. Second, an anthropometric survey has certain limitations related to the inaccuracy of children's dates of birth. Although we checked birth certificates to validate the reported ages, these certificates were not always available. Third, only one stool sample per participating child was examined by a double Kato-Katz thick smear, which likely led to an underestimation of the true prevalence of parasitic infections due to the low sensitivity of this technique.

Conclusion

More than half of the children living in remote hilly areas of Nepal suffer from an impaired nutritional status, nutritional deficiencies, intestinal parasitic infections, and to a lesser degree from diarrhoea. Better nutritional status of children was highly associated with higher economic status and improved nutrition provided to the child. The regular receipt of deworming tablets was equally important to better nutritional status. This indicates an indirect association between a better nutritional status and improved hygiene, because parasitic infections were highly associated with lacking sanitation and dirty hands. The presence of animal faeces in houses, caused by keeping animals in the household overnight and by painting mud floors with animal dung, was highly associated with diarrhoea and nutritional deficiencies in addition to hand hygiene and sanitation-related factors. Consequently, interventions to reduce the load of pathogens transmitted by animals into the household environment could be promising for improving children's health and call for further investigation.

Children's health status in remote areas in Nepal is alarming. Addressing this, our findings suggest interventions providing improved nutrition and promoting improved hygiene practices, including a reliable water supply to provide sufficient water for these.

List Of Abbreviations

AOR: Adjusted Odds Ratio

BMIZ: Body Mass Index Z score

EPG: Eggs per gram

FAO: Food and Agricultural Organisations

HAZ: Height for age Z score

KAP: Knowledge, Attitude and Practices

SDC: Sustainable Development Goals

WAZ: Weight for age Z score

WASH: Water, sanitation, and hygiene

WARM-P: Water Resource Management Programme

WHO: World Health Organisation

Declarations

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Authors contribution

The following authors contributed to the study design: RM, AS and SM. RM, AS, JS, DD, RS and MB coordinated the field and laboratory work, and supervised the research assistants. AS, RM, JS, DD, SM performed the statistical analysis and drafted the manuscript. All authors contributed to the interpretation of the data, manuscript writing, and revisions. 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.

Ethical approval and consent to participate

The study protocol was approved by the Stellungnahme der Kantonalen Ethikkommission, Zurich in Switzerland (KEK, reference no. 2018-00089) and the Nepal Health Research Council, Kathmandu in Nepal (NHRC, reference no. 2956). Caregivers of the participating child were informed about the objectives and procedure of the study, and written informed consent was obtained from parents or guardians when participants were children (under 16 years old). For illiterate caregivers, a fingerprint was obtained in the presence of a literate person from either the household or the village. Voluntary participation was emphasized, and caregivers were informed that they could withdraw at any time without obligations. A unique identifying code was assigned to each household. Results were communicated with the caregivers, and when the child was found to be positive for either intestinal parasites or nutritional deficiencies or malnutrition, they were referred to the collaborating government health facilities, where they received treatment free of charge.

Consent to publication

Not applicable

Competing Interests

The authors declare that they have no conflict of interest.

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Tables

Table 1 Water supply, water handling and water quality [N=1427]

Variables	[n(%)]	Surkhet A [n (%)]	Surkhet B [n (%)]	Dailekh [n (%)]	Accham [n (%)]	*p* value*
Main drinking water source						
Piped water in the house or yard	296 (20.7)	15 (4.3)	268 (73.4)	9 (2.5)	4 (1.1)	0.01
Piped water in the village	1077 (75.5)	292 (83.9)	97 (26.5)	340 (95.5)	348 (97.2)	
Open source[a]	25 (1.7)	20 (5.7)	0 (0.0)	5 (1.4)	0 (0.0)	
Protected source[b]	20 (1.4)	14 (4.0)	0 (0.0)	0 (0.0)	6 (1.7)	
Unmanaged piped system	4 (0.3)	2 (0.6)	0 (0.0)	2 (0.6)	0 (0.0)	
River, stream or canal	5 (0.3)	5 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)	
Household drinking water treated prior to the consumption	193 (13.5)	73 (21.0)	60 (16.4)	55 (15.4)	5 (1.4)	0.01
Water treatment methods used [e]						
Boiling	58 (4.1)	22 (6.3)	31 (8.5)	3 (0.8)	2 (0.6)	0.01
Filtration with a cloth	34 (2.4)	10 (2.9)	24 (6.4)	0 (0.0)	0 (0.0)	0.01
Flocculation and sedimentation	3 (0.2)	3 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	0.03
Chlorination	1 (0.1)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	0.38
Sodis	2 (0.1)	1 (0.3)	1 (0.3)	0 (0.0)	0 (0.0)	0.57
Use of filter	137 (9.6)	50 (14.4)	31 (8.5)	52 (14.6)	4 (1.1)	0.01
Water quality at the point of collection[f] of drinking water						
Total coliform bacteria (n=1136)						
0 CFU[c]/100 mL	7 (0.6)	0 (0.0)	0 (0.0)	7 (2.0)	0 (0.0)	0.01
1-10 CFU/100 mL	18 (1.6)	1 (0.5)	0 (0.0)	17 (4.9)	0 (0.0)	
10-100 CFU/100 mL	20 (1.8)	4 (2.1)	5 (1.6)	9 (2.6)	2 (0.7)	
100-1000 CFU/100 mL	884 (77.8)	101 (53.4)	274 (88.7)	258 (74.1)	251 (86.6)	
>1000 CFU/100 mL	207 (18.2)	83 (43.9)	30 (9.7)	57 (16.4)	37 (12.8)	
Escherichia coli						
0 CFU/100 mL	74 (6.5)	26 (13.7)	2 (0.6)	45 (13.0)	1 (0.3)	0.01
1-10 CFU/100 mL	315 (27.8)	94 (49.5)	83 (27.0)	74 (21.3)	64 (22.1)	
10-100 CFU/100 mL	574 (50.6)	59 (31.1)	201 (65.3)	139 (40.1)	175 (60.3)	
100-1000 CFU/100 mL	153 (13.5)	6 (3.2)	20 (6.5)	84 (24.2)	43 (14.8)	
>1000 CFU/100 mL	19 (1.7)	5 (2.6)	2 (0.7)	5 (1.4)	7 (2.4)	
Drinking water quality at the point of use[h]						
Total coliform bacteria (n=1257)						
0 CFU/100 mL	16 (1.3)	12 (4.0)	2 (0.9)	1 (0.3)	0 (0.0)	0.01
1-10 CFU/100 mL	27 (2.2)	15 (5.1)	8 (2.5)	4 (1.2)	0 (0.0)	
10-100 CFU/100 mL	40 (3.2)	15 (5.1)	8 (2.5)	15 (4.3)	2 (0.7)	
100-1000 CFU/100 mL	743 (59.1)	100 (33.7)	223 (68.8)	218 (62.5)	202 (70.4)	
>1000 CFU/100 mL	431 (34.3)	155 (52.2)	82 (25.3)	111 (31.8)	83 (28.9)	
Escherichia coli (n=1260)						
0 CFU/100 mL	60 (4.8)	33 (11.0)	13 (4.0)	13 (3.7)	1 (0.4)	0.01
1-10 CFU/100 mL	206 (16.4)	77 (25.7)	41 (12.7)	57 (16.3)	31 (10.8)	
10-100 CFU/100 mL	643 (51.0)	142 (47.3)	187 (57.7)	150 (43.0)	164 (57.1)	
100-1000 CFU/100 mL	292 (23.2)	32 (10.7)	71 (21.9)	115 (33.0)	74 (25.8)	
>1000 CFU/100 mL	59 (4.7)	16 (5.3)	12 (3.7)	14 (4.0)	17 (5.9)	
Hygiene condition of water transport container[i] (observation)						
Lower category	871 (61.0)	247 (71.0)	256 (70.1)	221 (62.1)	147 (41.1)	0.01
Middle category	214 (15.0)	33 (9.5)	34 (9.3)	42 (11.8)	105 (29.3)	
Higher category	342 (24.0)	68 (19.5)	75 (20.6)	93 (26.1)	106 (29.6)	
Hygiene condition of water storage containerk[j] (observation)						
Lower category	864 (60.5)	250 (71.8)	255 (69.9)	215 (60.4)	144 (40.2)	0.01
Middle category	212 (14.9)	28 (8.1)	35 (9.6)	44 (12.4)	105 (29.3)	
Higher category	351 (24.6)	70 (20.1)	75 (20.5)	97 (27.2)	109 (30.4)	

[a] *Open source refers to unprotected dug wells, ponds or unprotected springs.*

[b] *Protected source refers to protected wells and protected springs.*

[c] *CFU=Colony forming unit*

[h] *Point of use refers to the water taken from the drinking water container*

[i] *A new variable for the hygiene condition of the container used for the transport of drinking water was created using factor analysis with three conceptually similar categorical variables of : (i) water transport container is clean; (ii) water transport container has a lid; and (iii) water transport container is broken. The hygiene*

condition of the drinking water transport container was then categorised into three categories of lower, middle and better hygiene.

