Review

Risk Factors for Typhoid Fever: Systematic Review

Portia Boakye Okyere[1], MPhil; Sampson Twumasi-Ankrah[2], PhD; Sam Newton[1], PhD; Samuel Nkansah Darko[3], PhD; Michael Owusu Ansah[4], MD; Eric Darko[5], MSc; Francis Agyapong[5], MD; Hyon Jin Jeon[6], MPH; Yaw Adu-Sarkodie[5], PhD; Florian Marks[6,7,8,9], PhD; Ellis Owusu-Dabo[1], PhD

[1]School of Public Health, College of Health, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[2]Department of Statistics and Actuarial Science, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[3]Department of Molecular Medicine, College of Health, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[4]Community Health, College of Health, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[5]Department of Clinical Microbiology, College of Health, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[6]International Vaccine Institute, Seoul, South Korea, Republic of Korea
[7]Madagascar Institute for Vaccine Research (MIVR), University of Antananarivo, Antananarivo, Madagascar
[8]Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden
[9]Heidelberg Institute of Global Health, University of Heidelberg, Heidelberg, Germany

Corresponding Author:
Portia Boakye Okyere, MPhil
School of Public Health
College of Health
Kwame Nkrumah University of Science and Technology
KNUST-SPH, SMS PMB
Kumasi, 233
Ghana
Phone: 233 266075051
Email: portiaboky@gmail.com

Abstract

Background: Typhoid fever, a significant global health problem, demonstrates a multifaceted transmission pattern. Knowledge of the factors driving its transmission is critical for developing effective control strategies and optimizing resource allocation.

Objective: This review aimed to comprehensively synthesize evidence on risk factors associated with typhoid fever transmission from 1928 to 2024.

Methods: We searched PubMed, Scopus, Google Scholar, and Semantic Scholar databases using keywords related to risk, contributors, determinants, and causes of typhoid fever. We followed a registered protocol to support our search and triangulated the results.

Results: Overall, we retrieved 1614 articles, of which 219 were reviewed. Of these, 109 addressed multiple, non–mutually exclusive typhoid fever risk factors. Unsurprisingly, of the total articles reviewed on risk factors, approximately 70.6% (77/109) originated from the Asian continent (51/109, 46.8%) and the African continent (26/109, 23.9%). Half of the articles (55/109, 50.5%) focused on risk factors related to demographic and socioeconomic transmission, while 44% (48/109) of the articles examined foodborne transmission. Additional risk factors included water, sanitation, and hygiene practices: waterborne transmissions (45/109, 41.3%) and sanitation and hygiene practices (34/109, 31.2%), travel-related risk (19/109, 17.4%), antimicrobial use (14/109, 12.8%), climate-related factors (15/109, 13.8%), environment-related factors (9/109, 8.3%), typhoid carriers (11/109, 10.1%), and host-related risk factors (6/109, 5.5%).

Conclusions: This review identifies demographic and socioeconomic factors as key drivers of typhoid transmission, underscoring the need for targeted interventions. Strengthening street food regulation in urban Asia and investing in water infrastructure in rural Africa can significantly mitigate risk. Integrating water, sanitation, and hygiene interventions with typhoid vaccines can reduce immediate exposure while enhancing long-term immunity. Prioritizing these strategies in schools and high-risk communities is essential for sustainable typhoid control. Future research should focus on longitudinal studies to assess risk factor causality and vaccine impact, guiding more effective public health interventions.

(JMIR Public Health Surveill 2025;11:e67544) doi: 10.2196/67544

KEYWORDS
typhoid fever; risk factors; foodborne; waterborne; systematic review

Introduction

Background

Typhoid fever is a potentially fatal febrile systemic disease caused by *Salmonella enterica* serotype Typhi (*Salmonella* Typhi or *S* Typhi), a rod-shaped gram-negative bacterium belonging to the Enterobacteriaceae family. *S* Typhi exists exclusively in humans and causes illnesses (typhoid fever) that resemble many other febrile diseases [1]. In this study, the terms "typhoid fever" and "typhoid" are used interchangeably. A description of the infection was reviewed by Cunha [2], clearly separating it from other febrile illnesses and associating its clinical manifestation with significant pathological abnormalities in the spleen, mesenteric lymph nodes, and intestines. Nonetheless, the mainstay of diagnosis is a microbial culture, usually with blood or bone marrow samples. Although bone marrow culture is highly sensitive, it is both invasive and technically unfeasible in most settings. As a result, the disease is usually diagnosed with blood culture, despite its limited sensitivity of approximately 40% to 80%, partly due to antibiotic exposures before the patient visits the health facility [3].

