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"If there is no water, we cannot feed our children": The far-reaching consequences of water insecurity on infant feeding practices and infant health across 16 low-and middle-income countries

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Abstract

Objectives.—Infant feeding plays a critical role in child health and development. Few studies to date have examined the link between household water insecurity and infant feeding, and none in a cross-cultural context. Therefore, we examined the perceived impact of household water insecurity in four domains: (1) breastfeeding, (2) non-breastmilk-feeding, (3) caregiver capabilities, and (4) infant health. Our research was conducted as part of the Household Water Insecurity Experiences (HWISE) study.

Methods.—We interviewed respondents from 19 sites in 16 low-and middle-income countries (N=3,303) about the link between water insecurity and infant feeding. We then thematically analyzed their open-ended textual responses. In each of the four domains (breastfeeding, non-breastmilk-feeding, caregiver capabilities, infant health), we inductively identified cross-cultural metathemes. We analyze the distribution of themes across sites quantitatively and qualitatively.

Results.—Water was perceived to directly affect breastfeeding and non-breastmilk feeding via a number of pathways, including timing and frequency of feeding, unclean foods, and reduced dietary diversity. Water was perceived to indirectly affect infant feeding through caregiver capabilities by increasing time demands, exacerbating health, and requiring greater efficacy of caregivers. Respondents made connections between water challenges and infant health, e.g. increased risk of infectious diseases, undernutrition, and mortality.

Author Contributions

RCS and SLY conceptualized this study; RCS and MSB created the codebook and conducted the coding; RCS conducted the analysis with guidance from AW and support from JDM; RCS drafted the manuscript with SLY and MSB, with input from JDM. SLY, AW and HWISE Consortium author WJ conceptualized the HWISE Study through which this data was collected. HWISE Consortium authors led and managed data collection in their sites or otherwise supported data management (SMC). All authors reviewed and approved final manuscript.

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Conclusions.—These findings suggest that water presents many, and sometimes unexpected, challenges to infant feeding. By systematically investigating biocultural pathways by which water impacts infant and young child feeding, it will be possible to understand if, and how, water security can be leveraged to improve child nutrition and health.

Keywords

water insecurity; infant and young child feeding; caregiver capabilities; infant health; cross-cultural research

INTRODUCTION

Undernutrition is a global scourge, responsible for 45–56% of child deaths both directly and through the exacerbation of numerous diseases (Black et al., 2013; Pelletier, Frongillo, Schroeder, & Habicht, 1995). While significant progress has been made in reducing undernutrition in the past four decades – inclusive of stunting, wasting, micronutrient deficiencies, and fetal growth restriction – rates of undernutrition remain unacceptably high (Development Initiatives, 2018). As such, identifying new pathways by which infant nutrition can be improved, including methods for improving the quality and implementation of existing approaches, is necessary to bridge this gap. The field of human biology has a long history of examining key risk factors and consequences of undernutrition, particularly in small-scale populations and in low and middle income countries; however, to date the role of water insecurity in infant nutrition has scarcely been explored (Jehn & Brewis, 2009; Tanner, 2014).

Infant feeding sets the trajectory for early childhood growth, cognitive development, and adult health outcomes (Bhutta, 2013; Black et al., 2008; Mendez & Adair, 1999; Victora et al., 2016). The globally accepted infant and young child feeding guidelines recommend that neonates be breastfed immediately after birth and exclusively fed with breastmilk until six months of age (World Health Organization, 2003). Thereafter, breastmilk alone can no longer meet the growing infant's caloric and micronutrient needs, such that timely feeding of safe and adequately diversified complementary foods is recommended, in conjunction with continued breastfeeding, until at least two years of age (Rollins et al., 2016; World Health Organization, 2003). Complementary feeding among infants aged 6–11 months has been identified as the most important "window of opportunity" for nutrition policy and programs for infant and young child feeding (Na, Aguayo, Arimond, & Stewart, 2017). As such, understanding the barriers to and promoters of optimal infant feeding are critical for improving health and well-being.

Numerous determinants of infant and young child feeding have been explored, including but not limited to maternal empowerment (Santoso et al., 2019), maternal HIV status (Tuthill et al., 2014), household food security (Miller, Young, Boateng, Oiye, & Owino, 2019; Webb-Girard et al., 2012), household agricultural production (Kumar, Harris, & Rawat, 2015), and household market integration (Hirvonen & Hoddinott, 2017). The role of water in optimal feeding of breastmilk and non-breastmilk foods, however, has received minimal attention. To date, studies examining the relationship between water and infant feeding have primarily

focused on the quality of water and its use for hygiene in feeding non-breastmilk foods. For instance, the use of unsafe water for formula preparation or hygiene practices (e.g., poorly washed bottles) increases pathogen exposure and the risk of infectious disease, e.g. cholera and diarrheal-related mortality (Andresen, Rollins, Sturm, Conana, & Greiner, 2007; Fawzy et al., 2011; Ehiri et al., 2001; Peletz et al., 2011). Such water-related infections, in turn, jeopardize the absorption of nutrients (Dewey & Mayers, 2011; Harper, Mutasa, Prendergast, Humphrey, & Manges, 2018; Mbuya & Humphrey, 2016). Few studies, though, have considered how other dimensions of water – e.g., affordability, availability, accessibility, or stress related to water problems-may impact infant feeding.

We therefore posit that a broader conceptualization of water, i.e. household water insecurity, is necessary to understand its potential role as a driver of infant and young child feeding. Household water insecurity occurs when affordability, reliability, adequacy, and/or safety is significantly reduced as to threaten or jeopardize well-being, inclusive of physical and mental health and the capacity to undertake necessary and productive, social, and cultural activities (Jepson et al., 2017). Previous qualitative work among pregnant and postpartum women has found that water insecurity is deleterious to maternal and infant health through physical, psychosocial, nutritional, and economic pathways (Collins et al., 2019). It is highly plausible that water insecurity negatively impacts infant feeding through similar pathways.

Water insecurity has been shown to be both syndemic with food insecurity (Workman & Ureksoy, 2017) and a likely driver of it (Brewis, Workman, Wutich, Jepson, & Young, 2020). It has been shown to be associated with increased emotional, mental, and physical stress for women and caregivers (Aihara, Shrestha, & Sharma, 2016; Brewis, Choudhary, & Wutich, 2019; Collins et al., 2019; Stevenson, Ambelu, Caruso, Tesfaye, & Freeman, 2016; Workman & Ureksoy, 2017; Wutich & Ragsdale, 2008). Indeed, caregiver capabilities – the skills and attributes of a caregiver that determine their ability to care for a young child in ways that produce positive nutrition, health, and development outcomes – are critical for optimal infant feeding (Matare, Mbuya, Pelto, Dickin, & Stoltzfus, 2015). These capabilities or resources for caregiving include caregivers' education, beliefs and knowledge, self-efficacy, social support, autonomy to manage household resources, physical and mental health, and social support (Engle, Menon, & Haddad, 1999). As such, household water insecurity may indirectly affect infant feeding by exacerbating challenges to caregiver capabilities, including household food insecurity.

A nascent body of evidence has demonstrated that there are also many other ways by which household water insecurity may directly impact infant feeding, beyond sanitation and hygiene pathways, e.g., the transmission of waterborne diseases. In studies in rural, low-land districts of Lesotho and urban, semi-arid Bolivia, participants have reported that insufficient water limited their ability to cook for the household (Workman & Ureksoy, 2017; Wutich, 2009), which would undoubtedly affect resident children. Ethnographic work among women of mixed HIV status in Kenya expanded upon this; household water insecurity was qualitatively found to negatively affect the quality, quantity, and diversity of the foods that women fed their children (Collins et al., 2019). Furthermore, a recent analysis of nationally representative data from India found that suboptimal household water access was associated with failure to meet minimum dietary diversity among children aged 6–23 months

(Choudhary, Schuster, Brewis & Wutich, 2020). These studies suggest that water security may be an important determinant of optimal infant feeding, although the universe of potential impacts has not been adequately described.

To fill this knowledge gap and advance our understanding of the role of household water insecurity in infant feeding globally, we therefore conducted an exploratory study across 19 sites in 16 low-and middle-income countries. Our first objective was to identify the ways in which water insecurity was perceived to impact infant feeding in four *a priori* domains: (1) breastfeeding, (2) non-breastmilk feeding, (3) caregiver capabilities, and (4) infant health-a consequence of infant feeding-across sites. In each of these four domains, we inductively identified cross-cultural metathemes that describe key impacts and dynamics. Our second objective was to use these findings to develop a research agenda to guide subsequent biocultural studies on the impacts of household water insecurity on infant feeding.

METHODS

Study Context and Data Sources: The Household Water Insecurity Experiences (HWISE) Study

Data were drawn from the Household Water Insecurity Experiences (HWISE) study, an initiative to create the first cross-culturally equivalent tool to measure household water insecurity (Young, Boateng, et al., 2019). For the parent study, data were collected in 28 sites across 23 low-and middle-income countries between March 2017 and July 2018; sites were selected to maximize variation in region, geography, culture, infrastructure, seasonality, and problems with water (detailed in Young, Collins, et al., 2019). Although sampling strategy and sample size varied, 250 participants were targeted per site. The majority of sites used cluster-stratified random sampling, although some used purposive sampling (see Young, Collins, et al., 2019), as HWISE study modules were sometimes incorporated into other ongoing, site-specific research studies. Data collection was typically led by social scientists (e.g., anthropologists, geographers), most of whom had a long history of research at their respective site(s).

Within each household, one adult aged 16 years or older who self-identified as being knowledgeable about water in their household was invited to participate. Surveys were conducted through face-to-face interviews, with enumerators using either paper surveys or tablet-based questionnaires. Surveys were developed to be culturally and linguistically equivalent, and were translated and back-translated for each site. Following best practices, an implementation manual was developed and deployed at all sites to support standardized data collection and implementation fidelity, including standard probes.

