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Mini-Review

Food Safety Challenges in Refugee Camps: What Do We Know?

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ABSTRACT

Refugee camps provide basic necessities such as food, water, shelter, and medical treatment for displaced persons. Unsanitary conditions in refugee camps due to overcrowding, poor sanitation systems, lack of clean water, and minimal ways to cook and store food can lead to an increased risk of foodborne illness. This article reviews the limited literature on the epidemiology of foodborne illness in refugee camps, effective risk mitigation strategies, and opportunities for future research. Eleven relevant articles were identified, suggesting that research in this area is limited. Identified research focused on three pathogens—*Vibrio cholerae, Salmonella,* and hepatitis E virus—that can cause serious diseases such as cholera, salmonellosis, typhoid fever, and hepatitis E. Storage and handling of clean water for personal hygiene and food preparation were critical components for ensuring food safety. Knowledge pertaining to best practices for hygiene and food preparation also were identified as important. Gaps in current research include determination of the prevalence of pathogens in food sold in refugee camps and development of culturally relevant food safety supply chain quality management systems. More research that focuses on burden and attribution of foodborne illness and food safety interventions in refugee camps is necessary.

HIGHLIGHTS

- *Vibrio cholerae, Salmonella,* and hepatitis E virus infections are common in refugee camps.
- Limited research has been conducted on food safety in refugee camps.
- Proper sanitary conditions and clean water in refugee camps can reduce the risk of foodborne diseases.
- Study designs limit inferences about contamination sources and interventions.
- Effective food safety interventions and implementation strategies are needed.

Key words: Food safety; Hepatitis E; Refugee camps; *Salmonella*; *Vibrio cholerae*

Refugee camps are temporary settlements developed to house displaced people *(37, 39)*. Most inhabitants of refugee camps are displaced because of conflict and war, but others are displaced because of environmental disasters *(37)*. Although many refugees fled their native countries, some camps house internally displaced persons *(36, 37)*.

Refugee camps are not typically constructed to sustain life long term; they are meant to cover basic human needs, including medical treatment and food, during temporary displacement *(36, 38, 39)*. The economic impacts of refugee camps, which are often supported by the United Nations or other nongovernmental organizations, on host countries have been explored *(34, 41)*. Most camps are located far from cities to create a physical distinction. However, even when refugee camps are located near cities without physical barriers such as fences, it is still relatively easy to distinguish refugees from other citizens *(36)*.

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As the ability to communicate worldwide becomes more widespread, the conditions of refugee camps are more readily shared *(6)*. Those living in refugee camps can face overcrowding, poor sanitary conditions, and food insecurity. These conditions can result in respiratory problems, spread of infections, and gastrointestinal illnesses. For example, gastrointestinal illnesses were the most significant problem in refugee camps in Mexico *(40)* and Senegal *(31)*. Gastrointestinal illnesses can be caused by multiple pathogens that can be transmitted through contact with contaminated water, food, animals, and the environment. Access to clean water and proper water storage are important for mitigating gastrointestinal illnesses *(22, 26)* but are not the only factors contributing to these illnesses. Although some research has focused on waterborne diseases in refugee camps, little work has focused on food safety *(16, 27)*. Although no specific reports have highlighted food poisoning and food safety issues in refugee camps, patterns of diarrheal disease associated with food or transmitted through the fecal-oral route should be closely monitored *(8)*. Refugees living under unsanitary and food insecurity

