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INVESTIGATING THE RISK FACTORS FOR NON TYPHOIDAL SALMONELLA IN PEDIATRIC POPULATIONS: A SYSTEMATIC REVIEW

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ABSTRACT
The risk factors for non-typhoidal Salmonella infections in pediatric populations are not fully understood, but this remains a critical area of study for improving child health. The aim of this review is to systematically analyze the available literature about the risk factors of non typhoidal salmonella among pediatric populations. The risk factors for non-typhoidal Salmonella infections in children were examined in all papers published between 2019 and 2024 using a systematic review of the literature using PRISMA criteria. Google Scholar, PubMed, and ProQuest are the three electronic databases that the writers searched. The query "children" AND "risk factors" AND "non-typhoidal salmonella" OR "salmonellosis" was used. The outcomes were then examined appropriately. We initially identified 1983 articles and subsequently selected 7 articles that met the inclusion criteria. We identified several risk factors associated with non-typhoidal Salmonella infections and categorized them into four domains: environmental factors (such as open field waste disposal), behavioral habits (like inadequate handwashing), health conditions, and socio-demographic characteristics (such as lower parental education). Our review identified risk factors for non-typhoidal Salmonella infections in four domains: environmental factors, behavioral habits, health conditions, and socio-demographic characteristics.

Keywords: children; risk factors; non-typhoidal salmonella; salmonellosis

INTRODUCTION
A foodborne illness that is quite prevalent worldwide is non-typhoidal Salmonella infection. Human diarrheal enterocolitis is typically caused by non-typhoidal salmonella, although it can also result in severe invasive non-typhoidal infections (Ke et al., 2020). Non-typhoidal Salmonella invasive disease is a significant contributor to worldwide morbidity and mortality, representing a major public health challenge. This condition leads to severe illness and death across various populations, underscoring the urgent need for effective prevention and control measures on a global scale (GBD 2017 Non-Typhoidal Salmonella Invasive Disease Collaborators, 2019). Salmonella enterocolitis was projected to have caused 95·1 million cases (95% uncertainty interval [UI] 41·6–184·8), 50 771 deaths (2824–129 736), and 3·10 million DALYs (0·39–7·39) in 2017 by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2017 (Global Burden of Disease Study 2017, 2018a, 2018b, 2018c).

Children—especially young children—were the group most likely to contract non-typhoidal salmonella, according to earlier research. non-typhoidal salmonella is the primary cause of bacteremia, particularly in young children, those infected with HIV, those suffering from malnutrition, anemia, or malaria (Uche et al., 2017; Wang et al., 2018). Children's non-typhoidal salmonella infections continue to pose a major cost to healthcare systems and the global public health concern (Chen et al., 2023). Humans can contract non-typhoidal salmonella from environmental exposures and contaminated food consumption. unpasteurized milk cheese, raw veggies, undercooked beef, pig, eggs, and other fowl items are common food sources of non-

typhoidal salmonella infections. there have been occasional reports of non-typhoidal salmonella infection transmission by water, however it is uncommon. a number of outbreaks indicate a close correlation between non-typhoidal salmonella infections and food, water, and direct or indirect contact with sick animals or their surroundings (Mukherjee et al., 2020).

Previous studies have examined the risk factors associated with non-typhoidal salmonella infections in children, yet there is still a significant gap in comprehensive review studies on this topic. a systematic review is crucial as it synthesizes existing research, providing a holistic understanding of the risk factors and their interrelations. Such a review can highlight inconsistencies, identify gaps in current knowledge, and suggest directions for future research. By consolidating findings from multiple studies, this review aims to offer a more robust evidence base to inform public health strategies, improve prevention efforts, and enhance clinical interventions for children under five years old. Therefore in this review study, we aimed to elucidate the various risk factors associated with non-typhoidal Salmonella infections in children under five years old.

METHOD

In compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria, this systematic review was carried out. The authors utilized the search terms "children" AND "risk factors" AND "non-typhoidal salmonella" OR "salmonellosis" to search three electronic databases: Google Scholar, PubMed, and ProQuest. There were n = 1983 articles discovered in total. Initially, studies of any degree of evidence presenting clinical or preclinical results published in the recent five years (2019–2024) and addressing the risk factors of non-typhoidal salmonella among pediatric populations were the inclusion criteria that were used to screen the titles and abstracts. Every article published in a language other than English was disqualified. Every publication that addressed unrelated subjects, had a clear abstract, or used subpar scientific methods was eliminated.