[j] *A new variable for the hygiene condition of container used for the storage of drinking water was created using factor analysis with three conceptually similar categorical variables of : (i) water storage container is clean; (ii) water storage container has a lid; and (iii) water storage container is broken. The hygiene condition of the drinking water storage container was then categorised into three categories of lower, middle and better hygiene.*

**p-values were obtained by the $\chi 2$ test*

Table 2 Hygiene behavior and hygiene conditions[N=1427]

Variables	[n (%)]	Surkhet A [n (%)]	Surkhet B [n (%)]	Dailekh [n (%)]	Accham [n (%)]	*p* value*
Selected KAP[a] indicators on hygiene						
Handwashing times						
<5 times	408 (28.6)	102 (29.3)	64 (17.5)	101 (28.4)	141 (39.4)	0.01
5-10 times	935 (65.5)	225 (64.7)	251 (68.8)	251 (70.5)	208 (58.1)	
10-15 times	61 (4.3)	18 (5.2)	31 (8.5)	4 (1.1)	8 (2.2)	
> 15 times	23 (1.6)	3 (0.9)	19 (5.2)	0 (0.0)	1 (0.3)	
Handwashing with soap						
<5 times	1084 (76.0)	267 (76.7)	244 (66.8)	278 (78.1)	295 (82.4)	0.01
5-10 times	337 (23.6)	79 (22.7)	118 (32.3)	78 (21.9)	62 (17.3)	
10-15 times	5 (0.3)	2 (0.6)	2 (0.5)	0 (0.0)	1 (0.3)	
> 15 times	1 (0.1)	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	
Handwashing[b]						
When they look dirty	862 (60.4)	224 (64.4)	254 (70.0)	172 (48.3)	212 (59.2)	0.01
After going toilet	1402 (98.2)	342 (98.3)	356 (97.5)	354 (99.4)	350 (97.8)	0.21
After cleaning babys bottom	834 (58.4)	170 (48.8)	225 (61.6)	236 (66.3)	203 (56.7)	0.01
Before eating	1039 (72.8)	259 (74.4)	298 (81.6)	295 (82.9)	187 (52.2)	0.01
Before cooking	572 (40.1)	170 (48.8)	146 (40.0)	142 (39.9)	114 (31.8)	0.01
There are not special occasions	2 (0.14)	0 (0.0)	1 (0.3)	0 (0.0)	1 (0.3)	0.58
Do not know	3 (0.21)	1 (0.3)	0 (0.0)	2 (0.6)	0 (0.0)	0.29
Types of latrines used						
Water pit latrine	1200 (84.1)	322 (92.5)	252 (69.0)	315 (88.5)	311 (86.9)	0.01
Simple pit latrine	137 (9.6)	12 (3.5)	93 (25.5)	22 (6.2)	10 (2.8)	
No latrine	90 (6.3)	14 (4.0)	20 (5.5)	19 (5.3)	37 (10.3)	
Animal[c] kept inside the household overnight	851 (59.7)	162 (46.5)	174 (47.8)	190 (53.4)	325 (90.8)	0.01
Overall hygiene[d] condition of households (n=1425)						
Very low hygiene	752 (52.7)	106 (30.5)	126 (34.5)	202 (56.7)	318 (88.8)	0.01
Low hygiene	162 (11.4)	50 (14.4)	33 (9.0)	65 (18.3)	14 (3.9)	
Middle hygiene	101 (7.1)	44 (12.6)	25 (6.8)	22 (6.2)	10 (2.8)	
Moderate hygiene	92 (6.4)	41 (11.8)	22 (6.0)	22 (6.2)	7 (2.0)	
Better hygiene	318 (22.3)	107 (30.7)	157 (43.0)	45 (12.6)	9 (2.5)	
Hygiene condition of latrine (observation)[f]						
Lower category	695 (48.7)	213 (61.2)	200 (54.8)	166 (46.6)	116 (32.4)	0.01
Middle category	390 (27.3)	86 (24.7)	54 (14.8)	130 (36.5)	120 (33.5)	
Better category	342 (24.0)	49 (14.1)	111 (30.4)	60 (16.9)	122 (34.1)	
Hygiene condition of handwashing facilities (observation)[g]						
Lower category	289 (50.5)	87 (39.9)	148 (67.0)	43 (43.9)	11 (31.4)	0.01
Middle category	97 (17.0)	45 (20.6)	25 (11.3)	22 (22.4)	5 (14.3)	
Better category	186 (32.5)	86 (39.5)	48 (21.7)	33 (33.7)	19 (54.3)	
Hygiene condition of household environment (observation)[h]						
Lower category	289 (50.5)	87 (39.9)	148 (67.0)	43 (43.9)	11 (31.4)	0.01

Middle category	97 (17.0)	45 (20.6)	25 (11.3)	22 (22.4)	5 (14.3)	
Better category	186 (39.5)	86 (39.5)	48 (21.7)	33 (33.7)	19 (54.3)	
Hygiene condition of kitchen (observation)[i]						
Lower category	481 (33.7)	187 (53.7)	174 (47.7)	75 (21.1)	45 (12.6)	0.01
Middle category	637 (44.6)	128 (36.8)	120 (32.9)	206 (57.9)	183 (51.1)	
Better category	309 (21.6)	33 (9.5)	71 (19.4)	75 (21.1)	130 (36.3)	
Personal hygiene of participating child and their caregivers (observation)[j]						
Lower category	611 (42.8)	153 (44.0)	210 (57.5)	167 (46.9)	81 (22.6)	0.01
Middle category	424 (29.7)	92 (26.4)	72 (19.7)	130 (36.5)	130 (36.3)	
Better category	392 (27.5)	103 (29.6)	83 (22.7)	59 (16.6)	147 (41.1)	
Information received on WASH[k] promotion						
Received any information on water treatment and hygiene[l]	155 (10.9)	105 (30.2)	13 (3.6)	19 (5.3)	18 (5.0)	0.01
Information on water treatment and hygiene changed behaviour	139 (89.7)	95 (90.5)	10 (76.9)	17 (89.5)	17 (94.4)	0.42
Behaviours that changed after receiving information on water treatment and hygiene[m]						
"I purchased a product for water treatment"	16 (1.1)	5 (1.4)	0 (0.0)	9 (2.5)	2 (0.6)	0.01
"I am now regularly treating water"	32 (2.2)	20 (5.8)	2 (0.5)	9 (2.5)	1 (0.3)	0.01
"I am now sometimes treating water"	27 (1.9)	23 (6.6)	1 (0.3)	2 (0.6)	1 (0.3)	0.01
"I installed a handwashing station"	35 (2.4)	24 (6.9)	2 (0.8)	3 (0.8)	3 (0.8)	0.01
"I do wash my hands more often"	36 (2.5)	23 (6.6)	3 (0.8)	4 (1.1)	6 (1.7)	0.01
"I use soap to wash my hands more often"	90 (6.3)	63 (18.1)	6 (1.6)	15 (4.2)	6 (1.7)	0.01
"I wash my hands at the critical times"	65 (4.6)	51 (14.7)	6 (1.6)	6 (1.7)	2 (0.6)	0.01
" I regularly disinfect the water storage container with chlorine"	17 (1.2)	15 (4.3)	0 (0.0)	1 (0.3)	1 (0.3)	0.01
"I regularly wash the water storage container with soap"	21 (1.5)	18 (5.2)	0 (0.0)	3 (0.8)	0 (0.0)	0.01
"Other behaviour changed"	2 (0.1)	1 (0.3)	0 (0.0)	1 (0.3)	0 (0.0)	0.56
Household attended hygiene literacy class[n]	362 (25.4)	98 (28.2)	87 (23.8)	75 (21.1)	102 (28.5)	0.07
FCHVs[o] or other health workers visited household	537 (37.6)	131 (37.6)	115 (31.5)	123 (34.5)	168 (46.9)	0.01
Total times FCHVs/other health workers visited the household						
Once	468 (87.1)	102 (77.9)	99 (86.1)	112 (91.1)	155 (92.3)	0.01
Twice	60 (11.2)	28 (21.4)	8 (7.0)	11 (8.9)	13 (7.7)	
Trice	3 (0.6)	0 (0.0)	3 (2.6)	0 (0.0)	0 (0.0)	
Four times	1 (1.2)	0 (0.0)	1 (0.9)	0 (0.0)	0 (0.0)	
Don`t remember	5 (0.9)	1 (0.8)	4 (3.5)	0 (0.0)	0 (0.0)	
Effectiveness: HLC[p] or door to door visit						
Hygiene literacy class (HLC)	73 (23.0)	19 (25.0)	2 (2.5)	8 (11.9)	44 (45.8)	0.01
Door to door visit	166 (52.2)	48 (63.2)	45 (57.0)	53 (79.1)	20 (20.8)	
Both	79 (24.8)	9 (11.8)	32 (40.5)	6 (9.0)	32 (33.3)	