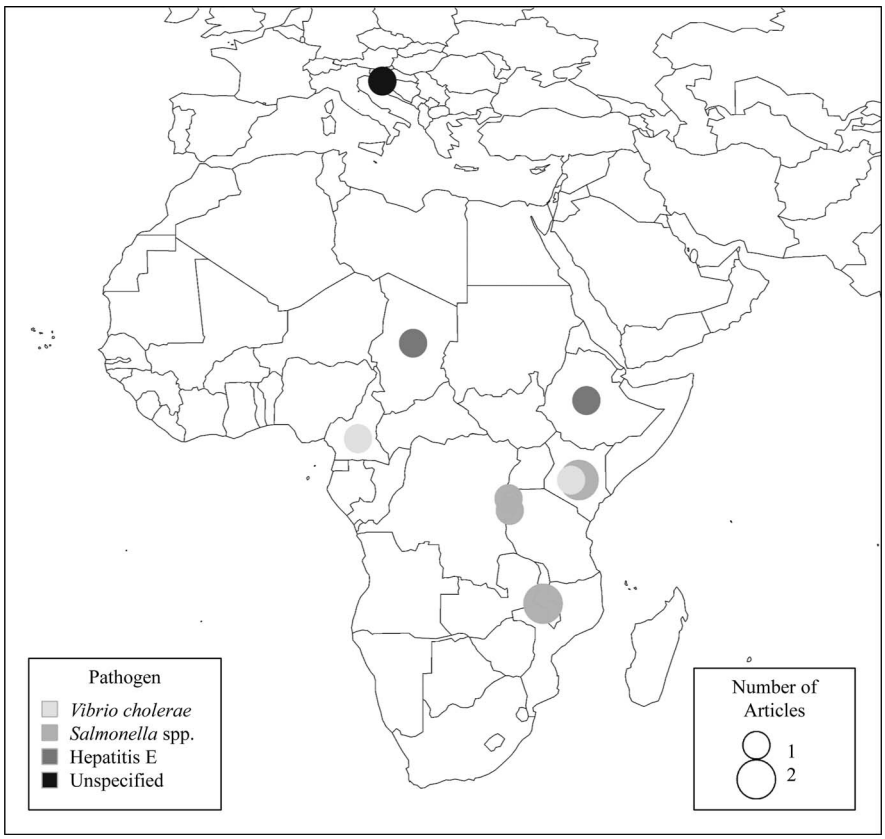

FIGURE 1. *Locations of studies on food safety in refugee camps.*

conditions may resort to using contaminated food ingredients, cooking food improperly, or eating spoiled food. Foodborne illness outbreaks have been associated with food from refugee camps *(26),* but there little research has been conducted on the burden of foodborne illness in refugee camps. The aim of this study was to review the literature on the public health impact of foodborne disease in refugee camps and the potential interventions for mitigating food safety risks to identify information gaps and inform future research.

METHODS

Relevant published articles were identified through electronic searches of publication databases, including PubMed (http://www.ncbi.nlm.nih.gov/pubmed), Google Scholar (https://scholar.google.com), Cab abstracts (https://www.cabdirect.org), and Web of Science (https://apps.webofknowledge.com), using key words relevant for this review. Search terms for Pub Med, Cab abstracts, and Web of Science were ("food safety" OR foodborne*) AND "refugee camp" AND ("refugee" or "displaced persons"). Search terms for Google Scholar were (refugee camp foodborne disease outbreaks) and (foodborne disease outbreak refugee). Although this literature review was not systematic, attempts were made to identify all relevant research. Titles and abstracts of identified articles were reviewed for relevance, and when appropriate a full review was conducted by one of three reviewers. References were reviewed to identify additional published works. Only original research studies were included in the review. The literature search was conducted between January and April 2020.

Eleven relevant original research articles were identified (Fig. 1 and Table 1). Ten articles were focused on outbreaks in African refugee camps caused by one of three pathogens: *Vibrio cholerae, Salmonella* Typhi, and hepatitis E virus (HEV). The remaining article addressed the burden of foodborne disease in Croatia between 1986 and 1992, including 474 outbreaks in refugee camps. The 10 pathogen-focused articles are summarized below by pathogen of concern, and the article addressing the burden of disease is summarized separately.

PATHOGENS OF CONCERN IN REFUGEE CAMPS

V. cholerae. *V. cholerae* is a gram-negative bacterium that causes cholera *(19)* and is a significant public health threat, especially in low- and middle-income countries. The burden of cholera worldwide is estimated at 1.3 to 4.0 million illnesses and 21,000 to 41,000 deaths per year *(3)*. The toxins produced by *V. cholerae* can cause abdominal pain, vomiting, watery stools, dehydration, and decrease in turgidity of skin, leading to wrinkling on hands and feet *(15)*.