RESULTS AND DISCUSSION

A total of 1983 articles were initially identified through our search. Following an initial screening process, we narrowed this down to 15 articles deemed suitable for full-text review. Upon thorough examination of these articles, 7 met all the inclusion criteria and were included in the final analysis. The selection and screening process is detailed in a PRISMA flowchart shown in Figure 1. Additionally, reference lists of the selected papers were examined to ensure comprehensive coverage of relevant studies. The chosen articles (Das et al., 2021; Dessale et al., 2023; Lee et al., 2021; Mbae et al., 2020; Muse et al., 2024; Peter et al., 2023; Woh et al., 2021) highlight various factors linked to non-typhoidal Salmonella infections in pediatric populations. These factors are summarized and presented in Table 1.

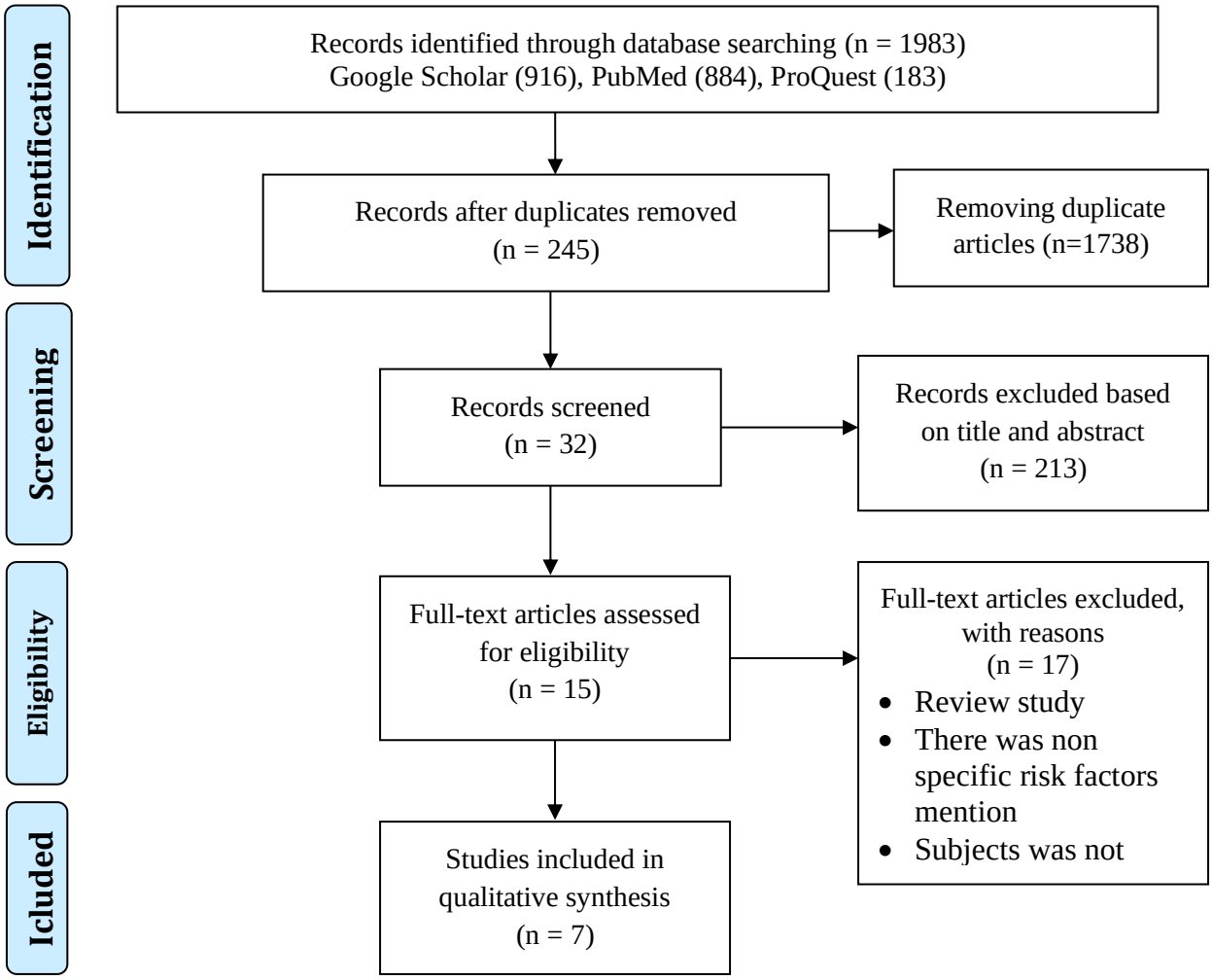

Figure 1. Search Results of Research Articles with PRISM Flow Diagrams

The authors conducted a comprehensive review of numerous risk factors identified in the primary studies. These risk factors were systematically categorized into four distinct domains: environmental factors, behavioral habits, health conditions, and socio-demographic characteristics. Environmental factors include disposing of waste in open fields (Muse et al., 2024), living in a rural area (Muse et al., 2024), having an unimproved source of drinking water (Dessale et al., 2023; Muse et al., 2024), using the public municipal tap to wash clothes (Peter et al., 2023), and having homes that use water pots as water storage containers (Mbae et al., 2020), use of pit latrines and open defecation (Mbae et al., 2020), having animals such as goats, cows, or chickens in the home (Das et al., 2021; Peter et al., 2023). Behavioral habits consist of handwashing and handwashing after touching animals (Das et al., 2021; Muse et al., 2024), child nail clipping is done seldom (every two weeks or less) (Dessale et al., 2023), preserving cooked food for later usage as a habit (Dessale et al., 2023), participation of the young person in social event (Dessale et al., 2023), kids who ate street food four or more times a week (Mbae et al., 2020), consuming food that has been bought from sources other than supermarkets, such as a restaurant, farm, or wet market (Woh et al., 2021), and consumption of raw meat (Muse et al., 2024).

Stunting (Das et al., 2021), longer duration of diarrhea (Das et al., 2021; Lee et al., 2021), lower C-reactive protein level, lower hemoglobin level or anemia, and longer fever duration (Das et al., 2021; Lee et al., 2021) are among clinical factor that associated with Non-typhoidal Salmonella. According to Dessale et al., 2023, parent/guardian educational status in elementary school or lower and the presence of two or more children under the age of five in the home are among the sociodemographic