Respondents were asked about sociodemographic characteristics, experiences with water insecurity, food insecurity, and perceived stress (Young, Collins, et al., 2019). Data for the present analysis come from responses to the open-ended question: "*Can you tell me some ways that the water situation here affects how infants (under 12 months of age) are fed*"? This question was asked in 22 of the 28 sites in the parent study. In 19 of those 22 sites, data were recorded in an open-ended manner, yielding unstructured textual responses. Given that our objective was to identify the many ways by which individuals perceive water to impact

infant feeding, we restricted our analytic sample to open-ended responses from these 19 sites across 16 low-and middle-income countries (Figure 1). Of the 5,395 households surveyed across these 19 sites, 2,092 were dropped for providing either no response (n=1,245) or uninterpretable responses of “I don’t know” or “not applicable” (n=847), such that the final dataset included a total of 3,303 respondents (Table 1).

The majority of responses were translated into English by the teams at each site. Data from sites in Guatemala, Bolivia, Colombia, and Mexico were translated from Spanish into English by the Northwestern University team.

Data analysis

We used a mixed-methods approach that combined *a priori* domains with inductive, cross-cultural metatheme identification and description (Bernard, Wutich, & Ryan, 2016; Hagaman & Wutich, 2017; Krippendorff, 2013; Wutich & Brewis, 2019). To begin, the first author identified four *a priori* domains related to major infant feeding constructs in the literature –breastfeeding, non-breastmilk feeding, and caregiver capabilities – as well as the domain of infant health, a consequence of infant feeding (Figure 2). The first two authors then created codes to describe these domains, drawing on previous literature, the study team’s site-specific knowledge and prior experiences, and preliminary analysis of the data. For each domain code, we established a definition, criteria for inclusion and exclusion, and typical, atypical, and “close-but-no” examples (MacQueen, McLellan, Kay, & Milstein, 1998). The codebook was first drafted in September 2017 and continued to be updated throughout the coding process.

After preliminary analysis of the first nine sites, the first two authors refined these codes. Any time a significant change was introduced, observations (each respondent’s text was the coding unit) were reviewed and reevaluated for application of that code. All excerpts were coded by the first two authors to ensure consistency and triple checked by a third coder; discrepancies were resolved through discussion by the coding team and finalized by the first author.

Responses were coded as data were collected and released (Table 1), though the coding system remained unchanged across data collection waves. Data were coded in Wave 1 using the software Dedoose v8.2 (SocioCultural Research Consultants, LLC; Los Angeles, CA) and in Wave 2 using the software Atlas.ti (Scientific Software Development GmbH, Berlin, Germany). A matrix of excerpts and attached codes was exported from each qualitative analysis software and merged using Stata v14 (StataCorp, College Station, TX).

Once all data were coded for the four research domains, we then analyzed the coded data for cross-cultural *metathemes* (Hagaman & Wutich, 2017) in each of the four domains. Metathemes can be defined as shared meaning that occurs across contexts and expressions. We analyze and describe these metathemes in order of decreasing frequency and universality, or predominance across sites (see Baxter & Eyles, 1997; Boatang & Adams, 2016). Based on our findings, we present a theoretical model of how water insecurity affects infant feeding, with the items derived directly from the metathemes that come from the cross-cultural analysis.

Using a mixed-methods approach common in content analysis and metathematic analysis (Bernard, Wutich, & Ryan, 2016; Hagaman & Wutich, 2017; Krippendorff, 2013; Wutich & Brewis, 2019), our analysis uses descriptive statistics and *t*-tests to compare respondents' views of whether water insecurity affected infant feeding. Specifically, we compared respondents based on: respondent gender and age, number of children and adults in the household, household water insecurity (Young, Boateng, et al., 2019) and household food insecurity (Coates, Swindale, & Bilinsky, 2007). Because one of the items in the final HWISE scale was added after completion of data collection in some sites, a composite household water insecurity score (range 0–33) was created by summing responses to the 11 HWISE Scale items asked across all sites, a measure that is highly predictive of scores to the 12-item HWISE scale at $p<0.001$.

Operationalization of domains

Our domains include three pertaining to infant feeding – breastfeeding, non-breastmilk feeding, and caregiver capabilities – as well as the domain of infant health, a consequence of infant feeding. We define *breastfeeding* as milk produced by the breast and, in these sites, fed at the breast (Labbok & Krasovec, 1990), as there was no discussion if breastmilk was fed via alternative routes. *Non-breastmilk feeding* includes all foods that are given to infants in addition to or as replacement for breastmilk, including formula and drinking water.

We use the *caregiver capabilities* framework set forth by Matare et al. (2015), which draws heavily from Engle, Menon, & Haddad (1999), to describe "the practices that translate food security and healthcare resources into a child's well-being." Since our study was not explicitly designed to capture the depth and nuances of caregiver capabilities, here we describe how we operationalized some of Matare et al.'s (2015) caregiver capability constructs in our data:

- Education, knowledge and beliefs as *hygiene knowledge, beliefs, and behaviors;* i.e. the knowledge, beliefs, and behaviors pertaining to best practices for hygiene as related to infant feeding. We recognize that knowledge and beliefs are the capabilities that shape behavior and should be reported as distinct constructs. However, the nature of our data precluded the parsing of knowledge and beliefs from behaviors, and so we group them together.
- Workload and time availability as *time*; i.e. how time is spent, reflective of demands on caregivers' time. This may overlap with timing of feeding breastmilk or non-breastmilk foods; it is distinct from allocation of household resources as it is a personal resource of the caregiver.
- Control of resources and intra-household allocation as *allocation of household resources*; i.e., captures the choices and tradeoffs caregivers make in household resources, and is exclusive of caregiver's time.
- Self-efficacy as *perceptions of caregiver efficacy*; i.e. how others perceive the effectiveness of caregivers in addressing and mitigating water problems so they do not affect infant feeding. Our data did not include empirical measures of self-efficacy.

Finally, *infant health* encompassed the state of infant wellbeing, inclusive of dehydration, hunger, undernutrition, morbidity, and mortality.

Ethical approvals

Study activities received necessary ethical approvals from institutional review bodies relevant to each site (Young, Collins, et al., 2019). Verbal or written informed consent was obtained from respondents in their preferred language by a trained enumerator.

RESULTS

Nearly three-quarters (78%) of the 3,303 individuals who provided a response were female and were, on average, 37.8 ± 13.5 years of age. Sampled households had 3.2 ±1.9 adults and 2.5 ± 1.9 children (Table 1). Of the 3,303 individuals who provided a response, 2,980 (90.2%) indicated that the water situation impacted infant feeding in some way (Table 2). Of the 9.8% reporting no effect on infant feeding, typical responses included the "water situation does not affect how infants are fed" (Woman, 20 years-old, Lilongwe, Malawi). Respondents who reported that water insecurity affected infant feeding tended to be from households with more children and more adults, and that experienced greater household food and water insecurity (Table 2). The proportion of households in each site who indicated there was an effect ranged from 100% in four sites to 69% in Accra, Ghana. There was no statistical difference by gender or age of respondents in terms of perceiving an effect among those who provided a response.

Among the 2,980 responses identifying an impact, metathemes were most frequently discussed in the non-breastmilk feeding domain, followed by metathemes in the infant health, caregiver capabilities, and breastfeeding domains. As the prompt "the water situation here" was intended to elicit the respondent's lived experiences of water insecurity as conceptualized by Jepson et al. (2017), we describe the results in terms of water insecurity affecting the domains of infant feeding and health.

Non-breastmilk Domain

Metathemes in the domain of feeding of non-breastmilk items were frequently and universally reported across sites, though their site-specific salience ranged greatly (Table 3). The most frequently described metatheme was water insecurity leading to delays in both food preparation and feeding (n=542 of 2,980; 13 of 19 sites). Time spent searching for water, fetching water, waiting in lines, or other facets of obtaining water delayed preparation of complementary foods and restricted their ability to feed infants, e.g., "*delay in feeding or preparing meals as mother goes to search for water*" (Man, 53 years-old, Lilongwe, Malawi).

Water insecurity leading to poor quality and insufficient quantity of drinking water for infants was universal across sites and the second most frequently described metatheme (n=426 of 2,980; 19 of 19 sites). The main concern was infants drinking water contaminated with pathogens, e.g., "*you have to be careful that the drinking water you use to feed infants is first boiled, otherwise there is a risk of typhoid"* (Man, 30 years-old, Kampala, Uganda). Chemical toxins were also of concern. Participants discussed a variety of methods used to

improve water quality for infant consumption, predominantly boiling water but also purchasing purified bottled or sachet water:

> "*When they are small, children need to be very careful about water they drink. There should always be bottled water-purified. Here you must not consume the tap water"* (Man, 78 years-old, Merida, Mexico)

However, water scarcity was perceived to limit purification techniques, e.g., "I *can't boil drinking water when it is scarce*" (Woman, 25 years-old, Kampala, Uganda). This related more generally to a problem with procuring sufficient quantities of clean water, e.g., "*drinking water [is] hard to find*" (Woman, 24 years-old, Lilongwe, Malawi). Limitations on both quality and quantity of drinking water exacerbated each other to create a situation where an "*infant only drinks when good water is available…[s/he is] dehydrated*" (Man, 56 years-old, Accra, Ghana).