[a] *Knowledge, attitude and practice*

[b] *Multiple responses possible for the occasions of handwashing*

[c] *Animals refers to any domestic animals such as chicken, goats, dogs, cats, cows, buffalos etc.*

[d] *A new variable of hygiene was created using frequency of handwashing, frequency of handwashing with soap, occasions for washing hands, the type of toilet used, and if animals are kept inside the household.*

[f] *A new variable for the observed hygiene condition of the toilet was created using factor analysis with conceptually similar categorical variables: (i) is the toilet clean; and (ii) are these materials available (sandals, drum with water, brush, none of these). The condition of toilet was then categorised into three categories with lower, middle and better hygiene.*

[g] *A new variable for the observed hygiene condition of the handwashing facilities was created using factor analysis with four conceptually similar categorical variables: (i) are handwashing facilities in good condition; and (ii) are handwashing facilities clean (iii) is soap available (iv) is water available. The condition of handwashing facility was then categorised into three categories with lower, middle and better hygiene.*

[h] *A new variable for the observed hygiene of the household environment condition was created using factor analysis with three conceptually similar categorical variables: (i) can you see trash spread outside the house; (ii) does the household have a garbage pit to dispose garbage (iii) can you see trash spread inside the house? The condition of household environment was then categorised into three categories with lower, middle and better hygiene.*

[i] *A new variable for the observed hygiene of the kitchen hygiene condition was created using factor analysis with four conceptually similar categorical variables: (i) are clean dishes kept high; (ii) is the entirety of food covered (iii) is there a rack to dry your utensils and dishes after washing and (iv) is there a significant number of flies in the kitchen (>10). The kitchen hygiene was then categorised into three categories with lower, middle and better hygiene.*

j *A new variable for the observed personal hygiene of the caregiver and the participating child was created using factor analysis with four conceptually similar categorical variables of: (i) wearing shoes; (ii) hands are clean (iii) piles of dirty clothes lying around in the house. The personal hygiene was then categorised into three categories with lower, middle and better hygiene.*

[k] *Water, sanitation and hygiene*

[l] *Information from Helvetas (local INGO) or other organizations*

[m] *Multiple responses possible*

[n] *Hygiene literacy class conducted by female community health volunteers or other health workers*

[0] *FCHVs: Female community health volunteers*

[p] *HLC: Hygiene literacy class*

Table 3 Association of risk factors with diarrhea in univariate and multivariate logistic regression

Risk factors [N (cases)=492]		Univariate logistic regression[a]			Multivariate logistic regression[b]		
		OR	95% CI	*p-value*	aOR	95% CI	*p-value*
Age of child	< 5 years	1.00			1.00		
	> 5 years	0.47	0.34-0.66	**0.00**	0.39	0.27-0.58	**0.01**
Sex of child	Male	1.00			1.00		
	Female	1.08	0.82-1.44	0.58	1.14	0.82-1.58	0.43
Number of children in the household	< 5	1.00			1.00		
	> 5	2.18	0.66-0.18	0.20			
Caregivers can read/write	Can neither read or write	1.51	1.04-2.19	**0.03**	1.21	0.76-1.95	0.41
	Can read only	0.22	0.03-1.62	**0.14**	0.22	0.03-1.79	0.16
	Can both read and write	1.00			1.00		
Involvement in the water supply system in the community	"yes" *vs.* "no"	0.81	0.39-1.66	0.57			
Socioeconomic status	Poor	1.13	0.79-1.66	0.48	1.13	0.73-1.74	0.58
	Middle	0.88	0.57-1.38	0.59	1.09	0.65-1.86	0.74
	Better	1.00			1.00		
Main drinking water source	Piped water in the house	1.00					
	Piped water in the village	0.81	0.50-1.31	0.39			
	Open source	1.07	0.33-3.49	0.92			
	Protected source	0.91	0.24-3.45	0.90			
	Unmanaged piped system	1.57	0.15-16.17	0.71			
	River, stream or canal	1.60	0.17-15.38	0.68			
Time to fetch drinking water	< 5 minutes	1.00			1.00		
	5-15 minutes	10.45	2.19-50.05	**0.00**	0.77	0.34-1.73	0.52
	16-60 minutes	4.24	1.01-18.05	**0.05**	0.60	0.25-1.43	0.25
	> 60 minutes	3.13	0.73-13.44	**0.12**	0.26	0.05-1.44	0.12
Interruption of main drinking water source for more than a week	"yes" *vs.* "no"	2.92	1.49-5.71	**0.00**	2.72	1.18-6.31	**0.02**
Knowledge on factors that make water unsafe for drinking	Open unprotected source	2.39	1.71-3.33	**0.00**	0.66	0.37-1.17	0.16
	Open defecation	1.23	0.91-1.66	**0.17**	1.36	0.82-2.26	0.23
	Deforestation	1.05	0.48-2.29	0.90			
Method of drinking water treatment used	Boiling	0.94	0.45-1.97	0.87			
	Filtration with cloth	0.98	0.37-2.61	0.97			
	Use of filter ("yes" *vs.* "no")	0.63	0.36-1.15	**0.12**	0.81	0.41-1.60	0.54
Handwashing with soap	<5 times	2.49	0.45-13.89	0.30	5.52	0.49-61.63	0.16
	5-10 times	0.56	0.39-0.82	**0.00**	1.35	0.77-2.38	0.29
	>10 times	1.00			1.00		
Times of handwashing	When they look dirty	0.41	0.30-0.54	**0.00**	0.47	0.32-0.71	**0.01**
	After going to toilet	0.23	0.10-0.52	**0.00**	0.37	0.13-1.02	**0.06**
	After cleaning babys bottom	0.64	0.48-0.84	**0.00**	0.80	0.53-1.19	0.27
	Before eating	0.57	0.42-0.78	**0.00**	0.78	0.51-1.17	0.23
	Before cooking	0.91	0.68-1.22	0.55			
Animals inside home overnight	"yes" *vs.* "no"	1.06	0.78-1.44	0.72			
Information received on WASH	"no" *vs.* "yes"	0.71	0.40-1.24	0.23			
Handwashing station installed	"no" *vs.* "yes"	0.57	0.17-1.89	0.35			
Wash hands during critical times	"yes" *vs.* "no"	0.91	0.41-2.01	0.83			
Attended hygiene literacy class	"no" *vs.* "yes"	0.47	0.32-0.68	**0.00**	0.76	0.46-1.25	0.29
Caregivers heard about intestinal parasites	"no" *vs.*"yes"	0.72	0.49-1.05	**0.09**	1.06	0.59-1.90	0.84
Awareness on measures against intestinal parasites	Wash hands with soap	0.99	0.62-1.58	0.95			
	Wear shoe	0.85	0.43-1.68	0.64			
	Drink clean water	0.81	0.53-1.22	0.30			
	Deworming	0.61	0.36-1.04	**0.07**	1.29	0.58-2.84	0.53
Type of toilet in the household	Water pit latrine	1.67	0.85-3.27	**0.14**	0.84	0.15-4.78	0.84
	Pit latrine	0.82	0.47-1.42	0.48	0.69	0.13-3.79	0.67
	No latrine	1.00			1.00		