characteristics linked to Salmonella not-typhoidal. In this review, we identified several factors associated with non-typhoidal Salmonella in children. Some environmental factors included the presence of animals in the house, households that using open fields for waste disposal, households that living in rural areas, households that using unimproved water sources, households that using water pots as water storage containers, or households that using pit latrines and open defecation. Animals in the household can be reservoirs for Salmonella, facilitating direct transmission to humans through contact or indirectly through contamination of food and water sources (Das et al., 2021). Open field waste disposal and the use of pit latrines and open defecation can contaminate soil and water, increasing the risk of fecal-oral transmission of Salmonella bacteria (Mbae et al., 2020). Living in rural areas often correlates with limited access to clean water and sanitation infrastructure, leading to higher exposure to contaminated water and food sources (Muse et al., 2024). Unimproved water sources and the use of water pots as water storage containers can lead to contamination with pathogens, including Salmonella, due to inadequate water treatment and poor storage practices (Dessale et al., 2023)

A number of behaviors linked to non-typhoidal Salmonella in children include not washing hands often enough, rarely trimming children's nails, freezing cooked food for later use, bringing kids to social events, eating street food four or more times a week, consuming food purchased from places other than supermarkets, like restaurants, farms, or wet markets, and consuming raw meat. Not washing hands often enough can lead to the transfer of Salmonella bacteria from contaminated surfaces to the mouth, especially after handling raw meat or touching animals (Das et al., 2021). Rarely trimming children's nails can result in bacteria accumulating under the nails, which can then be transferred to the mouth or food (Dessale et al., 2023). Freezing cooked food for later use without proper reheating can allow Salmonella bacteria to survive and multiply if the food is not stored or reheated correctly (Dessale et al., 2023). Bringing children to social events increases their exposure to other children and adults, potentially facilitating the spread of bacteria through contact or shared food (Dessale et al., 2023). Eating street food four or more times a week and consuming food from places other than supermarkets, such as restaurants, farms, or wet markets, can increase the risk of exposure to contaminated food, as these sources might have lower hygiene standards and inconsistent food safety practices (Mbae et al., 2020; Woh et al., 2021). Lastly, consuming raw meat is a direct route for ingesting Salmonella bacteria, which can lead to infection (Muse et al., 2024).