Food can become contaminated with *V. cholerae* during preparation, handling, storage, and processing *(25)*. Growth of *V. cholerae* occurs between 20 and 45°C *(21),* and the vegetative cells can be inactivated by thermal treatment. For example, the decimal reduction time for *V. cholerae* in crab meat was reported as 2.65 min at 60°C *(29)*. Proper refrigeration and cooking temperatures are essential for reduction of *V. cholerae*. Transmission of *V. cholerae* can occur through the fecal-oral route from ingestion of contaminated water or food *(4, 30)*. Refugee camps have particular challenges with *V. cholerae* outbreaks due to overcrowding, lack of adequate water distribution systems and/or sanitation infrastructure, and lack of safe food and water handling practices *(11)*.

TABLE 1. *Overview of articles on food safety in refugee camps*

Pathogen	Outbreak yr	Article title	Reference	Aim of study	Sample size	Refugee camp/location
Vibrio cholerae	1988	Practical field epidemiology to investigate a cholera outbreak in a Mozambican refugee camp in Malawi, 1988	*22*	Describe characteristics of the cholera outbreak in the camp and the likelihood that various food and water consumption patterns were associated with the disease	Descriptive: 951 cases Case-control: 51 cases, 51 controls	Mozambican camp, Malawi
	1990	Epidemic cholera among refugees in Malawi, Africa: treatment and transmission	*33*	Describe characteristics of the cholera outbreak in the camp and the likelihood that various food and water handling practices were associated with the disease	Descriptive: 6,114 people received intravenous treatment (chart review of 173 patients) Case-control A: 50 cases, 50 matched controls; case-control B: 47 cases, 245 controls	Nyamithuthu, Malawi
	2005	Cholera outbreak in Kenyan refugee camp: risk factors for illness and importance of sanitation	*28*	Determine risk factors for cholera and potential interventions	Descriptive: 522 cases of watery diarrhea (348 refugee camp residents) Case-control: 90 cases, 170 matched controls	Kakuma Camp, Kenya
	2009	Epidemic cholera in Kakuma Refugee Camp, Kenya, 2009: the importance of sanitation and soap	*20*	Describe characteristics of the cholera outbreak in the camp and risk factors for the disease	Descriptive: 224 cases (163 refugee camp residents) Case-control: 93 cases, 93 matched controls	Kakuma Camp, Kenya
	2013	Prevention practices from water borne diseases within households in the Bamendankwe Municipality—north west Cameroon	*11*	Determination of knowledge and prevention practices related to waterborne diseases	Cross-sectional survey: 120 people	Bamendankwe, Cameroon
Salmonella Typhi	2015	Knowledge, attitude and practice of hygiene and sanitation in a Burundian refugee camp: implications for control of a *Salmonella* Typhi outbreak	*23*	Assess the effectiveness of ongoing typhoid fever preventive interventions	Knowledge, attitude, and practices: 671 respondents derived from a larger case-control study of 1,036 refugee camp residents (259 cases, 777 controls)	Mahama Camp, Rwanda
	2015	Risk factors for transmission of *Salmonella* Typhi in Mahama Refugee Camp, Rwanda: a matched case-control study	*24*	Characterize further the epidemiology of the typhoid fever outbreak; identify risk factors for transmission and use these data to propose additional recommendations for controlling typhoid fever outbreaks in Mahama	Descriptive: 260 cases, 770 controls from a larger retrospective case control study of 1,036 refugee camp residents (259 cases, 777 controls)	Mahama Camp, Rwanda

TABLE 1. *Continued*

Pathogen	Outbreak yr	Article title	Reference	Aim of study	Sample size	Refugee camp/location
Hepatitis E virus	2012	Hepatitis E outbreak, Dadaab Refugee Camp, Kenya, 2012	*1*	Present the epidemiologic and laboratory findings for the acute jaundice syndrome cases identified during the outbreak of hepatitis E	Descriptive: 339 acute jaundice syndrome cases (includes refugee camp residents and others)	Dadaab, Kenya
	2014–2015	Hepatitis E outbreak among refugees from South Sudan—Gambella, Ethiopia, April 2014–January 2015	*7*	Describe data on the suspected hepatitis E outbreak among refugees in the Gambella region	Descriptive: 1,117 suspected cases of hepatitis E from refugee camp residents	Kule, Leitchuor, and Tierkidi Camps, Ethiopia
	2016	Learning from water treatment and hygiene interventions in response to a hepatitis E outbreak in an open setting Chad	*32*	Evaluate the coverage and use of water treatment and hygiene interventions used in a hepatitis E outbreak in Chad	Cross-sectional survey: 395 households that included women >18 yr of age	Chad
Unspecified	1986–1992	The incidence and costs of foodborne diseases in Croatia	*26*	Analyze the incidence and assess the costs of foodborne diseases in Croatia	Epidemiological study: 59,496 cases of salmonellosis and 339 outbreaks, 1986–1992	Croatia