Cleanliness of the toilet	"yes" *vs.* "no"	0.57	0.43-0.77	**0.00**	0.68	0.47-0.98	**0.04**
Materials available in toilet	Sandals/slippers	0.48	0.17-1.37	**0.17**	1.18	0.37-3.80	0.78
	Drum with water	0.77	0.54-1.08	**0.13**	1.35	0.28-6.69	0.71
	Brush	0.46	0.31-0.68	**0.00**	0.92	0.56-1.52	0.75
	None of these	1.41	0.93-2.13	**0.10**	0.86	0.16-4.48	0.86
Trash outside the house	"no" *vs.* "yes"	0.62	0.44-0.86	**0.01**	1.01	0.61-1.68	0.98
Trash spread inside the house	"yes" *vs.* "no"	1.33	0.98-1.81	**0.07**	1.30	0.81-2.10	0.27
Entirety of food covered	"yes" *vs.* "no"	0.59	0.48-0.80	**0.00**	1.26	0.81-1.96	0.30
Flies in the kitchen	"yes" *vs.* "no"	0.97	0.67-1.40	0.85			
Caregiver's hands clean	"yes" *vs.* "no"	0.53	0.38-0.73	**0.00**	0.84	0.51-1.38	0.50
Caregiver wearing shoe	"yes" *vs.* "no"	0.57	0.41-0.77	**0.00**	0.96	0.64-1.46	0.87
Child's hand clean	"yes" *vs.* "no"	0.45	0.34-0.61	**0.00**	0.62	0.40-0.96	**0.03**
Piles of dirty clothes in the house	"yes" *vs.* "no"	1.34	0.98-1.85	**0.07**	0.71	0.43-1.18	0.19
E. coli at point of use drinking water	"yes" *vs.* "no"	3.59	1.10-11.69	**0.03**	2.19	0.62-7.66	0.22
Total coliform at POU drinking water	"yes" *vs.* "no"	1.34	0.16-11.34	0.79			
Undernutrition	"yes" *vs.* "no"	1.12	0.83-1.51	0.47			
Presence of intestinal parasites	"yes" *vs.* "no"	1.19	0.84-1.70	0.33			
Floor	"mud" vs. "cement"	2.98	1.71-5.20	**0.01**	2.29	1.20-4.37	**0.01**

[a] *Odds ratios (OR) and p-values are based on the likelihood ratio test and the significant p-value from the univariable logistic regression model is indicated bold.*

[b] *Adjusted odds ratios (aOR) and p-vaules are based on likelihood ratio test of the mixed multivariable regression model. The model with random area intercepts included the categorical exposure variables age and sex of the participating child, socioeconomic domains and surveyed area. All the risk values that had p-values lower than 0.2 in the univariate analyses were included into the mixed multivariate regression analysis.*

Table 4 Prevalence and intensity of intestinal helminths and protozoa infections among children [N=962]

Parasite (No. of samples examined =962)	Prevalence of intestinal parasites [n (%)]	Sex		*p-value*	Age group		*p-value*	Area				*p-value*	Mean eggs per gram±SE (epg[b])
		Male	Female		<5 years	> 5years		Surkhet A [n(%)]	Surkhet B [n (%)]	Dailekh [n (%)]	Accham [n (%)]		
Nematodes													
Trichuris trichiura[a]	7 (0.7)	4 (0.7)	3 (0.7)	0.99	1 (0.2)	6 (1.6)	0.01	2 (0.8)	0 (0.0)	3 (1.7)	2 (0.8)	0.23	4.15 ±43.0
Hookworm[a]	31 (3.2)	16 (2.9)	15 (3.6)	0.54	18 (3.0)	13 (3.6)	0.64	13 (5.0)	7 (2.5)	8 (4.5)	3 (1.2)	0.06	16.8 ±92.6
Enterobius vermicularis[a]	26 (2.7)	15 (2.7)	11 (2.7)	0.94	14 (2.4)	12 (3.3)	0.38	3 (1.2)	4 (1.4)	9 (5.1)	10 (4.0)	**0.02**	20.8±99.4
Ascaris lumbricoides[a]	203 (21.1)	114(20.8)	89(21.5)	0.79	140(23.5)	63(17.3)	0.02	46(17.8)	68 (24.5)	68(38.4)	21 (8.4)	**0.01**	110±238.4
Cestodes													
Hymenolepsis nana[a]	44 (4.6)	18 (3.3)	26 (6.3)	**0.03**	27 (4.5)	17 (4.7)	0.92	1 (0.4)	9 (3.2)	10 (5.7)	24 (9.6)	**0.01**	34.4±152.2
Intestinal protozoa													
Giardia lamblia	225 (23.4)	144 (26.3)	81 (19.6)	**0.02**	145 (24.3)	80 (21.9)	0.40	67 (26.0)	12 (4.3)	33 (18.6)	113 (45.4)	**0.01**	

[a] *The intensity of intestinal helminths in all participating children is light infection i.e. for Trichuris trichiura: 1-999; hookworm: 1-1999; Enterobius vermicularis: 1-2999; Ascaris lumbricoides: 1-4999.*

[b] *Egg counts/ egg per gram of faeces describe the intensity of parasitic infection*

Table 5 Association of factors with parasitic infections in univariate and multivariate logistic regression