Water insecurity was understood to affect the quality of complementary foods across sites as manifested in two metathemes: unclean foods and preparing alternative foods. The water situation leading to unclean foods was driven by "*dirty water [used] for food preparation*" (Woman, 42 years-old, Accra, Ghana) (n=260 of 2,980; 17 of 19 sites), typically referring to water known to contain pathogens or visible silt. Sometimes foods remained unwashed and unclean due to water unavailability. More infrequently, participants reported preparing food with water that was salty, tasted unpleasant due to chemical treatment, or had leached rust from storage containers. Respondents expressed concern about transferring these undesirable properties to an infant's food. Additionally, respondents mentioned that poor food-related hygiene practices could contaminate foods, e.g. by using utensils and bottles that were either unwashed or washed with unclean water. For instance, one respondent noted *"lack of water for boiling dishes that will cause the baby to eat in a container [that] has not been washed or has not been properly cleaned"* (Woman, 22 years-old, Morogoro, Tanzania)

The second most common metatheme related to quality of non-breastmilk foods was substituting sub-optimal foods; it was similarly salient across sites (n=238 of 2,980; 15 of 19 sites). This involved replacing ideal foods with less preferred ones, characterized by statements such as *"if we don't have enough boiled water available [for preparing soft foods] then we have to feed children an alternative food"* (Woman, 40 years-old, Kampala, Uganda). In many cases, neither the specific foods (preferred or replacement) nor their nutritional quality were described. Respondents provided general statements such as the "*mother has to choose simple meals*" (Man, 43 years-old, Lagos, Nigeria). Sometimes participants reported feeding infants solid foods when lack of water prevented preparing foods of liquid consistency.

When the specific foods or their nutritional quality were described, the alternative foods that were introduced led to *decreased* variety and dietary diversity. Notably in Bahir Dar, Ethiopia, respondents provided detailed descriptions of food substitutions that represent lower dietary diversity, e.g., "*feed bread with tea when there is no water to make sauce*" (Woman, 22 years-old); main ingredients for 'sauce' in this site may include legume, tubers, vegetables, or animal protein. Participants across sites reported that their water situation also affected feeding of the local staple – e.g., porridge in Tanzania and Malawi, pap in Nigeria,

injera and sauce in Ethiopia – though the exact ingredients in the mixtures were often unspecified. In some contexts, water insecurity meant less preferred foods were substituted for the local staple, e.g., that infants were *"fed something different instead of normal meals like porridge*" (Woman, 24 years-old, Lilongwe, Malawi). In some cases, feeding infants "only" their staple food was perceived as problematic, as was the case in Chiquimula, Guatemala, where feeding infants solely tortillas and beans – without additional vegetables – was considered sub-optimal. Water insecurity prohibiting the growth of vegetables to supplement staple foods was mentioned a handful of times:

> *"Because I am poor, I want to be able to grow vegetables to feed my child because they are healthy. But because of our water situation I cannot grow vegetables around my home, we need better access to water."* (Woman, 39 years-old, Kampala, Uganda)

There were four mentions of water problems preventing preparation of a processed, micronutrient-fortified grain-based infant food (e.g., Cerelac in Ghana, *litto* in Nepal). Interestingly, a few participants mentioned substitutions that may have had preferred, similar, or higher nutritional content, e.g., "*feed egg when there is no water to prepare porridge*" (Woman, 35 years-old, Bahir Dar, Ethiopia)

Finally, water insecurity was described as causing less food to be prepared and fed per meal, and sometimes for meals to be skipped entirely (n=131 of 2,980; 14 of 19 sites). This metatheme was characterized by general statements such as: *"If there is no water, we cannot feed our children"* (33 years-old, Lagos, Nigeria). Specifically, respondents reported that households cooked less foods per meal, to the extent that there was "not enough" for a child to reach satiety. Skipping meals entirely so that infants were fed "*fewer meals than normal*" was also a phenomenon (Woman, 53 years-old, Lilongwe, Malawi). Others noted *"I reduce the amount of the food that I feed. If I [typically] feed the baby two servings, I would feed the baby once"* (Woman, 20 years-old, Bahir Dar, Ethiopia)

Decreased quantity was closely connected with the tradeoffs that caregivers are forced to navigate (see subsequent caregiver capabilities section). It was typified by statements such as "*the high price of water means I cannot feed infants as often as I would want"* (Woman, 30 years-old, Kampala, Uganda). Participants infrequently reported having to "*buy food instead of cooking when there is no water*" (Woman, 25 years-old, Lagos, Nigeria). There were a few mentions of drought reducing agricultural production which in turn decreased total quantity of available food for infants, in addition to limiting diversity as described above.

Caregiver Capabilities Domain

Metathemes within the caregiver capabilities domain were nearly universal (Table 4). When the person fulfilling the caregiver role was specified, it was almost always a mother (or in Punjab, Pakistan, a grandmother). The integral nature of water to caregiving in general, and motherhood in particular, was not probed on specifically, but emerged consistently, e.g., "*a real mother should always have water at home"* (Woman, 51 years-old, Lagos, Nigeria). Many felt that if a caregiver was capable, their infants would be shielded from the impacts of water insecurity.

Respondents shared how water insecurity presented challenges to caregivers' knowledge, beliefs and behaviors of personal hygiene across nearly all sites (n=368 of 2,980, 18 of 19 sites). Handwashing was a common concern for caregivers, e.g., "*sometimes when water is scarce, the mother does not wash her hands before feeding the infant, hence causing diseases*" (Woman, 27 years-old, Kampala, Uganda), as well as for infants, e.g., "*lack of water for washing the infant before eating which leads to the infant eating when not clean"* (Woman, 55 years-old, Morogoro, Tanzania). Storage contaminating water as a challenge to optimal hygiene practices was also mentioned a few times across sites.

The demands on caregiver time was the second most frequent metatheme in this domain (n=262 of 2,980; 13 of 19 sites). Time obtaining water impinged upon infant feeding and more generally caring for children, e.g., "*time for taking care of the baby is affected while mother goes to search for water* (Woman, 17 years-old, Lilongwe, Malawi). As reported above, the time spent waiting throughout the many steps in the procurement, management, and use of water resources was perceived to affect the timing and frequency of feeding: *"many people are unable to feed their infants on time, as they first have to go and fetch the water from far, wait in line, then when they return they have to boil the water"* (Woman, 46 years-old, Kampala, Uganda); we have included this finding here to emphasize how these competing demands on caregiver time are also an indication of workload in the context of capabilities. To minimize this impact, individuals sometimes described engaging others in the household to obtain water, these decisions introduced further tradeoffs:

> *"Because I am often busy, I send my children to fetch water, but because they are not strong enough they can't carry much. So it means that I don't always get water to feed my infants when I want to"* (Woman, 39 years-old, Kampala, Uganda)

Problems with water further complicated caregivers' allocation of household resources (n=170 of 2,980, 15 of 19 sites). Respondents referenced the cost of water, other non-breastmilk foods, and resources related to infant feeding, both implicitly and explicitly, as influencing budgetary and purchasing decisions. For example, participants described making decisions between purchasing water or food, e.g., *"money spent on water reduces budget for the children's meals"* (Man, 45 years-old, Kampala, Uganda) and "*when water is cut off I reverse the money I would have used to cook for the children to paying the bill"* (Woman, 52 years-old, Kampala, Uganda). The extensive boiling required to prepare some foods creates tradeoffs between fuel sources, water, and food. For example, households reported switching from preferred fuel sources like electricity, gas, or charcoal due to budget constraints or electricity outages to less-desirable fuels such as kerosene or sawdust, which are harder to heat water with: *"Because the water always needs boiling, charcoal is expensive so sometimes I have to feed [infants] cheaper foods or less than I would want to*" (Woman, 38 years-old, Kampala, Uganda)

Perceptions of caregiver efficacy as relevant to mitigating water insecurity to preserve optimal infant feeding practices was infrequent but nearly universally endorsed (n=166 of 2,980; 18 of 19 sites). This metatheme was characterized by the implicit assumption that navigating water problems and infant feeding are related to the skill and savvy of the caregiver, explicitly stated as "*it depends on each mother and how responsible they are* (Woman, Acatenango, Guatemala), or *"this depends on the person. If the person takes good*

care of their infant, the water will not affect their infant" (Woman, 37 years-old, Dushanbe, Tajikistan). Statements such as "*I plan my day, water does not affect how I feed my children*" (Woman, 22 years-old, Lagos, Nigeria) signaled that caregivers also subscribe to this position. Infrequently, the dedication and singular focus of caregivers was recognized, e.g., "*moms will not compromise anything for the feeding and health of their children,*" (Woman, 45 years-old, Kathmandu, Nepal). There were several instances of caregivers being judged harshly about their choices when their water responsibilities conflicted with infant feeding and other caregiver responsibilities. For instance, when this resulted in leaving the child alone or unsupervised: *"Water is the most basic need in the house; it leads to poor parenting by leaving the children in the house while struggling for water very early"* (Woman, 34 years-old, Kisumu, Kenya).

Few participants explicitly commented on the accuracy of the knowledge and beliefs of the caregiver. But when they did, they perceived caregiver *"knowledge is poor… it affects the preparation of food*" (Woman, 42 years-old, San Borja, Bolivia), or that *"inexperienced mothers may give unsafe water, prepare food with bad water* (Woman, 51 years-old, Accra, Ghana), or that "*due to the careless attitude of mothers, infants suffer from diseases*" (Woman, 40 years-old, Punjab, Pakistan). Notably, when mothers worked outside the home in the Punjab, Pakistan site, respondents claimed that grandmothers who were the primary infant caregiver sometimes implemented sub-optimal infant feeding practices based on "old myths," such as feeding of tea, biscuits, and (poor quality) water as early as two months.

Caregiver health was the least frequently mentioned, but fairly universal, metatheme within the caregiver capabilities domain (n=109 of 2,980; 16 of 19 sites). Physical health and nutritional status most often manifested as illness through contaminated water, e.g., *"Due to inadequate water parents can contract disease and transmit to their infants"* (Woman, 28 years-old, Accra, Ghana). The next most frequent manifestation was the mother not eating well herself. Caregivers being ill, "*weak,*" or "*lethargic*" was both a challenge to gathering water, e.g., *"we are weak, and energy is required to go and fetch water* (Woman, 34 years-old, Punjab, Pakistan), and a consequence of the effort expended in obtaining water.