Research conducted on foodborne transmission of *V. cholerae* in refugee camps is limited; of the 11 studies reviewed, 5 were investigations of *V. cholerae* infection outbreaks in Kenya, Malawi, and Cameroon (Fig. 1). Four included case-control studies conducted to determine the likelihood of risk factors such as food and water handling practices and their association with an individual with cholera *(20, 22, 28, 33)*. Three also included descriptive epidemiology studies of the spread of the outbreak over time in the particular refugee camp and refugees' knowledge about prevention and spread of *V. cholerae* *(11, 20, 33)*.

In 1988, the source and potential determinants of a cholera outbreak in a refugee camp in Malawi was investigated through a descriptive epidemiology study paired with a case-control study *(22)*. The descriptive epidemiology study included 951 individuals and revealed that the area in which the market was located was the source of the outbreak, resulting in a temporary closure of the market. A case-control study with 51 cases and 51 controls was also conducted to identify potential risk factors for cholera. Results revealed increased odds of cholera among those who had contact with the market, but the variance was large and differences were nonsignificant (odds ratio [OR] = 3.5; confidence interval [CI]: 0.7 to 16.8; $P < 0.09$). These results could be due to the fact that almost all individuals in the study went to the market to get food, but not everyone developed cholera and/or were exposed to the food items or water sources linked to the outbreak. A higher likelihood of cholera was found among those who had shallow wells (OR = 4.5; CI: 1.0 to 20.8), indicating that contaminated well water may have been the source. The authors hypothesized that the contamination could have been due to rain that destroyed latrines in the camp 15 days before the cholera outbreak; the rain may have aided in spreading *V. cholerae* from the latrines in the market to the wells.

In 1990, the association between in-home food preparation methods and the likelihood of cholera was investigated through descriptive epidemiology and two case-control studies during a cholera outbreak in a refugee camp in Malawi *(33)*. Chart reviews were conducted for 173 individuals of the 6,114 that visited the treatment center. The two case-control studies were conducted to identify determinants of cholera and transmission and included (i) individuals who were ill, with 50 cases and 50 controls, and (ii) households of ill individuals, with 27 cases and 245 controls. In both studies, access to firewood to cook food had a differential effect on the association with cholera. Reduced risk of cholera was associated with individuals who reheated leftover peas (OR = 0.2; CI: 0.02 to 1.0). A household that did not have firewood and subsequently consumed leftover peas without reheating had increased risk of cholera (OR = 8.0; CI: 1 to 64.0). Because *V. cholerae* is a heat-susceptible vegetative pathogen, access to proper refrigeration and cooking could reduce the risk of cholera in refugee camps.

In 2005, a retrospective descriptive epidemiology study and a case-control study were conducted following a cholera outbreak in Kenya's Kakuma Refugee Camp to

identify risk factors for cholera and potential interventions *(28)*. Electronic medical records from the camp hospital and health clinics were used to identify 418 hospitalized patients with watery diarrhea during the time of the outbreak; *V. cholerae* was confirmed in 33 of these patients. Ninety cases and 170 matched controls were enrolled in a case-control study to identify potential risk factors. In the multivariate analysis, individuals who shared a latrine with three or more households were more likely to have cholera than those who did not (OR = 2.17; CI: 1.01 to 4.68). In contrast, individuals who covered their water storage containers were less likely to have cholera than those who did not (OR = 0.49; CI: 0.25 to 0.96). These results suggest that risk of exposure to *V. cholerae* increased for individuals with less access to proper sanitation facilities. Individuals who recently arrived in the Kakuma Refugee Camp also had increased risk of cholera (OR = 4.66; CI: 1.35 to 16.05). Refugees who recently arrived in the camp may have had less access to resources needed to cook food and/or ensure proper sanitation, leaving them at increased risk of exposure to *V. cholerae*.