Overall parasitic infection [N=962/ N (cases)=492]		Univariate logistic regression[a]			Multivariate logistic regression[b]		
		OR	95% CI	*p-value*	aOR	95% CI	*p-value*
Age of the child	< 5 years	1.00			1.00		
	> 5 years	0.86	0.66-1.13	0.29	0.86	0.65-1.15	0.32
Sex of the child	Male	1.00			1.00		
	Female	0.90	0.69-1.17	0.43	0.88	0.66-1.16	0.35
Number of children in the household	< 5	1.00					
	> 5	2.01	0.49-8.11	0.34			
Caregivers can read/write	Can neither read or write	1.09	0.74-1.61	0.66	1.20	0.79-1.84	0.40
	Can read only	3.15	0.83-12.0	**0.09**	4.07	1.00-16.55	**0.05**
	Can both read and write	1.00			1.00		
Involvement in the water supply system in the community	"yes" *vs.* "no"	1.89	1.05-3.42	**0.03**	1.58	0.80-3.13	0.19
Socioeconomic status	Poor	1.00			1.00		
	Middle	0.85	0.61-1.78	0.33	0.85	0.59-1.22	0.39
	Better	0.86	0.56-1.32	0.49	0.90	0.57-1.45	0.66
Main drinking water source	Piped water in the house	1.00			1.00		
	Piped water in the village	1.39	0.87-2.21	**0.17**	1.11	0.66-1.86	0.71
	Open source	1.33	0.47-3.73	0.59	1.49	0.49-4.50	0.48
	Protected source	1.18	0.40-3.49	0.76	0.78	0.23-2.56	0.68
	River, stream or canal	6.79	0.72-64.33	**0.09**	5.37	0.51-56.21	0.16
Time to fetch drinking water	< 5 minutes	1.00					
	5-15 minutes	1.53	0.66-3.55	0.34			
	16-60 minutes	1.23	0.53-2.78	0.60			
	> 60 minutes	1.07	0.38-3.01	0.90			
Main drinking water source functioning now	Functioning well	1.00					
	Functioning irregularly	1.24	0.61-1.96	0.76			
Interruption of main drinking water source for more than a week	"no" *vs.* "yes"	1.76	0.91-3.41	**0.09**	1.33	0.65-2.70	0.44
Knowledge on factors that make water unsafe for drinking	Open unprotected source	1.09	0.77-1.54	0.62			
	Open defecation	1.09	0.83-1.45	0.53			
	Deforestation	1.97	0.97-3.99	**0.06**	1.81	0.65-2.70	0.13
Method of drinking water treatment used	Boiling	0.96	0.50-1.86	0.91			
	Filtration with cloth	0.77	0.33-1.85	0.57			
	Use of filter ("yes" *vs.* "no")	1.55	1.00-2.41	**0.05**	1.25	0.76-2.05	0.39
Clean drinking water storage container	"no" *vs.* "yes"	1.88	1.04-3.41	**0.04**	1.66	0.86-3.19	0.13
Handwashing with soap	<5 times	1.00					
	5-10 times	1.08	0.79-1.47	0.64			
	>10 times	0.25	0.03-2.23	0.21			
Times of handwashing	When they look dirty	0.10	0.76-1.31	0.99			
	After going to toilet	0.58	0.23-1.49	0.26			
	After cleaning babys bottom	1.00	0.77-1.31	0.98			
	Before eating	1.07	0.79-1.46	0.65			
	Before cooking	1.14	0.87-1.48	0.35			
Animals inside home overnight	"yes" *vs.* "no"	1.13	0.84-1.51	0.41			
Information received on WASH	"no" *vs.* "yes"	1.90	1.21-3.00	**0.01**	1.09	0.44-2.71	0.85
Handwashing station installed	"no" *vs.* "yes"	2.66	1.05-6.73	**0.04**	1.64	0.51-5.12	0.39
Use soap to wash hands	"yes" *vs.* "no"	1.69	0.96-2.99	**0.07**	1.27	0.50-3.21	0.61
Wash hands during critical times	"yes" *vs.* "no"	1.98	0.97-3.67	**0.06**	0.74	0.28-1.98	0.55
Sometimes treating water	"no" *vs.* "yes"	3.68	1.39-9.71	**0.01**	2.40	0.76-7.57	0.14
Attended hygiene literacy class	"no" *vs.* "yes"	1.47	1.08-1.99	**0.01**	1.36	0.96-1.92	0.08
Caregivers heard about intestinal parasites	"no" *vs.*"yes"	1.36	0.98-1.88	**0.06**	0.98	0.67-1.43	0.92
Type of toilet in the household	Water pit latrine	1.00			1.00		
	Pit latrine	2.25	1.12-4.49	**0.02**	6.12	1.57-23.90	**0.01**
	No latrine	1.67	0.96-2.91	**0.07**	3.93	1.08-14.25	**0.04**
Cleanliness of the toilet	"yes" *vs.* "no"	0.89	0.69-1.16	0.40			

Materials available in toilet	Sandals/slippers	0.86	0.45-1.65	0.66			
	Drum with water	1.36	0.96-1.91	**0.08**	0.46	0.14-1.48	0.19
	Brush	1.14	0.84-1.54	0.41			
	None of these	1.39	0.91-2.12	**0.12**	3.22	0.94-11.03	0.06
Soap available at handwashing facility	"yes" *vs.* "no"	0.87	0.55-1.37	0.55			
Trash outside the house	"yes" *vs.* "no"	1.38	1.03-1.86	**0.03**	1.30	0.89-1.90	0.18
Trash spread inside the house	"yes" *vs.* "no"	1.09	0.82-1.45	0.57			
Entirety of food covered	"yes" *vs.* "no"	1.06	0.78-1.43	0.72			
Flies in the kitchen	"yes" *vs.* "no"	1.05	0.76-1.44	0.78			
Caregiver's hands clean	"yes" *vs.* "no"	0.75	0.54-1.04	**0.09**	0.61	0.41-0.89	**0.01**
Caregiver is wearing shoes	"yes" *vs.* "no"	1.21	0.90-1.62	0.21			
Child's hand clean	"yes" *vs.* "no"	0.88	0.67-1.15	0.33			
Piles of dirty clothes in the house	"yes" *vs.* "no"	0.71	0.53-0.95	**0.02**	1.28	0.88-1.86	0.19
E. coli at point of use drinking water	"yes" *vs.* "no"	1.34	0.71-2.47	0.37			
E. coli at point of collection drinking water	"yes" *vs.* "no"	1.05	0.55-2.00	0.88			
Total coliforms at POC drinking water	"yes" *vs.* "no"	1.33	0.22-8.24	0.76			
Total coliforms at POU drinking water	"yes" *vs.* "no"	1.63	0.53-4.99	0.39			
Presence of undernutrition	"yes" *vs.* "no"	1.02	0.77-1.34	0.92			
Pesence of nutritional deficiencies	"yes" *vs.* "no"	1.14	0.85-1.51	0.38			
Presence of diarrhea	"yes" *vs.* "no"	1.16	0.81-1.65	0.41			

[a] *Odds ratios (OR) and p-values are based on the likelihood ratio test and p-value <0.02 in univariabte logistic regression model is indicated bold, likewise p-value <0.05 in multivariate logistic regression is indicated bold.*

[b] *Adjusted odds ratios (aOR) and p-vaules are based on likelihood ratio test of the mixed multivariable regression model. The model with random area intercepts included the categorical exposure variables age and sex of the participated child, socioeconomic domains and surveyed area. All the risk values that had p-values lower than 0.2 in the univariate analyses were included into the mixed multivariate regression analysis.*

Table 6 Children's nutrition [N=1427]