The disease transmission is by the fecal-oral route and can take 2 main forms: direct transmission, where food and water in the immediate environment are contaminated through poor hygiene and sanitation practices, either by transient or chronic carriers; and indirect transmission, where the broader environment becomes contaminated when sewage pollutes water supplies, raw human feces or untreated sewage is used as fertilizer for crops, or piped water is inadequately treated [4].

Typhoid fever is reported to affect people of all ages, although children are more susceptible than other age groups [5]. Before 2000, the global burden of typhoid fever was estimated at 16 million illnesses and 600 thousand deaths annually [6]. In 2000, approximately 21.7 million illnesses and 216,000 deaths occurred [7]. By 2010, annual estimates indicated approximately 26.9 million cases and 200,000 fatalities [8]. However, a more recent estimate from 2017 to 2024 suggests a decline in the annual incidence of typhoid cases [9,10]. Despite this decrease, typhoid fever remains a significant public health concern, particularly in areas with limited access to clean water and sanitation. Typhoid fever can be prevented and controlled concurrently with vaccinations and advancements in food safety, water quality, hygiene, and sanitation [11]. Three main generations of typhoid vaccines are presently approved for use by the World Health Organization (WHO): typhoid conjugate vaccines (TCVs), live attenuated Ty21a, and the unconjugated Vi polysaccharide vaccines [4]. The WHO strongly recommends using TCVs for all ages due to their superior immunological properties, suitability for use in younger children, and predicted longer period of protection above 2 years, which was a major limitation for using the Vi polysaccharide. However, to inform the choice of vaccination in a country, evidence is needed on both the scope of the problem and the risk factors contributing to disease transmission [11]. Despite notable progress in typhoid control, the disease remains a significant cause of morbidity and mortality to which billions of people worldwide are continuously exposed, particularly in Asia and sub-Saharan Africa.

Typhoid fever susceptibility involves multiple factors, each contributing through distinct transmission pathways. In endemic countries, knowledge of typhoid fever risk factors is critical for developing effective control strategies and allocating resources. Several epidemiological and modeled studies [12-14] have explored location- and time-specific risk factors for typhoid fever. In addition, various review studies have been undertaken to comprehensively understand and address the risk of typhoid across different transmission routes. For instance, Lee et al [15] used geospatial modeling to develop a typhoid risk index based on factors such as water sources, toilet facilities, and population density, providing insight into the geographical distribution of typhoid risk in impoverished countries. Similarly, Kim et al [16] investigated the relationship between observed incidence rates and geospatial covariates, such as access to improved water and sanitation, as well as broader health and environmental conditions influencing the transmission of *S* Typhi. Furthermore, Brockett et al [17] systematically reviewed case-control studies to uncover associations between water, sanitation, and hygiene (WASH) practices, food exposures, and typhoid fever. Similarly, Mogasale et al [18] conducted a meta-analysis spanning 1990 to 2013 to estimate the risk of typhoid associated with inadequate access to safe water. In addition, Wang et al [19], in a systematic review and meta-analysis, described the patterns of salmonellosis outbreaks in China from 1970 to 2023. Other reviews have examined specific aspects of typhoid transmission. For instance, the study by Ma et al [20] reviewed human genetic variants affecting susceptibility to enteric fever infection, while Levantesi et al [21] assessed the contribution of natural freshwater and drinking water as routes of *Salmonella* contamination from 2000 to 2010.

Objectives

While these studies provide valuable insights into different aspects of typhoid risk, a holistic synthesis of socioeconomic, environmental, and other factors remains lacking. Furthermore, previous reviews have often been limited in temporal scope or focused on specific transmission pathways. To address this gap, this study examined typhoid risk factors across a broader time frame (1928-2024) and incorporated a multidimensional perspective on transmission dynamics. By systematically integrating evidence from diverse sources, we aimed to provide a more comprehensive understanding of typhoid fever risk factors, which can inform targeted interventions to reduce typhoid incidence worldwide.