Mental health and stress were described half as frequently as physical health and nutritional status, most often in the Punjab, Pakistan and Kampala, Uganda sites. The context of the stress was infrequently unpacked, but notable drivers were the worry of having enough water for infant feeding and care and the fear associated with exposing children to illness through the multiple potential exposures to unclean water described above:

> *"If you collect water from an unprotected spring, it is contaminated with sewage and even human and animal feces. I worry for my children and others in the community. I boil the water for a long time before giving to my children but even so, they get sick"* (Man, 34 years-old, Kampala, Uganda).

Water situations were perceived to cause "mental sickness" and "tensions" within individuals and arguments with others, as "*worrying about water causes fights and stress"* (Man, 57 years-old, Punjab, Pakistan). A few empathetic statements recognized that being a "*mother is [a] very tough job, [it is] always stressful, and the burden has impacts on health*"

(Man, 44 years-old, Punjab, Pakistan) and that mothers never get a break, having to obtain water even when ill and on holidays.

Breastfeeding Domain

Breastfeeding metathemes were the least frequently discussed and least universal, mentioned in only 12 of 19 sites (Table 5). Respondents in Bahir Dar, Ethiopia and Kampala, Uganda discussed the relationship most frequently. Within the breastfeeding domain, the most common but least universal theme was increased breastfeeding to protect against the previously described water-related challenges to non-breastmilk feeding (n=54 of 2,980; 4 of 19 sites). This was driven by increasing episodic breastfeeding in the Bahir Dar, Ethiopia site. For example, water insecurity forced women to substitute breastmilk for other preferred complementary foods: *"When there is water, we feed them porridge and everything, and when there is no water, we feed them just breastmilk"* (Woman, 24 years-old, Bahir Dar, Ethiopia).

The second most frequent and more universal metatheme was water insecurity decreasing frequency of breastfeeding (n=28 of 2,980; 7 of 19 sites). Typically, this occurred due to missing standard feeding times and delays. This was represented by statements such as "*less breastfeeding [occurs] as the mother is busy fetching water*" (Woman, 20 years-old, Lilongwe, Malawi). This is similar to how water insecurity, predominantly obtaining water, was perceived to delay non-breastmilk feeding and closely related to caregiver time demands.

Water impacting breastmilk production (n=20 of 2,980; 6 of 19 sites) was reported to be driven by a lack of water for growing and cooking foods, thereby preventing mothers from eating well, e.g., "*inadequate water makes gardening hard hence less food for the mother implying less breastmilk"* (Man, 50 years-old, Kampala Uganda) and "*it's hard to breastfeed when you're not eating well, especially when you have no water to cook enough food"* (Woman, Kampala, Uganda). Decreased breastmilk production due to limited consumption of water or stress were each mentioned four times, e.g., "*anxiety makes my breastmilk dry as there is no permanent solution of water*" (Woman, 32 years-old, Punjab, Pakistan). Infrequent breastfeeding of infants leading to decreasing milk supply and maternal physical illness were mentioned twice and once, respectively.

Breastmilk as a vector for exposure to pathogens (n=18 of 2,980; 5 of 19 sites) was perceived to be driven by consumption of unsafe water: *"The mothers of infants have to drink good quality water for the health of their infants because the microbes move to the infant's body through the milk of mothers and the infants get different diseases"* (Man, 72 years-old, Dushanbe, Tajikistan). Water issues making it difficult to wash the breast was a specific and infrequently mentioned hygiene-related concern in the breastfeeding domain (n=8 of 2,980; 4 of 19 sites).

Infant Health Domain

Metathemes in the infant health domain were the second most frequently mentioned and were universal across all sites (Table 6). Infant morbidity was the most frequent and universal theme within the infant health domain and was mentioned in every site (n=743 of

2,980; 19 of 19 sites). Morbidity was most often perceived to be related to the consumption of unclean water or food prepared with unclean water, as described in the non-breastmilk feeding domain, and less frequently related to scarcity of water and resultant poor hygiene. Beyond frequent mentions of generalized "sickness", specific morbidity sub-themes included infectious disease (e.g., cholera and typhoid), diarrhea and dysentery, stomach pains, and skin irritation, e.g., "*infants suffer stomachache and diarrhea because their utensils are not cleaned properly"* (Woman, 58 years-old, Morogoro, Tanzania).

The metatheme undernutrition was infrequently mentioned but universal across all sites (n=158 of 2,980; 19 of 19 sites). While undernutrition is related to or underlying all infant feeding and health concerns, this metatheme reflects explicit concern for water insecurity leading to slow or stunted growth, poor weight gain or weight loss, descriptions of malnourishment or poor nutrition, and delayed or impaired cognitive development. Undernutrition was most often specified as a consequence of infections, e.g., *"malnourished child is due to repeated infections*" (Man, 20 years-old, Punjab, Pakistan) and that the child experiences *"diarrhea, feels bad and does not absorb nutrients….[it] is dangerous"* (Woman, 57 years-old, Merida, Mexico). Sometimes poor growth or weight gain was specified as related to feeding inadequate quality (variety) or quantity of non-breastmilk foods.

Water insecurity leading to infants experiencing states of dehydration (n=62 of 2,980; 14 of 19 sites) and hunger (n=60 of 2,980; 11 of 19 sites) were present in the majority of sites. Dehydration was related to not having enough water, and sometimes as the result of diarrhea. Hunger was often described as relating to delays in feeding or insufficient quantity of foods.

Infant mortality was the most infrequent and least universal metatheme in the infant health domain (n=17 of 2,980; 6 of 19 sites). Mortality was closely linked with exposure to unsafe water, causing infectious diseases, diarrhea, and dehydration that could be fatal:

> *"Children are mostly infected by this dirty water. Doctors have forbidden us to use this water. But we cannot boil as we don't have gas here. We have been habitual [in using] this water. One of our babies has died some years ago because of cholera. In summer there are flies which contaminate everything."* (Woman, 48 years-old, Punjab, Pakistan)

DISCUSSION

In this article, we report that the vast majority of 3,303 respondents in 19 sites with varying degrees of water insecurity perceived that their water situation adversely affected infant feeding and infant health. This was perceived to occur directly (through non-breastmilk feeding and breastfeeding) and indirectly (through caregiver capabilities), and in infant health. Our focus on infants captures both the period of greatest breastfeeding potential at 0–5 months and the critical age of 6–11 months when breastfed children experience significant challenges accessing sufficient micronutrients in the transition to non-breastmilk foods (Dewey, 2013).

Non-breastmilk feeding was the most frequently and universally endorsed domain, followed by infant health, caregiver capabilities, and, to a much lesser extent, breastfeeding. The non-breastmilk feeding domain was most perceived as affected; this may be due to the very visible role of water in preparing and feeding non-breastmilk foods with water in the household. We find the unprompted endorsement of caregiver capability metathemes to recognize the pressures that women – typically both the household water managers and caregivers – experience in contexts of limited resources and water challenges across the world. Finally, that breastfeeding was the least endorsed domain may suggest that this is less of a pressing concern in the context of water insecurity affecting infant feeding globally, though important nonetheless for those who expressed perceptions such as decreased milk supply or contaminated breastmilk. Alternatively, we recognized that the question wording may have directed respondents towards non-breastmilk foods; and that breastfeeding is not universal, is typically gendered, and occurs for a shorter period of time, all of which may also have decreased prevalence of reported metathemes in this domain.

Below, we introduce our conceptual framework of the pathways by which water insecurity may impact infant feeding and infant health, drawn directly from the cross-culturally identified metatheme findings (Figure 3), and propose research recommendations accordingly. We encourage future research to employ a biocultural approach to systematically evaluate the diverse pathways by which water insecurity impacts infant and young child feeding, as well as the magnitude of its effects on dietary intake and related behaviors, such as food preparation and hygiene practices.

Non-breastmilk feeding

Our findings that inadequate or unsafe water are perceived to introduce risk to infant health through drinking, preparation of formula, and the cooking and serving of foods (i.e., unclean, contaminated; Table 3) is well-documented (Redmond & Griffith, 2009; Renfrew, 2003). However, our key finding that water insecurity may also impact infant meal quality through the replacement of preferred non-breastmilk foods with less preferred, less water-intensive substitutions has received less attention in the infant feeding literature; though substitutions when first choice foods are not available are documented in the food insecurity literature (e.g., Frongillo, Chowdhury, Ekström, & Naved, 2003; Schuster, Wein, Dickson, & Chan, 2011).

We found that individuals perceived water insecurity as leading to the preparation of foods that provide infants with low dietary diversity when preferred or staple foods take too much water to cook, or when staple or vegetable crops fail because of drought or flooding. Our findings align with the literature that households may be forced to make a difficult decision between purchasing water or food (Collins et al., 2019; Mason, 2015), though we move the literature one step further because our analyses are specific to non-breastmilk foods for infants. Collectively, these pathways may be responsible for the failure to meet minimum dietary diversity associated with suboptimal household water access and low regional water availability observed in nationally representative data in India (Choudhary et al., 2020). This is important because dietary diversity predicts micronutrient density in diets of both breastfed and non-breastfed infants and young children (Moursi et al., 2008), and because

micronutrient deficiencies lead to morbidity, increase risk of mortality, and affect growth (Black et al., 2013). The scope of future assessments of drivers of dietary diversity should include water-related factors, such as quantification of household water insecurity and ethnography probing about water in relation to dietary diversity.