In 2009, risk factors were investigated in a subsequent cholera outbreak in the same refugee camp through a descriptive epidemiology study and a case-control study *(20)*. The descriptive epidemiological study of 224 cases of cholera included 163 refugees. The case-control study included 93 cases and 93 matched controls from the refugee population. Consumption of milk at home (OR = 0.52; CI: 0.27 to 0.99) and consumption of vegetables cooked at home (OR = 0.40; CI: 0.19 to 0.83) were significant protective factors for cholera. Consumption of food from sources outside of the home was not significantly associated with cholera. Individuals who self-reported washing their hands with soap in this study were less likely to have cholera (OR = 0.25; CI: 0.09 to 0.71) than those who did not. These results indicate that following safe food handling practices such as hand washing and cooking food could decrease the risk for exposure to *V. cholerae*.

A cross-sectional survey was conducted in Cameroon in 2013 to determine knowledge, attitudes and practices about the causes and prevention of waterborne diseases, including *V. cholerae (11)*. Of the 120 respondents, only 17% stated that eating and drinking clean food and water prevents waterborne disease. Potential solutions identified to decrease cholera outbreaks in refugee camps included increased education about proper food and water handling and building infrastructure to provide clean drinking water.

Although cholera associated with contaminated food or unhygienic food handling practices is a significant public health problem in refugee camps *(11, 20, 22, 28, 33),* the published literature is limited to four case-control studies and one cross-sectional survey. However, although each of these studies suffered from significant limitations, such as misclassification (i.e., incorrect identification of sources of the outbreak) and recall bias (i.e., individuals not correctly remembering their potential exposures to *V. cholerae*), these studies provide important insights that could inform future work on mitigating the risk of cholera from contaminated food in refugee camps. Several authors cited the need for increased education on food safety and sanitation practices aimed at preventing the spread of *V. cholerae* in refugee camps. Community-based participatory research should be conducted to determine which intervention strategies, such as fuel-efficient stoves or mixing foods with acidic ingredients to decrease the growth of *V. cholerae,* would decrease the risk of cholera outbreaks in refugee camps. Safe drinking water storage and distribution are critical for reducing cholera outbreaks; refugees that live in unsanitary conditions have increased risk of cholera. Identification of risk factors for foodborne spread of disease can help in prioritization of interventions and prevention of disease. Surveillance of foodborne disease in refugee camps is needed to identify outbreaks quickly and minimize the spread of disease. To optimize the use of resources, including time and money needed to create and run refugee camps, more studies on the transmission pathways and prevention of foodborne spread of cholera are needed to mitigate the recurring problem of cholera outbreaks in refugee camps.

Salmonella. *Salmonella* strains are medically important intracellular gram-negative facultative anaerobic foodborne pathogens *(5, 17)*. *Salmonella enterica* subsp. *enterica* is the species of most global concern to both animal and human health *(17)*. In humans, *S. enterica* can invade the intestinal epithelium in the ileum and colon causing gastroenteritis or can spread to systemic sites causing sepsis *(17)*. The disease and clinical signs in humans depend largely on the serovar and host susceptibility *(9)*. *Salmonella* serovars are grouped as nontyphoidal *(45, 46)* and typhoidal. Approximately 11 to 20 million people are sickened and 128,000 to 161,000 die from typhoid fever (caused by *S. enterica* serovar Typhi) each year globally, although morbidity and mortality is significantly greater in low- and middle-income countries *(2)*. *Salmonella* Typhi is typically spread through contaminated food or water and enters the bloodstream of the host *(46),* causing an acute, systemic, life-threatening infection characterized by prolonged fever, headaches, anorexia, lethargy, constipation, and diarrhea. Antimicrobial therapy is typically needed to effectively treat infections *(24)*. Increasing antibiotic resistance among *Salmonella* strains is allowing typhoid fever to spread more rapidly, especially in overcrowded communities and communities with flooding or subpar sanitation systems, which are common conditions in refugee camps *(46)*.