Table 1.
Description of Primary Studies

No	Author names (Year)	Study Design	Study Location	Sample Size	Population	Risk Factors Identified	Outcome
1	Das et al., (2021)	Prospective case–contro	sub-Saharan Africa and South Asia	1,512	Children under age 5 years with Non-typhoidal Salmonella infection in sub-Saharan Africa and South Asia	• The presence of goat or cow in the house • Handwashing after handling an animal • Stunting • Longer duration of diarrhea	Non-typhoidal Salmonella moderate-to-severe diarrhea
2	Dessale et al., (2023)	Cross-sectional	Ethiopia	222	Under-five diarrheic children	• Parent/guardian educational status ≤ elementary school • Presence of two or more under-five children in the family • Unimproved source of drinking water • The habit of storing cooked foods for later use • Attendance of the child at social gatherings • Infrequent child fingernail trimming (every ≥ 2 weeks)	Culture-confirmed Salmonella and Shigella
3	Mbae et al., (2020)	A house-to-house baseline census	Kenya	16,236	Children less than 16 years of age	• Households that used water pots as water storage containers • Use of pit latrines and open defecation • Children eating street food 4 or more times per week was higher	Salmonellosis
4	Muse et al., (2024)	Cross-sectional	Ethiopia	239	Children under-five children with diarrhe	• Unimproved water source • Open field waste disposal habit • Rural residence • Hand-washing practice • Raw meat consumption	Occurrence of Salmonella and Shigella species
5	Lee et al., (2021)	Retrospective study	Taiwan	569	Inpatient children with nontyphoidal salmonellosis from 2010 to 2018	• Longer fever duration • Longer diarrhea duration • Lower CRP level • Lower hemoglobin level and anemia	Community-acquired Salmonella bacteremia

6	Peter et al., (2023)	Cross-sectional case-control	Kenya	382	Children aged 0-5 years	• Used public municipal tap as water source for washing • Keeping animals and the chicken count	Non-typhoidal Salmonella
7	Woh et al., (2021)	Case-control	Hong Kong	102 cases and 204 control	Cases were children aged above 30 days to below 5 years hospitalised for gastroenteritis at three public hospitals in Hong Kong with culture confirmed non-typhoidal Salmonella infection. Controls were age-matched (±2 months) children admitted for a reason other than gastroenteritis	Having food purchased from places other than a supermarket, that is from wet market/restaurant/farm	Non-typhoidal Salmonella gastroenteritis

Physical condition such as stunting, longer duration of diarrhea, lower C-reactive protein level, lower hemoglobin level or anemia, and longer fever duration also associated with non-typhoidal Salmonella in children. Stunting, a sign of chronic malnutrition, can weaken the immune system, making children more susceptible to infections, including NTS (Das et al., 2021). Longer duration of diarrhea can lead to severe dehydration and further compromise the child's immune response, exacerbating their vulnerability to infections (Das et al., 2021; Lee et al., 2021). Lower CRP levels, a marker of inflammation, may indicate an inadequate immune response to infection (Lee et al., 2021). Lower hemoglobin levels or anemia reduce the oxygen-carrying capacity of the blood, leading to fatigue and weakening the body's ability to fight off infections (Das et al., 2021). Lastly, a longer duration of fever often signifies a prolonged inflammatory response, which may indicate a severe or unresolved infection, such as NTS (Lee et al., 2021). Having parent or guardian who has educational status in elementary school or lower and the presence of two or more children under the age of five in the home also associated with non-typhoidal Salmonella in children. Parental educational status is linked to knowledge of and adherence to hygiene practices and food safety measures, influencing the risk of NTS infections (Dessale et al., 2023). Larger household size with multiple young children increases the likelihood of exposure to contaminated food, water, and living environments, contributing to higher infection rates (Dessale et al., 2023).

CONCLUSION

In conclusion, our review systematically categorized numerous risk factors associated with non-typhoidal Salmonella infections into four domains: environmental factors, behavioral habits, health conditions, and socio-demographic characteristics. Environmental factors such as open field waste disposal, rural residence, and the use of unimproved sources of drinking water were

consistently linked with increased risk. Keeping animals like goats, cows, or chickens in the home also emerged as significant environmental risks. Behavioral habits, such as inadequate handwashing practices, infrequent child fingernail trimming, and the habit of storing cooked foods for later use, were also identified as contributing factors. Additionally, socio-demographic characteristics such as lower parental educational status and having multiple under-five children in the household were associated with increased risk. Clinical factors including stunting, longer duration of diarrhea, lower CRP levels, lower hemoglobin levels or anemia, and longer fever durations were found to be clinical markers associated with non-typhoidal Salmonella infections. To mitigate the risk of non-typhoidal Salmonella infections in pediatric populations, public health efforts should focus on improving environmental sanitation, promoting proper handwashing practices, and educating communities on safe food handling and storage. Additionally, targeted interventions should address socio-demographic factors such as educational attainment and household composition. By addressing these factors comprehensively, we can work towards reducing the burden of non-typhoidal Salmonella infections among children.

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