Our findings also suggest that inadequate supplies of safe water can decrease the quantity of non-breastmilk foods, such that infants are fed less per meal and sometimes meals are skipped all together. This was driven by insufficient water for boiling, which is particularly important in preparing soft foods for infants, inability to purchase foods or fuel when money was allocated to buying water, and crops devastated by drought or flooding. Decreased quantity of food intake puts children at risk for inadequate micro-and macro-nutrient deficiencies which negatively impacts infant and child growth and health (Black et al., 2013). Although these are plausible pathways by which water insecurity impacts infant and young child feeding, we were unable to find treatment of this topic in published literature, suggesting that investigation in other settings would help us to understand the generalizability.

In sum, careful and thorough dietary data coupled with quantification of water insecurity and probing about drivers of dietary decisions will advance our understanding of how water insecurity shapes the consumption of non-breastmilk foods.

Caregiver Capabilities

Perhaps the most interesting finding was the unprompted endorsements of the impact of water insecurity on many facets of caregiver capabilities (Table 4). Our findings revealed that caregiver efficacy was perceived to be critical in mitigating adverse effects of water insecurity on infant feeding, and that there were high expectations for caregivers. Indeed, both household water management and infant feeding are considered the domains of women and mothers globally (Pickering & Davis, 2012). In fact, maternal self-efficacy predicts optimal breastfeeding behaviors (Dennis, 1999; Nichols, Schutte, Brown, Dennis, & Price, 2009) and mediates uptake of complementary feeding interventions and behaviors (Sanghvi, Jimerson, Hajeebhoy, Zewale, & Nguyen, 2013; Zhang, Shi, Chen, Wang, & Wang, 2009; Zongrone et al., 2018). Our findings suggest that water insecurity further complicates the already difficult context that caregivers are forced to navigate to feed their child; this is important because often it is often not a lack of knowledge but rather exactly those contextual barriers that shape caregiver behavior related to child feeding (Schuster, Szpak, Klein, Sklar, & Dickin, 2019). Future research on the effects of water insecurity on infant feeding should include assessments of caregiver self-efficacy to unpack this relationship.

Caregivers are forced to regularly evaluate tradeoffs that impact dietary diversity and quantity of non-breastmilk foods. Recognizing that water factors into these daily decisions is important in understanding how these calculations – which are shown to impact dietary diversity (Ickes, Wu, Mandel, & Roberts, 2018) – are made. Therefore, infant feeding research related to resources should include assessment of dimensions of water insecurity, e.g., water availability, access, and affordability, when considering water as a household resource necessary for preparation of the optimally diverse foods in palatable consistency.

Finally, time is a personal resource of the caregiver, and coping with water insecurity diverts time away from infant feeding and other care important for early childhood development. The opportunity cost associated with acquiring or managing household water may be felt by the infant in terms of feeding, similar to how water obligations are felt by school-aged children missing school (Robson, Porter, Hampshire, & Munthali, 2013) and adults missing social engagements or religious services (Stevenson et al., 2016). Effects on infant feeding may be greater in contexts where caregivers are forced to invest more time in household water management tasks over long periods. Nonetheless waits or interrupted chores means that caregivers are unable to spend their time in the most productive ways (McGuire & Popkin, 1990), and specifically disrupts timing of infant feeding. Delayed infant feeding leads to disrupted feeding schedules and infants being hungry; it is also is a likely driver of increasing stress and cortisol among caregivers, particularly mothers. This may affect infant development of appetite and satiety cues, leading to decoupling of self-regulation of caloric intake (Brown & Lee, 2012). It may limit caregiver's attention to them if the infant is left with others while mother searches for water (Engle & Pelto, 2011). Depending on the broader context of caregiving, this may also negatively affect caregiver bonding (Black & Dewey, 2014). Quantification of caregiver time spent, especially on water acquisition and allocation, would help to identify if, how, and when water insecurity diverts caregiver time from infant feeding and other caregiving.

Water insecurity may create or exacerbate challenges to caregiver health. Poor caregiver health limits caregiver capabilities in respect to infant feeding (Winkvist, 1995) and is predictive of poor infant growth and health outcomes (Rahman, Iqbal, Bunn, Lovel, & Harrington, 2004). Unclean water can lead to infectious diseases and inadequate water can lead to limited consumption of foods and poor nutritional status for caregivers, adding constraints on their ability to feed and care for children. While stress and worry about procuring sufficient and safe water for the household and interpersonal conflict over water has been documented (Collins et al., 2019; Stevenson et al., 2016; Wutich, 2009; Wutich & Ragsdale, 2008), worry about exposing infants to infectious diseases through unsafe water and non-breastmilk foods is an unexplored line of inquiry. Assessing the physical, nutritional, and mental health and stress of the caregiver concurrently with quantifying water insecurity may provide more insight into how water indirectly affects infant feeding.

Breastfeeding

Reverting to episodic exclusive breastfeeding was reported a response in two sites to when water availability or quality limited the ability to prepare or acquire non-breastmilk foods. Breastmilk can satisfy infant nutritional needs until six months of age, and then breastfeeding frequency is expected to decrease as consumption of non-breastmilk foods increases (Menon, Bamezai, Subandoro, Ayoya, & Aguayo, 2015). But our findings suggest the direction of this relationship may change depending on the circumstances. Documenting the frequency with which caregivers revert to exclusive breastfeeding after non-breastmilk foods have been introduced, due to unavailability of foods or water to prepare them, would help to clarify the importance of this pathway.

Water insecurity limiting the timing and frequency of breastfeeding has the potential to decrease the amount of milk received by the infant, which can indeed limit breastmilk production (Scavenius, van Hulsel, Meijer, Wendte, & Gurgel, 2007). Insufficient breastmilk, whether perceived or occurring, can lead to early introduction of non-breastmilk foods, which in turn decreases breastmilk production (Tully & Dewey, 1985). Breastmilk production is a common concern for lactating women globally (Gatti, 2008) and specifically in the context of food insecurity (Miller et al., 2019; Webb-Girard et al., 2012; Young et al., 2014). Quantifying whether water insecurity impacts breastfeeding behaviors or breastmilk production will be important in creating responsive programming and policy.

There is some evidence for another pathway, that water insecurity could lead to contaminated breastmilk. There is currently no biomedical evidence of water-borne, water-washed, or water-based pathogens consumed by lactating women to pass through tight junctions in the breast (Lawrence & Lawrence, 2004). A range of chemical contaminants (e.g., persistent organic pollutants, pesticides, heavy metals including lead) can be passed through the breastmilk (Mead, 2008). But breastmilk has lower levels of metals (e.g. mercury, lead, arsenic, cadmium, and selenium) than maternal blood, perhaps because metals are contained in red blood cells but it is the blood serum components that are transferred into breastmilk (Sakamoto, Chan, Domingo, Kubota, & Murata, 2012). This has led breastfeeding to be considered protective against transmitting arsenic among lactating women with high levels of arsenic exposure (Concha, Vogler, Nermell, & Vahter, 1998; Fängström et al., 2008) and a lower source of arsenic exposure for infants compared to powdered formula and water (Carignan et al., 2015). While washing the breast before breastfeeding is not typically recommended, it has been discussed in the milk expression literature to reduce bacterial contamination (Karimi et al., 2012). Integrating risk assessment of breastmilk in sites where water contamination is a significant concern may be appropriate.

Finally, a burgeoning literature suggests that maternal hydration may adversely affect lactation among women in water-poor contexts. Lactating women in the hot-humid Amazon are more likely to be dehydrated compared with non-lactating women (Rosinger, 2015), even when typical water consumption exceeds recommendations (Rosinger & Tanner, 2015). Simultaneously quantifying water insecurity, maternal hydration, and milk production would help to evaluate this relationship, and answer the call laid out by Bentley (1998) in understanding how hydration affects human milk production and feeding.

An under-appreciated driver of infant undernutrition?

Water insecurity was perceived to affect infant undernutrition, hunger, dehydration, morbidity, and mortality (Table 6) through the domains of breastfeeding, non-breastmilk feeding, and caregiver capabilities. Indeed, water insecurity is a very plausible driver of sub-optimal infant feeding beyond what is described in the sanitation and hygiene literature. It is worth considering if water insecurity plays a potentiating role in poor child nutrition and health, in much the same way that undernutrition exacerbates child mortality (Pelletier et al., 1995). Longitudinal and concurrent quantification of household water insecurity and child nutrition and health would provide more insights.

Limitations

Our exploratory study relies on the responses to one general, open-ended question asked in 19 sites across 16 low-and middle-income countries. As such, we were unable to systematically elicit data on all domains or metathemes, nor did we attempt to elicit specific behaviors central to infant feeding. These categories of data include, but are not limited to, the quality and quantities of foods that were prepared, the cleanliness of food preparation and feeding, or detailed breastfeeding practices. Furthermore, respondents were adults who self-identified as knowledgeable about household water and were not sampled on familiarity with infant feeding or even on the presence of young children in the household. The fact that three-quarters of respondents were women suggests that many were likely knowledgeable. Still, lower frequency of metathemes among some domains, including breastfeeding, may be reflective of older ages of respondents' children or no children, low prevalence of (exclusive) breastfeeding across sites, unfavorable attitudes towards breastfeeding, or discomfort of men in discussing breastfeeding at sites – for which we collected no data. Further, social desirability bias may have influenced some of the respondents.

The study was not designed to systematically collect health indicators, either self-reported or biomarkers, e.g. anthropometry or dehydration. We hope that this first foray into perceptions of how water insecurity affects infant feeding will stimulate interest among colleagues to take up the suggested research agenda and collect this important biocultural and biosocial information.

It is important to note that these study site samples are not representative of their respective nations, and that findings cannot be generalized to countries or regions. However, this sampling frame does not limit the value of these data for theorizing and generating hypotheses about pathways by which water can impact infant feeding. Conversely, as we focused on the metathemes that were apparent across sites, our analysis may overlook important site-specific impacts on infant feeding; localized dimensions certainly deserve more attention in future studies. Additionally, although best practices were followed with development and implementation of a training manual, there may have been differences within and between sites on probes that may influence the presentation of site-specific information.