Despite the potential public health impact, only 2 of the 11 articles identified in this review focused on *Salmonella* Typhi in refugee camps, and both studies were conducted by the same research group as part of an extended epidemiological investigation of typhoid fever in Rwanda *(23, 24)*. One article was a report of a retrospective case-control study conducted to identify risk factors associated with the transmission of *Salmonella* Typhi in the Mahama Refugee Camp *(24)*. In the other study, a cross-sectional survey was used to evaluate knowledge, attitudes, and practices among refugees and to assess the effectiveness of typhoid fever preventive interventions *(23)*.

In 2016, a matched case-control retrospective study was conducted after a typhoid fever outbreak in Rwanda's Mahama Refugee Camp to characterize and identify risk factors for the outbreak *(24)*. Medical records from the camp health facility were used to identify 1,894 suspected cases of typhoid fever among the camp's 48,000 residents. Systematic random sampling was used to select 260 cases and 770 controls matched on age, gender, and neighborhood for participation in the study. A structured questionnaire was used to collect data on sociodemographic characteristics, symptoms, and potential risk factors. Convenience samples of water from household storage cans and water reservoirs in the refugee camp and food and beverage samples from the markets were also collected and tested. Having a family member infected with *Salmonella* Typhi in the previous 3 months (OR = 2.65; CI: 1.84 to 3.79), poor or inconsistent hand washing after using the latrine (OR = 1.78; CI: 1.21 to 2.62), poor knowledge about how to prevent and control typhoid fever (OR = 1.63; CI: 1.12 to 2.38), eating food prepared at home (OR = 2.75; CI: 1.53 to 4.96), and eating food at the community market (OR = 11.39; CI: 2.10 to 61.75) were all significant risk factors for typhoid fever. The information for this study was self-reported (or reported by caregivers for participants younger than 15 years old) retrospectively, so prevention and control measures implemented in response to the outbreak could have biased the results. Other enteric diseases have clinical signs similar to those of typhoid fever, so some cases may have been misclassified as typhoid fever; however, the researchers increased the ratio of controls to cases from 2 to 3 to adjust for this limitation.

In conjunction with the case-control study, a cross-sectional survey was conducted in the same population to assess the knowledge, attitude, and practices and to evaluate the effectiveness of typhoid fever preventive interventions *(23)*. A total of 671 cases and controls responded to the questionnaire, which consisted of mostly close-ended questions and was delivered via interview in Kinyarwanda, a language commonly understood among individuals from Burundi and Rwanda. The study team also conducted environmental assessments during which they observed participants' sanitation and hygiene practices. Respondents who spent <6 months in the refugee camp and those >35 years old were less likely to wash their hands before eating (OR = 1.86, CI: 1.17 to 2.96 and OR = 1.47, CI: 1.01 to 2.16, respectively) or after using the latrine (OR = 2.24, CI: 1.4 to 3.61 and OR = 1.47, CI: 1.05 to 2.32, respectively), whereas employed respondents were more likely to wash their hands (OR = 0.48, CI: 0.32 to 0.70). Participants who resided in the refugee camp for 6 months were less likely to have heard about typhoid fever and know how the disease was transmitted or prevented (OR = 1.8; CI: 1.25 to 2.58), whereas participants with primary school and high school education were more likely to have this knowledge (OR = 0.50; CI: 0.34 to 0.72). Only 25% of participants had received health education about typhoid fever prevention. Overall results indicated low knowledge levels and poor attitudes about typhoid fever but high self-reported percentages of hand washing before eating and after restroom use. However, the environmental assessments revealed that hand washing practices were subpar and not compliant with the World Health Organization (WHO) recommendations, potentially adding to persistent transmission of *Salmonella* Typhi in the refugee camp.

In refugee camps, lack of access to safe water increases the risk of *Salmonella* infections. Poor hand washing and food preparation practices and the location of temporary shelters near possibly contaminated water sources add to the challenge of controlling *Salmonella* Typhi in refugee camps. Even when disease prevention methods and hand washing stations are provided, proper education and targeted outreach is needed to mitigate the risk of infections and outbreaks. Adequate food safety education and control interventions are needed in refugee camps to control infections. Studies should be conducted as early as possible in an outbreak to identify the parties responsible for food preparation and water gathering. Although the studies reviewed included evaluation of the incidence of *Salmonella* Typhi, they did not include evaluation of the incidence of nontyphoidal *Salmonella* serovars that are known public health risks. Nontyphoid *Salmonella* serovars are major contributors to foodborne disease worldwide and likely contribute to the considerable disease burden in refugee camps *(18)*. More studies are needed to determine the prevalence of nontyphoid *Salmonella* in refugee camps.