Methods

Search Strategy

We searched PubMed, Scopus, Google Scholar, and Semantic Scholar databases for articles published on risk factors for typhoid fever. The search was conducted in June 2023, and titles and abstracts from databases were downloaded and saved. Each database was searched using the following terms and keywords: risk factors, factors, contributors, determinants, causes, predictors, susceptibility factors, factors of exposures, predisposing factor, typhoid fever, typhoid, *Salmonella* typhoid, *Salmonella* Typhi, *S* Typhi, typhoid disease, typhoidal salmonellosis, and typhoidal *Salmonella*, and searches excluded terms related to perforation, complication, virulence, severity, and nontyphoidal infections. We placed no restrictions on the publication year, but the language was restricted to English. We followed a protocol adapted from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which was registered with the Open Science Framework in January 2024 [22] to structure our search. See Multimedia Appendix 1 for the PRISMA checklist. This study used published articles, and as such, permission from the institutional review board was not required.

Study Screening and Selection Criteria

We screened and selected studies on typhoid fever risk factors based on the inclusion and exclusion criteria summarized in Textbox 1.

Textbox 1. Inclusion and exclusion criteria for the desk review search strategy on typhoid fever risk factors.

Inclusion criteria

- Studies with confirmed S Typhi infections or outbreaks identified through the following: culture of bodily fluids or stool; polymerase chain reaction; Widal or other serological methods
- Epidemiological or modeled studies of any design

Exclusion criteria

- Studies on severe infections (complications and mortality)
- Studies that classified typhoid fever solely based on clinical indicators (ie, signs and symptoms) or with unclear diagnostic methods
- Studies involving nonhuman participants (animals, water, and farm produce)
- Articles whose full text was not available in English or those inaccessible

Further details on inclusion and exclusion criteria can be found in the review protocol [22].

The titles and abstracts retrieved from each database were imported into EndNote X8.2 (build 13302), merged into a single reference list, and duplicates were eliminated. The deduplicated list was then uploaded to a web-based systematic review tool, Rayyan (Qatar Computing Research Institute) [23] for title and abstract screening. All included citations were exported into Microsoft Excel (version 16.16.27) for full-text retrieval and screening. Each subsequent process, including title and abstract review, full-text review, and data extraction, was performed using predefined screening guidelines outlined in the screener instruction section of the review protocol [22] to ensure consistency. One author (PBO) performed the initial screening with supervision from coauthors (EO-D, SN, and ST-A). Discrepancies in the study selection were resolved through discussion among authors (PBO, EO-D, SN, and ST-A), with unresolved cases adjudicated by EO-D. Additional relevant articles were identified through other sources (expert input) and included after being assessed using the same eligibility criteria. Data were then extracted into Microsoft Excel and a shared Google Sheets spreadsheet (Google LLC; Multimedia Appendix 2). All authors reviewed the final dataset for completeness and accuracy.