Conclusion

This cross-cultural mixed-methods study has described how individuals perceive water insecurity to shape infant feeding and infant health through breastfeeding, non-breastmilk feeding, and caregiver capabilities (Figure 3). Quantifying household water insecurity and understanding its connections to feeding breastmilk and non-breastmilk items are necessary steps to understanding the magnitude of these effects. How household water insecurity impacts caregivers' abilities to care for infants and ultimately shape infant health also presents a new set of possibilities for interventions. In-depth ethnography coupled with interrogations of larger, more detailed nutrition and biobehavioral health data are needed to better understand the complex interactions between the experiences of water insecurity and infant feeding around the world. It is our hope that this biocultural research agenda is taken up by the interdisciplinary infant and young child feeding community and that rigorous

assessment of water insecurity is included in future research. Water insecurity has been an under-investigated component of infant and young child feeding, and maternal and child health more broadly, and assessments of its causes and consequences will provide important information in the global pursuit to prevent and mitigate infant and child undernutrition.

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Site Context: Insights into Kisumu, Kenya

Kisumu households are situated just a few kilometers from Africa's largest freshwater lake, Lake Victoria. However, household face water problems including seasonal shortages, flooding, and contamination with both pathogens and small-molecules (chemicals and heavy metals). The preponderance of households do not have on-plot water available, which means that fetching water is often a daily task. Women are primarily responsible for the acquisition of water, its distribution among household members, and its allocation for household tasks-many of which are water-intensive. Even though smaller jerry cans are ubiquitous virtually in all households, the lack of large capacity tanks for storage was felt to be a major cause of water insecurity. Indeed, the predominant infant feeding metathemes pertained to delays in infant feeding (42.5%, Table 3), driven by perceptions that water insecurity increases water-related time demands at the expense of infant feeding and care (second-highest proportion of any site at 24.5%, Table 4).

Site Context: Insights into Dushanbe, Tajikistan

Water challenges in the capital city of Dushanbe include dilapidated, poorly connected Soviet-era infrastructure. In the urban center, this was characterized by low pressure in the upper floors of apartment buildings. Residents sometimes installed illegal pumps to improve their water access, fueling conflict by decreasing others' access and perpetuating the narrative of the wealthy stealing water. On the urban periphery, water is stored in large tanks, which are often repurposed and are associated with contamination. Prominent infant feeding metathemes largely reflected water quality concerns; respondents only raised non-breastmilk feeding metathemes of poor-quality drinking water and unclean or contaminated non-breastmilk foods. Similarly, they endorsed caregiver capabilities metathemes that were related to contamination--hygiene knowledge, beliefs and behavior and caregiver health – at higher proportions compared with metathemes in that domain. No breastfeeding metathemes were mentioned; though breastfeeding is largely unpopular in this site as providing formula is a marker of wealth status. Following the concerns about contamination, 54% of Dushanbe respondents raised the metatheme of infant morbidity-the highest proportion of any site for infant morbidity and the second highest proportion for any metatheme.

Summary of Biocultural Research Recommendations

Feeding Practices

- Longitudinally assess infant and young child dietary data (e.g., breastfeeding and non-breastmilk feeding, dietary diversity) with measurements of water insecurity across seasons
- Assess relationship between water insecurity, maternal hydration, and breastmilk production

Caregiver Capabilities

- Assess caregiver self-efficacy in managing water insecurity challenges to infant feeding
- Incorporate water-related tasks into measurement of caregiver time use in the context of infant and young child feeding and caregiving
- Include water in qualitative and quantitative assessments of caregiver decision-making in terms of household resource allocation
- Evaluate how water insecurity affects the physical, nutritional, and mental health and stress of caregivers, inclusive of biomarkers

Infant Health

- Longitudinally quantify household water insecurity alongside child nutrition and health indicators and outcomes

Figure 1.

Open-ended data on how water insecurity affects infant feeding were collected from 19 sites across 16 low-and middle-income countries as part of the Household Water Insecurity Experiences (HWISE) study (N=3,303).

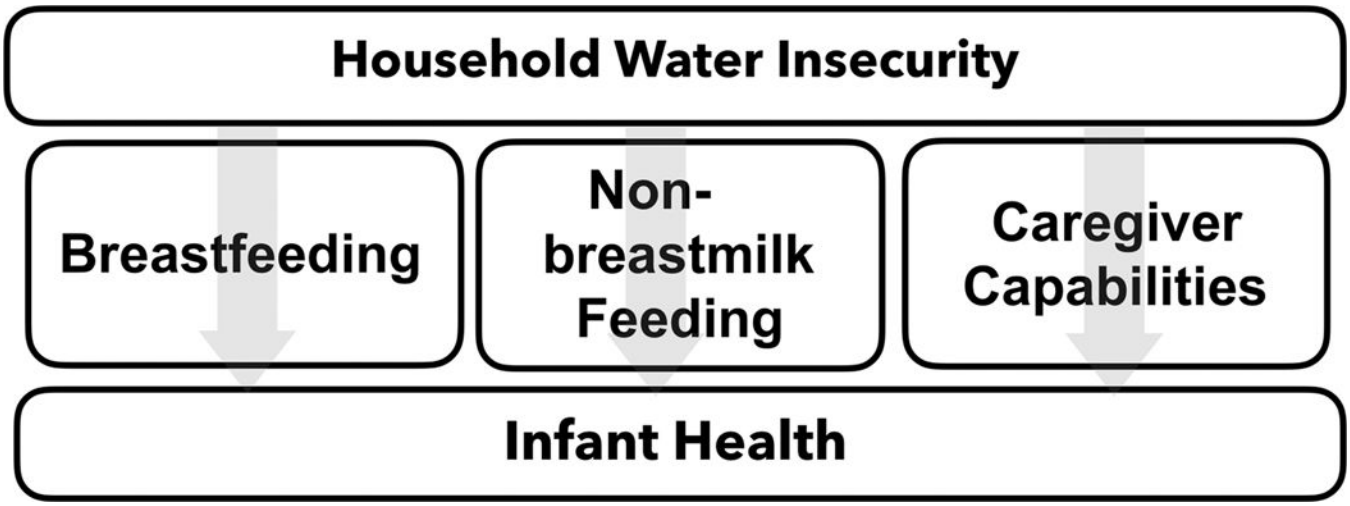

Figure 2.
A priori domains of infant feeding and infant health water insecurity impacts infant feeding,

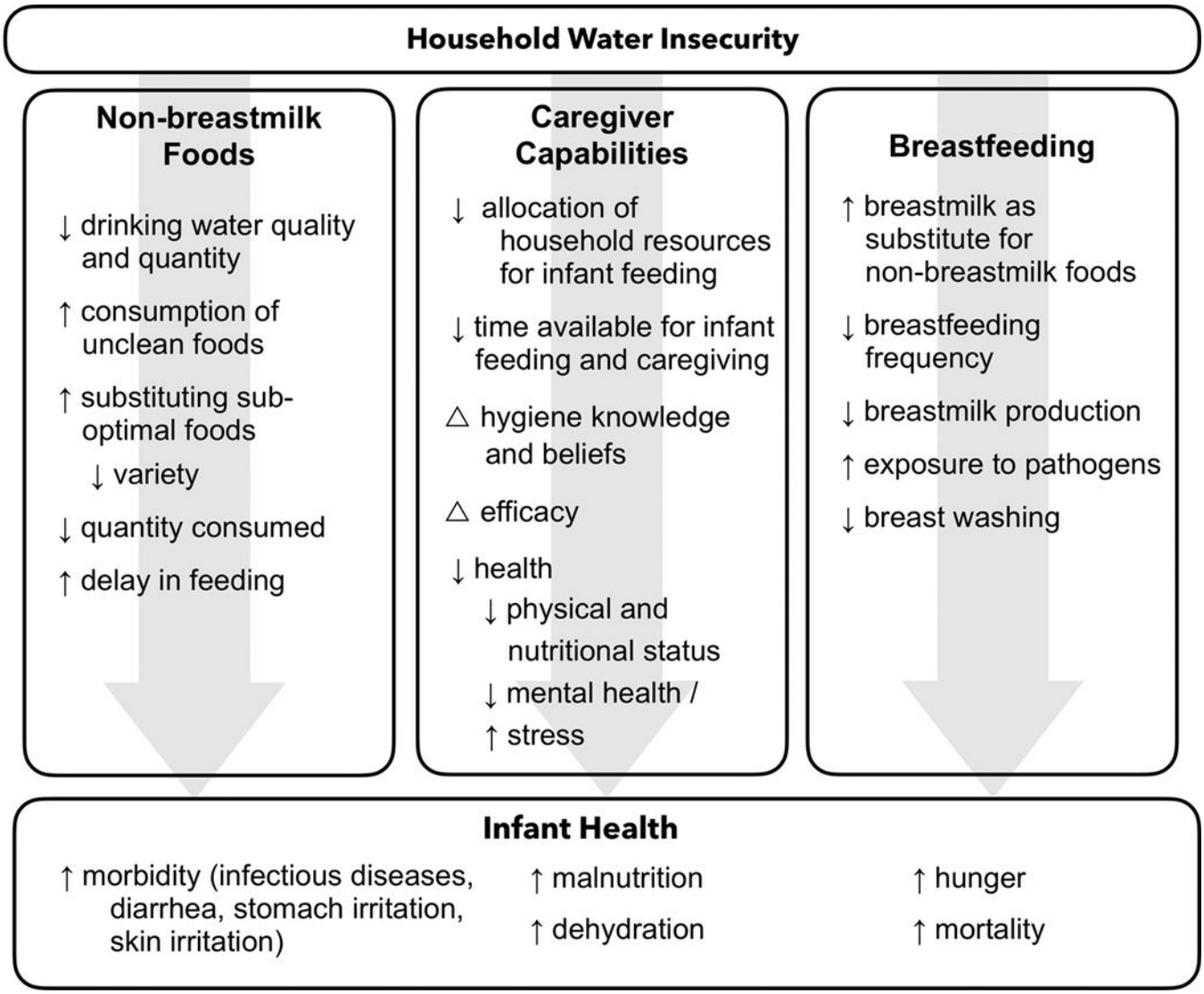

Figure 3.