Nutrition and dietary variables	[n (%)]	Sex		*p*-value*	Age		*p*-value*	Area				*p*-value*
		Male (n=790)	Female (n=637)		<6 months (n=908)	> 6 months (n=519)		Surkhet A [n(%)]	Surkhet B [n (%)]	Dailekh [n (%)]	Accham [n(%)]	
Child breastfed	1422 (99.6)	787 (99.6)	635 (99.7)	0.83	906 (99.8)	516 (99.4)	0.27	345 (99.1)	364 (99.7)	356 (100.0)	357 (99.7)	0.26
Total months of breastfeeding of child												
<6 months	19 (1.3)	9 (1.1)	10 (1.6)	0.30	14 (1.5)	5 (1.0)	**0.01**	9 (2.6)	6 (1.6)	4 (1.2)	0 (0.0)	**0.01**
6-12 months	773 (54.2)	416 (52.7)	357 (56.0)		552 (60.8)	221 (42.6)		175 (50.3)	181 (49.6)	208 (58.4)	209 (58.4)	
>12 months	635 (44.5)	365 (46.2)	270 (42.4)		342 (37.7)	293 (56.4)		164 (47.1)	178 (48.8)	144 (40.5)	149 (41.6)	
Complementary feeding for the child started <6months												
Yes	1384 (97.0)	766 (97.0)	618 (97.0)	0.95	883 (97.3)	501 (96.5)	0.45	318 (91.4)	357 (97.8)	355 (99.7)	354 (98.9)	**0.01**
No	43 (3.0)	24 (3.0)	19 (3.0)		25 (2.7)	18 (3.5)		30 (8.6)	8 (2.2)	1 (0.3)	4 (1.1)	
Child's meal consumption per day												
< 2 meals	40 (2.8)	24 (3.0)	16 (2.5)	0.55	33 (3.6)	7 (1.4)	**0.01**	22 (3.2)	10 (2.7)	4 (1.1)	15 (4.2)	0.09
>3 meals	1387 (97.2)	766 (97.0)	621 (97.5)		875 (96.4)	512 (98.6)		337 (96.8)	355 (97.3)	352 (98.9)	343 (95.8)	
Child receiving food supplements in addition to regular meal												
Yes	618 (43.3)	351 (44.5)	267 (41.9)	0.33	403 (44.4)	215 (41.5)	0.29	166 (47.8)	179 (49.0)	159 (44.7)	114 (31.8)	**0.01**
No	808 (56.7)	438 (55.5)	370 (58.1)		505 (55.6)	303 (58.5)		181 (52.2)	186 (51.0)	197 (55.3)	244 (68.2)	
Dietary Diversity Scores (DDS)[a] based on food consumed in past one week												
1	158 (11.1)	95 (12.0)	63 (9.9)	0.23	102 (11.2)	56 (10.8)	0.58	63 (18.1)	16 (4.4)	65 (18.2)	14 (3.9)	**0.01**
2	147 (10.3)	85 (10.8)	62 (9.7)		88 (9.7)	59 (11.4)		78 (22.4)	29 (7.9)	28 (7.9)	12 (3.3)	
3	170 (11.9)	83 (10.5)	87 (13.7)		109 (12.0)	61 (11.8)		59 (16.9)	52 (14.2)	33 (9.3)	26 (7.3)	
4	154 (10.8)	79 (10.0)	75 (11.8)		92 (10.1)	62 (12.0)		48 (13.8)	35 (9.6)	31 (8.7)	40 (11.2)	
5	160 (11.2)	93 (11.8)	67 (10.5)		106 (11.7)	54 (10.4)		26 (7.5)	37 (10.1)	36 (10.1)	61 (17.0)	
6	162 (11.3)	80 (10.1)	82 (12.9)		101 (11.1)	61 (11.8)		25 (7.2)	62 (17.0)	39 (11.0)	36 (10.1)	
7	158 (11.1)	87 (11.0)	71 (11.2)		105 (11.6)	53 (10.2)		26 (7.5)	47 (12.9)	30 (8.4)	55 (15.4)	
8	158 (11.1)	94 (11.9)	64 (10.0)		94 (10.3)	64 (12.3)		11 (3.2)	44 (12.1)	42 (11.8)	61 (17.0)	
9	160 (11.2)	94 (11.9)	66 (10.4)		111 (12.2)	49 (9.4)		12 (3.4)	43 (11.8)	52 (14.6)	53 (14.8)	

[a] *the dietary diversity scores are based on the type of food consumed in the week preceeding the survey. The food was categorized into nine food groups such as (i) starchy staples (ii) beans/peas/lentils, (iii) nuts (iv) dairy products (v) meat/fish (vi) eggs (vii) leafy green vegetables; (viii) other vegetables and (ix) fruits. The details of the food consumption can be found in the Table D, supplementary materials.*

Table 7 Prevalence of children's undernutrition and signs of nutritional deficiencies

Malnutrition indicators, clinical outcomes and nutritional deficiency	[N (%)]	Sex		*p-value*	Age group		*p-value*	Area				*p-value*
		Male	Female		<5 years	> 5years		Surkhet A [n (%)]	Surkhet B [n (%)]	Dailekh [n (%)]	Accham [n (%)]	
Malnutrition indicators												
Stunting (n=1389)												
Severe[a]	248 (17.9)	146 (18.8)	102 (16.7)	0.51	158 (17.8)	90 (17.9)	0.81	29 (8.5)	49 (13.8)	87 (25.1)	83 (23.9)	**0.01**
Moderate[b]	370 (26.6)	209 (26.9)	161 (26.3)		241 (27.2)	129 (25.6)		73 (21.5)	83 (23.3)	104 (30.1)	110 (31.7)	
Normal[c]	771 (55.5)	422 (54.3)	349 (57.0)		487 (55.0)	284 (56.5)		238 (70.0)	224 (62.9)	155 (44.8)	154 (44.4)	
Thinness (n=1344)												
Severe[a]	55 (4.1)	25 (3.4)	30 (5.0)	0.31	36 (4.2)	19 (3.9)	0.83	12 (3.7)	14 (3.9)	16 (4.8)	13 (4.0)	0.31
Moderate[b]	96 (7.1)	54 (7.2)	42 (7.0)		63 (7.4)	33 (6.7)		19 (5.9)	22 (6.2)	34 (10.2)	21 (6.4)	
Normal[c]	1193 (88.8)	667 (89.4)	526 (88.0)		752 (88.4)	441 (89.4)		293 (90.4)	322 (89.9)	284 (85.0)	294 (89.6)	
Underweight (n=1360)												
Severe[a]	142 (10.4)	83 (11.0)	59 (9.8)	0.63	88 (10.2)	54 (10.9)	0.88	16 (4.9)	33 (9.2)	49 (14.4)	44 (13.3)	**0.01**
Moderate[b]	265 (19.5)	151 (20.0)	114 (18.9)		171 (19.8)	94 (19.0)		40 (21.1)	57 (15.8)	85 (25.1)	83 (25.1)	
Normal[c]	953 (70.1)	522 (69.0)	431 (71.3)		606 (70.1)	347 (70.1)		274 (83.0)	270 (75.0)	205 (60.5)	204 (61.6)	
Clinical outcomes and signs/symptoms of nutritional deficiency (n=1427)												
Wasted appearance	197 (13.8)	95 (12.0)	102 (16.0)	**0.03**	145 (16.0)	52 (10.0)	**0.01**	29 (8.3)	33 (9.0)	66 (18.5)	69 (19.3)	**0.01**
Bitot's spot	283 (19.8)	168 (21.3)	115 (18.1)	0.13	147 (16.2)	136 (26.2)	**0.01**	27 (7.8)	65 (17.8)	89 (25.0)	102 (28.5)	**0.01**
Loss of hair pigment	153 (10.7)	80 (10.1)	73 (11.5)	0.42	114 (12.6)	39 (7.5)	**0.01**	12 (3.5)	46 (12.6)	56 (15.7)	39 (10.9)	**0.01**
Dry and infected cornea	189 (13.2)	108 (13.7)	81 (12.7)	0.60	114 (12.6)	75 (14.5)	0.31	25 (7.2)	26 (7.1)	49 (13.8)	89 (24.9)	**0.01**
Oedema	38 (2.7)	18 (2.3)	20 (3.14)	0.32	28 (3.1)	10 (1.9)	0.91	4 (1.2)	5 (1.4)	9 (2.5)	20 (5.6)	**0.01**
Pale conjunctiva	513 (35.9)	279 (35.3)	234 (36.7)	**0.01**	309 (34.0)	204 (39.3)	**0.05**	83 (23.9)	95 (26.0)	154 (43.3)	181 (50.6)	**0.01**
Bowed legs	37 (2.6)	25 (3.2)	12 (1.9)	0.13	23 (2.5)	14 (2.7)	0.85	7 (2.0)	3 (0.8)	9 (2.5)	18 (5.0)	**0.01**
Spongy bleeding gums	232 (16.3)	131 (16.6)	101 (15.9)	0.71	104 (11.5)	128 (24.7)	**0.01**	37 (10.6)	68 (18.6)	70 (19.7)	57 (15.9)	**0.01**
Dermatitis	818 (57.3)	464 (58.7)	354 (55.8)	0.23	511 (56.3)	307 (59.2)	0.29	155 (44.5)	200 (54.8)	235 (66.0)	228 (63.7)	**0.01**
Red inflamed tongue	261 (18.3)	138 (17.5)	123 (19.3)	0.37	167 (18.4)	94 (18.1)	0.90	24 (6.9)	62 (17.0)	80 (22.5)	95 (26.5)	**0.01**
Subdermal haemorrhage	66 (4.6)	39 (4.9)	27 (4.2)	0.53	36 (4.0)	30 (5.8)	0.12	8 (2.3)	16 (4.4)	19 (5.3)	23 (6.4)	**0.06**
Goitre	9 (0.63)	7 (0.9)	2 (0.3)	0.18	7 (0.8)	2 (0.4)	0.38	1 (0.3)	3 (0.8)	1 (0.3)	4 (1.1)	0.41
Overall nutritional deficiency (n=1427)	1113 (78.0)	58 (72.5)	1055 (78.3)	0.22	697 (76.8)	416 (80.2)	0.14	216 (62.1)	269 (73.7)	306 (86.0)	322 (89.9)	**0.01**