HEV. HEV is a nonenveloped RNA virus that causes the liver disease hepatitis E. HEV causes an estimated 20 million infections annually, leading to 44,000 deaths *(44),* and is the leading cause of acute hepatitis in low- and middle-income countries, especially in Africa and Asia *(35)*. The virus infects the liver, but infected individuals are typically asymptomatic. When clinical signs develop, the disease is often self-limiting and characterized by fever, loss of appetite, nausea, vomiting, jaundice (yellowing of the skin), and an enlarged and tender liver *(14)*. In rare cases, HEV can cause acute liver failure, and the risk of mortality from HEV infection is high for pregnant women in the third trimester *(35)*. Identification of the source of HEV infections is challenging. Clinical signs of HEV infection are not distinguishable from those of other forms of hepatitis. The incubation period is 2 to 10 weeks, making source tracing difficult during an outbreak, and routes of transmission differ by region. In areas with poor sanitation and limited water treatment systems, HEV can contaminate water sources and be transmitted through the fecal-oral route *(42, 48)*. In regions with low HEV prevalence, water treatment systems eliminate the virus from the drinking water supply, and outbreaks are uncommon.

As for the other pathogens, HEV studies in refugee camps are scarce. Of the 11 studies identified, only 3 included investigations of hepatitis E outbreaks *(1, 7, 32)*. Two studies included the epidemiologic and laboratory findings for cases of acute jaundice syndrome identified during a hepatitis E outbreak in the Dadaab Refugee Camp in Kenya and suspected hepatitis E cases during an outbreak among refugees in the Gambella region in Ethiopia *(1, 7)*. The third study included a cross-sectional survey conducted

to evaluate the coverage and use of water treatment and hygiene interventions during a hepatitis E outbreak in Chad *(32)*.

In 2012, an epidemiology study was conducted to describe an outbreak of acute jaundice syndrome in the Dadaab Refugee Camp in Kenya and in two nearby villages *(1)*. Of the 339 identified affected individuals, 170 were tested for HEV immunoglobulin M, and 131 (77.1%) of these tests were positive. Control measures such as training of health care workers, increasing community awareness, improving hygiene promotion activities, and speeding up latrine construction were initiated, and the outbreak ended. Unfortunately, violence and the resulting danger to aid workers prevented an evaluation of the effectiveness of the interventions.

From 2014 to 2015, an outbreak of 1,117 suspected hepatitis E cases was identified in a refugee camp in the Gambella region of Ethiopia *(7)*. Passive surveillance of health facilities, active community screenings at mass food distributions, and household visits were conducted as part of the outbreak investigation. The number of cases peaked during the rainy season, suggesting waterborne transmission. Very few cases were laboratory confirmed; only 21 individuals were tested for HEV RNA, and 57% were positive. The outbreak was hypothesized to be limited by high levels of immunity, improved sanitation, and early detection through community screening, but no studies were completed to confirm this hypothesis.

In 2016, a cross-sectional survey was conducted following a hepatitis E outbreak in Chad to examine the coverage and use of hygiene and water treatment interventions in a refugee camp that houses 50,000 residents *(32)*. Surveyors interviewed randomly selected women from 395 households who self-identified as overseeing water collection. Study participants were interviewed with structured questionnaires in their homes and received a hygiene kit as a part of the study (99%). Before receiving the intervention, 17% of study participants refused chlorination of water, citing religious beliefs that only natural water sources should be used for washing before prayer. Subsequent engagement of religious leaders improved acceptance of chlorinated water, and 97% of respondents reporting acceptance of chlorination of the water. Subsequent testing of free residual chlorine (FRC) concentrations in the drinking water storage container was used to determine whether the water in the home was chlorinated. Despite the high self-reported acceptance of chlorinated water, spot checks for sufficient FRC revealed detectable concentrations in only 43% of the households. Water obtained from private wells were also more likely than other sources to have safe FRC concentrations. Participants who poured water into a previously empty container rather than a partially full container were more than twice as likely to have water with safe FRC concentrations. Those participants who sourced the water <18 h before the test was conducted had a significantly higher likelihood of safe FRC concentrations than did participants who sourced the water >18 h before the test. The study did not have a baseline for FRC concentrations, so the effectiveness of the intervention could not be evaluated.