Conceptual framework of the pathways by which water insecurity impacts infant feeding, and subsequently, infant health. ↑ indicates increase, ↓ indicates decrease, and △ indicates depends on.

Table 1.

Overview of 19 Household Water InSecurity Experiences study sites and respondents included in this analysis, by World Bank region

World Bank Region	Site (n)	Coding wave[a]	Urbanicity	Season	Sampling strategy	Respondent sex, % female	Respondent age, mean (sd)	Number of adults living in household, mean (sd)	Number of children living in household, mean (sd)
Africa	Bahir Dar, Ethiopia (n=241)	1	Rural	Rainy	Stratified random	100	36.0 (12.8)	2.8 (1.3)	2.2 (1.5)
	Accra, Ghana (n=136)	1	Urban	Rainy	Simple random	80.2	36.7 (13.3)	3.8 (3.7)	2.6 (3.2)
	Kisumu, Kenya (n=207)	1	Rural	Neither rainy nor dry	Simple random	80.0	38.4 (15.1)	2.6 (1.4)	2.8 (1.9)
	Lilongwe, Malawi (n=270)	1	Peri-urban	Neither rainy nor dry	Cluster random	86.7	32.1 (11.8)	3.0 (1.6)	2.5 (1.5)
	Lagos, Nigeria (n=184)	1	Urban	Rainy	Multi-stage random	74.4	38.2 (10.0)	2.8 (2.9)	2.1 (1.3)
	Morogoro, Tanzania (n=231)	2	Urban & peri-urban	Rainy	Cluster random	79.2	41.0 (15.1)	3.6 (2.1)	2.6 (2.1)
	Singida, Tanzania (n=171)	1	Rural	Dry	Purposive, community led	62.6	32.8 (9.0)	2.5 (1.2)	3.7 (1.7)
	Arua, Uganda (n=203)	2	Rural	Rainy	Cluster random	84.7	34.5 (12.9)	2.7 (1.5)	3.6 (2.1)
	Kampala, Uganda (n=170)	1	Urban	Dry	Purposive	67.1	37.4 (11.6)	3.0 (1.7)	2.7 (1.9)
Europe & Central Asia	Dushanbe, Tajikistan (n=195)	1	Urban	Dry	Cluster random	75.9	40.9 (14.3)	3.6 (1.7)	1.8 (1.7)
Latin American and the Caribbean	San Borja, Bolivia (n=117)	2	Rural	Dry	Simple random	67.6	40.1 (13.1)	3.7 (2.1)	2.3 (1.5)
	Cartagena, Colombia (n=232)	2	Urban	Dry	Simple random	71.1	40.2 (14.8)	3.5 (2.0)	2.0 (1.5)
	Acatenango, Guatemala (n=67)	2	Peri-urban	Dry	Cluster random	97.7	48.0 (14.8)	2.8 (1.3)	2.1 (1.4)
	Chiquimula, Guatemala (n=80)	2	Rural	Dry	Systematic random	91.3	32.8 (11.5)	2.8 (1.2)	4.0 (1.9)
	Gressier, Haiti (n=148)	2	Peri-urban	Dry	Stratified random	98.0	35.7 (12.3)	3.3 (1.5)	2.4 (1.3)

World Bank Region	Site (n)	Coding wave[a]	Urbanicity	Season	Sampling strategy	Respondent sex, % female	Respondent age, mean (sd)	Number of adults living in household, mean (sd)	Number of children living in household, mean (sd)
	Mérida, Mexico (n=197)	2	Urban	Dry	Cluster random	65.0	45.4 (15.8)	3.3 (1.5)	1.4 (1.6)
Middle East & North Africa	Beirut, Lebanon (n=60)	2	Urban	Rainy	Cluster random	86.7	35.0 (11.4)	2.5 (0.93)	2.5 (1.8)
South Asia	Kathmandu, Nepal (n=184)	1	Urban	Rainy	Cluster random	75.0	41.5 (12.6)	3.8 (1.9)	1.1 (1.0)
	Punjab, Pakistan (n=210)	2	Rural & peri-urban	Dry	Cluster random	59.5	35.6 (10.0)	4.1 (1.8)	4.2 (2.0)
	Total (N=3,303)					78.0	37.8 (13.5)	3.2 (1.9)	2.5 (1.9)

[a]Coding wave 1 was conducted October-December 2017 using Dedoose; coding wave 2 was conducted June-September 2018 using Atlast.ti.

Table 2.

Characteristics of participants who responded to the question asking how their water situation affected infant feeding, by effect or no effect (N=3,303) [†]

	Effect (n=2,980)	No effect (n=323)	*p*-value
Female, %	77.5	82.3	0.057
Age, mean (sd)	37.99 (13.44)	36.57 (13.43)	0.066
Water insecurity score (0–33), mean (sd)	8.82 (8.43)	5.02 (6.46)	<0.0001
Children in household, mean (sd)	2.56 (1.96)	2.22 (1.68)	0.0026
Adults in household, mean (sd)	3.22 (1.95)	2.98 (1.57)	0.0324
Household food insecurity, mean (sd)	7.42 (6.81)	6.05 (6.46)	<0.001
Site			<0.001
Singida, Tanzania (n=171)	100.0%	0.0%	
Beirut, Lebanon (n=60)	100.0%	0.0%	
San Borja, Bolivia (n=117)	100.0%	0.0%	
Punjab, Pakistan (n=210)	100.0%	0.0%	
Cartagena, Colombia (n=232)	99.6%	0.4%	
Kampala, Uganda (n=170)	98.8%	1.2%	
Bahir Dar, Ethiopia (n=241)	96.7%	3.3%	
Acatenango, Guatemala (n=67)	95.5%	4.5%	
Kisumu, Kenya (n=207)	94.7%	5.3%	
Lilongwe, Malawi (n=270)	92.2%	7.8%	
Dushanbe, Tajikistan (n=195)	89.2%	10.8%	
Mérida, Mexico (n=197)	88.8%	11.2%	
Kathmandu, Nepal (n=184)	88.6%	11.4%	
Chiquimula, Guatemala (n=80)	85.0%	15.0%	
Gressier, Haiti (n=148)	81.8%	18.9%	
Morogoro, Tanzania (n=231)	80.1%	19.9%	
Arua, Uganda (n=203)	78.3%	22.2%	
Lagos, Nigeria (n=184)	77.2%	22.8%	
Accra, Ghana (n=136)	69.1%	30.9%	

[†]Total N and site-specific n represent the number of participants who responded definitively that water affected or did not affect infant feeding.

Table 3.

Frequency of metathemes reported within the non-breastmilk feeding domain among respondents who identified an effect of water on infant feeding, reported as proportion (%) by site (N=2,980) [†,‡]

	Non-breastmilk Feeding Metathemes				
Site (n respondents who indicated effect)	**Delay in feeding**	**Drinking water**	**Unclean foods**	**Substitution of less preferred foods**	**Quantity**
Arua, Uganda (n=158)	53.5%	6.9%	1.9%	1.3%	5.0%
Morogoro, Tanzania (n=185)	49.7%	7.0%	24.9%	3.2%	1.6%
Kampala, Uganda (n=168)	42.9%	15.5%	8.9%	13.1%	13.7%
Kisumu, Kenya (n=196)	42.3%	1.0%	7.7%	3.6%	5.6%
Kathmandu, Nepal (n=163)	39.3%	1.8%	3.1%	4.3%	0.6%
Lilongwe, Malawi (n=249)	34.1%	34.9%	11.6%	3.6%	14.1%
Singida, Tanzania (n=171)	12.9%	21.1%	1.2%	1.2%	2.9%
Accra, Ghana (n=94)	8.5%	18.1%	17.0%	2.1%	5.3%
Lagos, Nigeria (n=142)	7.7%	31.7%	13.4%	4.9%	2.8%
Chiquimula, Guatemala (n=68)	4.4%	4.4%	8.8%	14.7%	0.0%
Bahir Dar, Ethiopia (n=233)	4.3%	0.9%	5.6%	64.8%	10.7%
Cartagena, Colombia (n=231)	2.6%	5.2%	10.4%	0.0%	1.7%
Punjab, Pakistan (n=210)	0.5%	13.3%	11.4%	2.4%	1.4%
Beirut, Lebanon (n=60)	0.0%	6.7%	0.0%	0.0%	0.0%
Gressier, Haiti (n=120)	0.0%	7.4%	0.0%	0.8%	0.0%
Dushanbe, Tajikistan (n=174)	0.0%	10.9%	9.8%	0.0%	0.0%
Acatenango, Guatemala (n=64)	0.0%	14.1%	3.1%	0.0%	3.1%
San Borja, Bolivia (n=117)	0.0%	18.8%	12.8%	3.4%	0.0%
Mérida, Mexico (n=175)	0.0%	44.6%	3.4%	1.7%	1.1%
TOTAL	18.2%	14.3%	8.7%	8.0%	4.40%

[†]Total N and site-specific n represent the number of participants who responded definitively that water does affect infant feeding.

[‡]Proportions represent frequency of those within a site reporting each metatheme; therefore, proportions will not sum to 100% within a site across metathemes or across sites within a metatheme.

Table 4.