[a] *z score of < -3*

[b] *z score of < -2 and ≥ -3*

[c] *z score ≥ -2*

p-values are calculated by χ2 test

Table 8 Association of undernutrition* with various factors in univariate and multivariate logistic regression analysis

Undernutrition [N (cases)=760]		Univariate logistic regression[a]			Multivariate logistic regression[b]		
		OR	95% CI	*p-value*	aOR	95% CI	*p-value*
Age of the participating child	< 5 years	1.00			1.00		
	> 5 years	0.98	0.78-1.23	0.83	1.01	0.72-1.42	0.95
Sex of the participating child	Male	1.00			1.00		
	Female	1.01	0.81-1.27	0.89	0.95	0.68-1.33	0.77
Number of children in the household	< 5	1.00					
	> 5	1.05	0.32-3.42	0.93			
Socioeconomic status	Poor	1.00			1.00		
	Middle	0.73	0.54-0.99	**0.04**	0.70	0.43-1.11	0.13
	Better	0.57	0.41-0.80	**0.00**	0.43	0.25-0.75	**0.01**
Caregivers' literacy	Can neither read or write	0.75	0.30-1.88	0.55			
	Can read only	1.10	0.80-1.52	0.56			
	Can both read and write	1.00					
Occupation of the household head	Agriculture	1.22	0.96-1.53	**0.10**	1.05	0.71-1.53	0.82
	Business	0.90	0.62-1.29	0.55			
	Daily laborer	1.11	0.88-1.40	0.37			
	Government service	0.50	0.28-0.92	**0.03**	0.54	0.21-1.38	0.20
	Other independent work	0.46	0.46-13.08	0.29			
	None	0.38	0.11-1.32	**0.13**	0.49	0.12-2.04	0.33
Household involved in management of the water system	"yes" *vs.* "no"	0.84	0.51-1.40	0.51			
Handwashing with soap	<5 times	1.00					
	5-10 times	0.93	0.72-1.20	0.57			
	>10 times	1.04	0.21-5.29	0.96			
Animals inside home overnight	"no" *vs.* "yes"	0.94	0.74-1.20	0.64			
Information received on WASH	"yes" *vs.* "no"	0.91	0.71-1.18	0.49			
Heard about intestinal parasites	"yes" *vs.* "no"	0.77	0.59-1.01	**0.06**	1.39	0.76-2.55	0.29
Awareness on measures against intestinal parasites	Wash hands with soap	0.92	0.64-1.31	0.65			
	Drink clean water	0.84	0.63-1.13	0.26			
	Regular deworming	0.65	0.46-0.92	**0.02**	0.44	0.20-0.94	**0.03**
Complementary feeding of the participating child started <6months	"yes" *vs.* "no"	0.64	0.33-1.23	**0.18**	1.95	0.60-6.36	0.27
Received additional meal (snacks)	"yes" *vs.* "no"	0.65	0.51-0.83	**0.00**	0.57	0.38-0.84	**0.01**
DDS[c]	1	1.00			1.00		
	2	1.09	0.67-1.77	0.73	1.01	0.47-2.15	0.98
	3	1.41	0.89-2.25	**0.14**	0.85	0.41-1.74	0.66
	4	1.13	0.71-1.83	0.60	0.90	0.44-1.84	0.77
	5	1.35	0.84-2.18	0.22	0.84	0.40-1.75	0.63
	6	1.02	0.64-1.64	0.93	0.50	0.24-1.04	0.06
	7	1.85	1.13-3.03	**0.02**	1.69	0.77-3.73	0.19
	8	1.26	0.78-2.05	0.34	0.84	0.40-1.77	0.65
	9	1.61	0.99-2.61	**0.05**	1.76	0.80-3.90	0.16
Production of own food	"yes" *vs.* "no"	0.86	0.68-1.07	**0.18**	0.67	0.46-0.97	**0.03**
Giardia lamblia	"yes" *vs.* "no"	0.91	0.64-1.28	0.57			
Presence of intestinal helminths	"yes" *vs.* "no"	1.27	0.94-1.70	**0.12**	1.36	0.93-1.98	0.11
Ascaris lumbricoides	"yes" *vs.* "no"	1.15	0.82-1.62	0.41			
Trichuris trichiura	"yes" *vs.* "no"	1.68	0.31-9.19	0.55			
Hymenolepsis nana	"yes" *vs.* "no"	1.48	0.75-2.93	0.26			
Enterobius vermicularis	"yes" *vs.* "no"	2.19	0.85-5.62	**0.10**	2.01	0.70-5.79	0.19
Latrine hygiene	Lower category	1.00					
	Middle category	1.11	0.85-1.45	0.44			
	Better category	1.12	0.85-1.47	0.44			
Kitchen hygiene	Lower category	1.27	0.98-1.65	**0.08**	1.26	0.82-1.94	0.29
	Middle category	1.15	0.84-1.58	0.39	0.86	0.48-1.53	0.61
	Better category	1.00			1.00		
Personal hygiene of participating child and their caregivers	Lower category	1.32	1.01-1.73	**0.04**	1.43	0.92-2.22	0.11
	Middle category	1.04	0.79-1.37	0.77	0.83	0.51-1.35	0.46
	Better category	1.00			1.00		
E. coli at POU[d] drinking water	"yes" *vs.* "no"	1.48	0.84-2.59	**0.17**	0.87	0.34-2.24	0.77
E. coli at POC[e] drinking water	"yes" *vs.* "no"	1.63	0.96-2.76	**0.07**	1.27	0.59-2.71	0.25

Total coliforms at POC drinking water	"yes" *vs.* "no"	5.31	1.01-27.9	**0.05**	3.81	0.32-45.49	0.29
Total coliforms at POU drinking water	"yes" *vs.* "no"	2.32	0.72-7.48	**0.16**	1.47	0.18-12.04	0.72
Presence of diarrhea	"yes" *vs.* "no"	1.08	0.81-1.46	0.59			
Presence of nutritional deficiencies	"yes" *vs.* "no"	1.06	0.84-1.35	0.63			

[a] *Odds ratios (OR) and p-values are based on the likelihood ratio test, p-values <0.2 in the univariate logistic regression model are marked bold.*

[b] *Adjusted odds ratios (aOR) and p-vaules are based on likelihood ratio test of the mixed multivariable regression model. The model with random area intercepts included the categorical exposure variables age and sex of the participated child, socioeconomic domains and surveyed area. All the risk values that had p-values lower than 0.2 in the univariate analyses were included into the mixed multivariable regression analysis, p-.values <0.05 in the multivariate logistic regression model are marked bold*

[c] Dietary diversity score

[d] Point of use

[e] Point of collection

** Undernutrition included the presence or absence of stunting, BMIZ(thinness) or underweight.*

Table 9 Association between nutritional deficiencies* and various factors in univariate and multivariate logistic regression