Available research has indicated that although hepatitis E outbreaks are occurring in refugee camps, little is known about the sources of the outbreaks or the effectiveness of intervention strategies. None of the studies identified the source of the HEV, which is important for understanding where to focus intervention strategies to prevent future hepatitis E outbreaks. Future research on the effectiveness of interventions must consider program design, program implementation, and community preferences to effectively reduce the risk of disease *(47)*. None of the identified articles included an examination of the role of food in hepatitis E outbreaks even though HEV has been identified as an emerging foodborne pathogen *(12)*. In all three studies, interventions were used to mitigate the outbreaks, but the effectiveness of these strategies was not formally evaluated. More research on the effectiveness of interventions is needed to reduce the risk of hepatitis E outbreaks in refugee camps.

BURDEN OF FOODBORNE DISEASE

Quantification of the burden of foodborne disease is critical to developing policy measures aimed at reducing foodborne disease. For example, the WHO estimates that 31 foodborne pathogens cause 600 million foodborne illnesses, 420,000 deaths, and 33 million lost healthy life years globally each year *(13)*. These burden estimates, which are comparable to the burden of malaria and tuberculosis *(43),* have garnered significant attention and motivated the Africa Union and the World Trade Organization to host meetings on food safety for the first time.

Studies of the burden of foodborne disease in refugee camps are scarce, as evidenced by the dearth of studies identified in this review. Related analysis on the burden of disease in refugee camps due to inadequate access to clean water and necessary sanitation facilities have focused on cases of diarrhea but did not include analysis of particular foodborne diseases or cost of illness estimates *(10)*. In one study conducted in Croatia, researchers examined the incidence and cost of foodborne diseases in the country from 1986 to 1992, which included 474 outbreaks in refugee camps in 1992 resulting in 1,585 illnesses *(26). Salmonella* was the predominant cause of the illnesses, accounting for 736 of the 1,585 illnesses. Of the 474 outbreaks, 161 (34%) were associated with a specific food vehicle. Of those 161 outbreaks, 115 (71%) were associated with consumption of beef, 19 (12%) with chicken, and 27 (17%) with minced meat. Although the authors estimated the cost of foodborne disease in Croatia to be 2 million USD, the cost of foodborne disease in refugee camps was not estimated.

Foodborne disease outbreaks from pathogens including *V. cholerae, Salmonella,* and HEV are occurring in refugee camps, but no published literature on the burden of foodborne illness in refugee camps was found. Estimates of this burden (e.g., in terms of quality-adjusted life years or disability-adjusted life years) and the costs associated with foodborne disease in refugee camps represent a substantial

opportunity for future research. Estimates would aid in policy development to address the needs of refugees and prevent foodborne illness in refugee camps.

CONCLUSIONS

The epidemiology of foodborne disease in refugee camps is not well understood. Outbreaks of diseases caused by *V. cholerae, Salmonella,* and HEV in refugee camps have been reported in the published literature, but such publications are limited and most are not recent. The studies reviewed addressed the epidemiology of select foodborne pathogens and the effectiveness of interventions such as proper sanitary conditions, access to clean water, and education. Limitations of the studies, such as misclassification of asymptomatic cases, recall bias, and ability to conduct research on site, have prevented conclusions from being drawn about the effectiveness of interventions and source(s) of illness in some cases. The food safety knowledge, attitudes, and practices of refugees need further research to develop a more complete understanding of the current challenges facing refugees for ensuring food safety and better targeting intervention strategies. Estimates of the burden of foodborne disease in refugee camps are needed to catalyze policy development to prevent and treat foodborne illness in refugee camps and to inform the allocation of resources, including funding for future research. To optimize resource usage for the prevention and control of outbreaks in refugee camps, more studies are needed to understand the epidemiology of foodborne disease in refugee camps and to identify effective intervention strategies for mitigating food safety risks.

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