Frequency of metathemes reported within the caregiver capabilities domain among respondents who identified effect of water on infant feeding, reported as proportion (%) by site (N=2,980)[†,‡]

	Caregiver Metathemes						
Site	**Hygiene knowledge, beliefs, and behaviors**	**Time demands**	**Allocation of household resources**	**Caregiver efficacy**	**Caregiver health**	***Physical and nutritional status*[§]**	***Mental health and stress*[§]**
Mérida, Mexico (n=175)	35.4%	0.0%	19.4%	0.6%	0.6%	0.6%	0.0%
Arua, Uganda (n=158)	32.7%	30.8%	0.6%	3.8%	3.1%	3.1%	0.0%
Cartagena, Colombia (n=231)	21.6%	0.4%	0.0%	2.6%	0.9%	0.0%	0.9%
Bahir Dar, Ethiopia (n=233)	16.3%	0.9%	4.7%	2.1%	0.4%	0.4%	0.0%
Morogoro, Tanzania (n=185)	15.7%	3.8%	2.2%	3.8%	1.6%	1.6%	0.0%
Acatenango, Guatemala (n=64)	15.6%	0.0%	1.6%	1.6%	4.7%	3.1%	0.0%
San Borja, Bolivia (n=117)	14.5%	0.0%	1.7%	0.9%	0.9%	0.9%	0.0%
Kisumu, Kenya (n=196)	10.7%	24.5%	1.0%	8.2%	1.0%	0.0%	1.0%
Chiquimula, Guatemala (n=68)	10.3%	7.4%	0.0%	2.9%	2.9%	2.9%	0.0%
Punjab, Pakistan (n=210)	9.5%	14.3%	6.2%	13.8%	22.9%	16.2%	8.1%
Lagos, Nigeria (n=142)	9.2%	5.6%	22.5%	13.4%	2.8%	1.4%	0.7%
Kampala, Uganda (n=168)	8.3%	16.1%	19.6%	5.4%	13.7%	7.7%	6.0%
Dushanbe, Tajikistan (n=174)	7.5%	2.3%	2.9%	2.9%	5.7%	4.0%	0.0%
Accra, Ghana (n=94)	7.4%	0.0%	17.0%	10.6%	1.1%	1.1%	0.0%
Kathmandu, Nepal (n=163)	5.5%	14.7%	4.9%	20.2%	0.6%	0.0%	0.6%
Singida, Tanzania (n=171)	2.3%	11.1%	0.0%	2.9%	0.0%	0.0%	0.0%
Gressier, Haiti (n=120)	0.8%	0.0%	5.0%	0.8%	0.0%	0.0%	0.0%
Lilongwe, Malawi (n=249)	0.4%	15.3%	0.8%	4.0%	0.8%	0.8%	0.0%
Beirut, Lebanon (n=60)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	12.3%	8.8%	5.7%	5.6%	3.7%	2.5%	1.1%

[†]Total N and site-specific n represent the number of participants who responded definitively that water does affect infant feeding.

[‡]Proportions represent frequency of those within a site reporting each metatheme; therefore, proportions will not sum to 100% within a site across metathemes or across sites within a metatheme.

[§]Distinct subthemes of the metatheme morbidity; frequencies of these subthemes are included in the reported frequency for morbidity.

Table 5.

Frequency of metathemes reported within the breastfeeding domain among respondents who identified an effect of water on infant feeding, reported as proportion (%) by site (N=2,980)[†,‡]

Site	Breastfeeding Metathemes				
	Breastfeeding as replacement for non-breastmilk foods	**Breastfeeding frequency**	**Breastmilk production**	**Exposure to pathogens**	**Breast washing**
Bahir Dar, Ethiopia (n=233)	19.7%	0.0%	0.0%	0.0%	0.0%
Chiquimula, Guatemala (n=68)	8.8%	0.0%	1.5%	0.0%	0.0%
Beirut, Lebanon (n=60)	1.7%	0.0%	0.0%	0.0%	0.0%
Arua, Uganda (n=158)	0.6%	1.9%	1.9%	0.0%	2.5%
Lagos, Nigeria (n=142)	0.0%	2.1%	0.7%	0.0%	0.0%
Lilongwe, Malawi (n=249)	0.0%	2.0%	0.8%	0.0%	0.0%
Kathmandu, Nepal (n=163)	0.0%	4.3%	0.0%	0.0%	0.0%
Accra, Ghana (n=94)	0.0%	0.0%	0.0%	2.1%	0.0%
Kisumu, Kenya (n=196)	0.0%	1.0%	0.0%	0.0%	1.0%
Dushanbe, Tajikistan (n=174)	0.0%	0.0%	0.0%	5.7%	0.0%
Singida, Tanzania (n=171)	0.0%	0.0%	0.0%	0.0%	0.0%
Kampala, Uganda (n=168)	0.0%	2.4%	6.5%	2.4%	0.0%
Mérida, Mexico (n=175)	0.0%	0.0%	0.0%	0.0%	0.6%
Acatenango, Guatemala (n=64)	0.0%	0.0%	0.0%	0.0%	0.0%
Gressier, Haiti (n=120)	0.0%	0.0%	0.0%	0.0%	0.0%
San Borja, Bolivia (n=117)	0.0%	0.0%	0.0%	0.9%	0.0%
Punjab, Pakistan (n=210)	0.0%	1.9%	1.0%	0.5%	0.0%
Morogoro, Tanzania (n=185)	0.0%	0.0%	0.0%	0.0%	0.5%
Cartagena, Colombia (n=231)	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	1.8%	1.0%	0.6%	0.6%	0.3%

[†]Total N and site-specific n represent the number of participants who responded definitively that water does affect infant feeding.

[‡]Proportions represent frequency of those within a site reporting each metatheme; therefore, proportions will not sum to 100% within a site across metathemes or across sites within a metatheme.

Table 6.

Frequency of metathemes reported in the infant health domain, among respondents who identified an effect on water on infant feeding, reported as proportion (%) by site (N=2,980)[†,‡]

	Infant Health Metathemes								
Site	**Morbidity**	***Infectious disease*[§]**	***Diarrhea*[§]**	***Stomach irritation*[§]**	***Skin irritation*[§]**	**Undernutrition**	**Dehydration**	**Hunger**	**Mortality**
Dushanbe, Tajikistan (n=174)	53.4%	2.9%	1.1%	17.8%	1.7%	1.1%	0.0%	0.0%	0.0%
Acatenango, Guatemala (n=64)	48.4%	17.2%	25.0%	21.9%	1.6%	7.8%	0.0%	0.0%	1.6%
Beirut, Lebanon (n=60)	45.0%	40.0%	11.7%	33.3%	20.0%	1.7%	0.0%	0.0%	0.0%
Chiquimula, Guatemala (n=68)	39.7%	2.9%	22.1%	10.3%	0.0%	2.9%	4.4%	4.4%	0.0%
Punjab, Pakistan (n=210)	39.5%	23.8%	2.9%	13.3%	3.3%	23.3%	5.2%	0.5%	2.4%
Kathmandu, Nepal (n=163)	39.3%	6.7%	22.1%	4.3%	0.6%	1.2%	1.8%	1.8%	0.0%
Mérida, Mexico (n=175)	37.7%	9.1%	10.3%	7.4%	2.3%	5.1%	1.1%	0.0%	2.9%
San Borja, Bolivia (n=117)	35.0%	15.4%	17.1%	9.4%	6.8%	1.7%	0.9%	0.0%	0.0%
Cartagena, Colombia (n=231)	28.6%	4.3%	6.5%	15.6%	9.5%	19.5%	1.7%	0.0%	0.0%
Accra, Ghana (n=94)	27.7%	1.1%	4.3%	1.1%	11.7%	1.1%	6.4%	4.3%	1.1%
Gressier, Haiti (n=120)	26.4%	1.7%	18.2%	1.7%	11.6%	0.8%	0.0%	0.0%	0.0%
Morogoro, Tanzania (n=185)	22.7%	5.9%	5.9%	13.0%	1.1%	0.5%	0.5%	1.1%	0.0%
Singida, Tanzania (n=171)	18.1%	10.5%	21.1%	15.8%	0.6%	1.8%	2.9%	2.9%	0.0%
Kampala, Uganda (n=168)	17.3%	17.3%	2.4%	1.2%	1.8%	10.1%	4.8%	3.6%	2.4%
Bahir Dar, Ethiopia (n=233)	14.6%	6.0%	1.7%	0.0%	0.0%	3.4%	4.3%	1.7%	0.0%
Kisumu, Kenya (n=196)	7.7%	3.1%	0.0%	0.0%	0.0%	1.5%	0.5%	11.2%	0.0%

	Infant Health Metathemes								
Site	**Morbidity**	***Infectious disease*[§]**	***Diarrhea*[§]**	***Stomach irritation*[§]**	***Skin irritation*[§]**	**Undernutrition**	**Dehydration**	**Hunger**	**Mortality**
Lilongwe, Malawi (n=249)	7.6%	1.2%	1.6%	0.0%	0.0%	0.8%	0.0%	1.6%	0.0%
Arua, Uganda (n=158)	6.9%	3.8%	2.5%	0.0%	1.9%	2.5%	3.1%	4.4%	0.0%
Lagos, Nigeria (n=142)	4.2%	1.4%	1.4%	2.8%	0.0%	0.7%	1.4%	0.0%	0.7%
TOTAL	24.9%	8.0%	7.6%	7.6%	3.1%	5.3%	2.1%	2.0%	0.6%

[†]Total N and site-specific n represent the number of participants who responded definitively that water does affect infant feeding.

[‡]Proportions represent frequency of those within a site reporting each metatheme; therefore, proportions will not sum to 100% within a site across metathemes or across sites within a metatheme.

[§]Distinct subthemes of the metatheme morbidity; frequencies of these subthemes are included in the reported frequency for morbidity.