Nutritional deficiencies [N(cases)=912]		Univariate logistic regression[a]			Multivariate logistic regression[b]		
		OR	95% CI	*p-value*	aOR	95% CI	*p-value*
Age of the participating child	< 5 years	1.00			1.00		
	> 5 years	1.59	1.25-2.02	**0.01**	1.84	1.30-2.62	**0.01**
Sex of the participating child					1.00		
	Male	1.00					
	Female	0.98	0.78-1.23	0.84	1.04	0.76-1.42	0.80
Number of children in the household	< 5	1.00			1.00		
	> 5	2.81	0.60-13.27	**0.19**	3.05	0.32-29.12	0.33
Socioeconomic status[c]	Poor	1.14	0.83-1.58	0.42	1.10	0.70-1.72	0.68
	Middle	1.20	0.84-1.71	0.30	1.37	0.81-2.32	0.23
	Better	1.00			1.00		
Occupation of the household head							
	Agriculture	0.96	0.76-1.21	0.73			
	Business	0.75	0.52-1.09	**0.13**	0.84	0.49-1.45	0.54
	Daily labourer	0.65	0.51-0.83	**0.01**	0.75	0.52-1.06	0.10
	Government service	1.04	0.59-1.83	0.88			
	Other independent work	0.25	0.04-1.36	**0.11**	0.51	0.07-3.67	0.50
	None	4.93	0.62-39.22	**0.13**	2.70	0.22-32.85	0.44
Handwashing with soap	<5 times	1.00			1.00		
	5-10 times	0.66	0.51-0.85	**0.01**	1.08	0.65-1.80	0.76
	>10 times	0.65	0.12-3.44	0.61	3.39	0.36-31.77	0.28
Times of handwashing	When they look dirty	0.56	0.44-0.71	**0.01**	0.74	0.50-1.08	0.12
	After going to toilet	0.39	0.14-1.09	**0.07**	0.13	0.01-1.10	0.06
	After cleaning baby’s bottom	0.40	0.32-0.52	**0.01**	0.60	0.40-0.92	**0.02**
	Before eating	1.02	0.78-1.33	**0.15**	0.75	0.49-1.15	0.19
	Before cooking	1.44	1.14-1.82	**0.01**	1.07	0.67-1.68	0.78
Animals inside home overnight	"yes" *vs.* "no"	1.67	1.32-2.13	**0.01**	1.71	1.17-2.51	**0.01**
Information received on WASH[d]	"yes" *vs.* "no"	0.65	0.45-0.95	**0.02**	1.03	0.56-1.89	0.93
Family members attended hygiene literacy class from health workers	"yes" *vs.* "no"	0.97	0.75-1.26	0.82			
Child suffered from any illnesses:							
Fever	"yes" *vs.* "no"	0.98	0.78-1.24	0.89			
Cough	"yes" *vs.* "no"	1.09	0.86-1.37	0.47			
Respiratory difficulties	"yes" *vs.* "no"	1.97	1.40-2.78	**0.01**	1.32	0.79-2.18	0.29
Diarrhea[e]	"yes" *vs.* "no"	1.05	0.77-1.44	0.75			
Blood in stool	"yes" *vs.* "no"	2.87	1.25-6.60	**0.01**	1.72	0.50-5.90	0.39
Mucus in stool	"yes" *vs.* "no"	3.10	1.42-6.75	**0.01**	2.07	0.67-6.38	0.20
Blood in urine	"yes" *vs.* "no"	1.99	0.39-9.98	0.40			
Heard about intestinal parasites[f]	"yes" *vs.* "no"	0.53	0.40-0.70	**0.01**	1.12	0.46-2.69	0.80
Awareness on measures against intestinal parasites							
	Washing hands with soap	0.39	0.27-0.57	**0.01**	0.56	0.26-1.24	0.15
	Cutting finger nails	0.22	0.13-0.37	**0.01**	0.83	0.32-2.15	0.71
	Wash fruits/vegetables before consumption	0.13	0.05-0.33	**0.01**	0.64	0.17-2.45	0.52
	Wear shoe	0.13	0.07-0.23	**0.01**	0.24	0.09-0.62	**0.01**
	Drink clean water	0.61	0.45-0.82	**0.01**	1.63	0.67-3.95	0.28
	Deworming regularly	0.85	0.60-1.21	0.38			
Child ever breastfed	"yes" *vs.* "no"	0.80	0.12-5.17	0.82			
Total months child breastfed	<6 months	2.82	1.07-7.42	**0.04**	3.99	0.86-18.50	0.08
	6-12 months	1.64	0.62-4.33	0.31	1.90	0.41-8.84	0.41
	>12 months	1.00			1.00		
Complementary feeding of the participating child started <6months	"yes" *vs.* "no"	0.57	0.30-1.09	**0.09**	0.52	0.17-1.62	0.26
Material of the home’s floor	"earth" vs. "cement"	1.01	0.74-1.37	0.95			
Dietary diversity scores		1.00			1.00		

	1						
	2	1.07	0.66-1.74	0.77	0.75	0.36-1.54	0.44
	3	1.15	0.72-1.85	0.55	0.70	0.34-1.46	0.34
	4	2.06	1.23-3.44	**0.01**	1.12	0.52-2.44	0.76
	5	1.86	1.09-3.12	**0.02**	1.67	0.77-3.61	0.19
	6	1.28	0.78-2.10	0.32	0.89	0.43-1.84	0.75
	7	1.30	0.79-2.16	0.30	0.93	0.44-1.96	0.86
	8	0.83	0.51-1.37	0.48	0.84	0.41-1.74	0.65
	9	0.27	0.17-0.45	**0.01**	0.51	0.25-1.05	0.07
Production of own food	"yes" *vs.* "no"	0.52	0.41-0.67	**0.01**	0.51	0.35-0.76	**0.01**
Latrine hygiene							
	Lower category	1.00			1.00		
	Middle category	1.38	1.02-1.86	**0.04**	1.43	0.93-2.20	0.10
	Better category	0.68	0.52-0.90	**0.01**	0.61	0.41-0.91	**0.01**
Kitchen hygiene							
	Lower category	1.00			1.00		
	Middle category	1.33	1.01-1.74	**0.04**	0.89	0.58-1.34	0.57
	Better category	0.47	0.34-0.65	**0.01**	0.40	0.22-0.75	**0.01**
Personal hygiene of participating child and their caregivers	Lower category	2.24	1.68-3.00	**0.01**	1.90	1.17-3.10	**0.01**
	Middle category	1.93	1.46-2.55	**0.01**	1.84	1.22-2.76	**0.01**
	Better category	1.00			1.00		
Hygiene status of water transport container							
	Lower category	1.00			1.00		
	Middle category	0.97	0.68-1.38	**0.03**	0.60	0.23-1.58	0.30
	Better category	0.55	0.42-0.72	**0.01**	0.91	0.31-2.66	0.87
Hygiene status of water storage container							
	Lower category	1.00			1.00		
	Middle category	1.10	0.77-1.59	0.59	1.84	0.69-4.87	0.22
	Better category	0.54	0.42-0.72	**0.01**	0.77	0.26-2.25	0.64
Presence of intestinal parasites	"yes" *vs.* "no"	0.88	0.66-1.17	0.37			
Presence of undernutrition	"yes" *vs.* "no"	1.07	0.84-1.35	0.59			
E. coli in POC[m] drinking water	"yes" *vs.* "no"	0.93	0.55-1.57	0.79			
Coliforms in POC[n] drinking water	"yes" *vs.* "no"	6.53	1.24-34.29	**0.03**	10.44	1.61-67.4	**0.01**
E. coli in POU drinking water	"yes" *vs.* "no"	1.08	0.63-1.85	0.78			
Coliforms in POU drinking water	"yes" *vs.* "no"	2.33	0.79-6.88	**0.13**	1.78	0.33-9.46	0.50

[a] *P-values and odds ratios are based on likelihood ratio test. P-value <0.2 in the univariate logistic regression model are marked in bold.*

[b] *P-values and adjusted odds ratios (aOR) are based on the likelihood ratio test of the multivariate logistic regression model. The mixed multivariate logistic regression model with random area intercepts included the categorical exposure variables sex, age-group, socio-economic conditions and project area. The risk factors having a p-values <0.2 in the univarable analyses were included into the multivariate regression analysis. P-values <0.05 in the multivariate logistic regression model are marked bold.*

[c] *Socio-economic status was derived from a factor analysis using principal component analysis of variables indicating the wealth index*

[d] *Water sanitation and hygiene*

[e] *Passage of loose stool three or more than three times per day*

[f] *Overall soil transmitted helminths and intestinal protozoa*

* *Nutritional deficiency: presence of wasted appearance, bitot's spot, loss of hair pigment, dry and infected cornea, oedema, pale conjunctiva, bowed legs, spongy bleeding gums, dermatitis, red inflamed tongue, subdermal haemorrhage and goitre*

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTableCfinal.docx
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- SupplementaryTableAfinal.docx
- SupplementaryTable1.docx

- SupplementaryTableBfinal.docx