Data Extraction

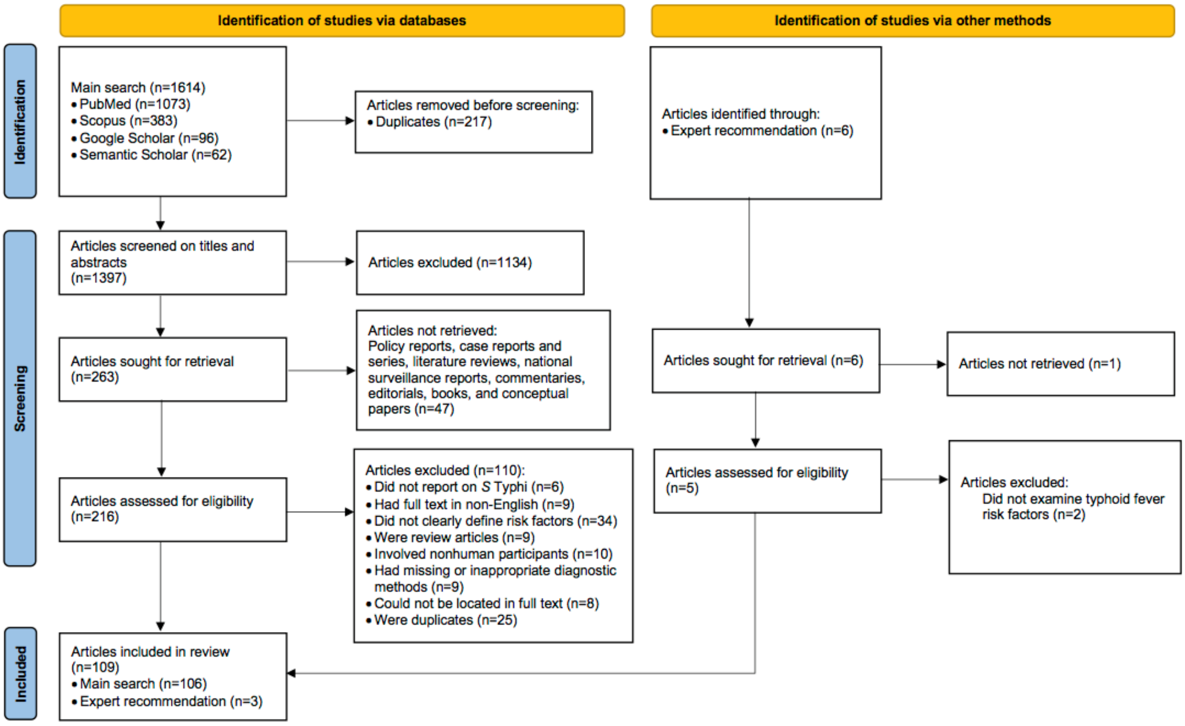
Electronic searches were performed using the internet to locate all eligible articles, and all relevant data relating to the research question were manually extracted into Microsoft Excel after reading the full text. The extracted data included specific risk factors for typhoid fever in all eligible articles. In addition, data on the route of transmission, sources of infection, year of publication, data collection period, town or district, country and continent of the study, study setting (outbreak or endemic), diagnostics method, study type, number of *S* Typhi cases, total participants enrolled, ages of participants, study design, and citations were extracted (Multimedia Appendix 2). We grouped the ages of participants into 3 categories based on inclusion age and age ranges: “children” were ≤15 years, “adults” were >15 years, and “mixed ages” were both children and adult participants. Information on typhoid fever susceptibility was grouped according to their transmission routes: waterborne and foodborne transmissions, host risk factors, vaccination, travel-related risk, health education, occupational risk, population growth and overcrowding, sanitation and sewage systems, climate and meteorological factors, antimicrobial resistance factors were extracted.

Results

Overview

Our search strategy initially identified 1614 articles published between 1928 and 2023. After removing 217 duplicates, 1397 titles and abstracts remained for screening. Of these, 1181 were excluded, with the majority (687 articles) not examining typhoid fever risk factors. After a full-text review of 219 articles from the main databases (216 articles) and expert recommendations (3 articles). Other reasons for exclusion included 25 duplicates of the same study published by different authors in different journals; 10 studies involving nonhuman participants such as farm-produced and water samples; 17 articles with non-English full texts or unavailable full texts; 6 articles not specifically related to *S* Typhi; and 9 articles with missing or inappropriate diagnosis based on recall typhoid fever episodes, unclear diagnosis, and clinical indicators (signs and symptoms). Furthermore, to avoid content duplication, 9 review articles were excluded, as shown in Figure 1. Finally, 109 published articles were included in this study [12-14,24-128] (Multimedia Appendix 2).

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of search strategies and article selection of risk factors for typhoid fever (2024).



Study Characteristics

Among the 109 eligible articles, data were extracted from publications spanning 1972 to 2024 (Multimedia Appendix 2), covering 6 continents: 24% (26/109) from Africa, 46.8% (51/109) from Asia, 0.9% (1/109) from South America, 8.3% (9/109) from North America, 10.1% (11/109) from Europe, and 6.4% (7/109) from Australia. Furthermore, 2.8% (3/109) of the articles collected data from mixed continents, while one article (1/109, 0.9%) relied on the GeoSentinel Surveillance Network database, lacking specific location details (Table S1 in Multimedia Appendix 3). Regarding transmission routes, multiple non–mutually exclusive typhoid risk factors were identified across the eligible articles (Table 1) for both common and specific risk factors. Waterborne transmission was reported in 41.3% (45/109) of the articles, while 44% (48/109) of the articles focused on foodborne transmission. Demographic and socioeconomic factors were identified in more than 50.5% (55/109) of the studies, with hygiene and sanitation discussed in 31.2% (34/109) of the studies. Additional risk factors included travel-related exposure (19/109, 17.4%), climatic influences (15/109, 13.8%), and antimicrobial use (14/109, 12.8%; Table S2 in Multimedia Appendix 3). Across 103 papers, 253,951 typhoid fever cases were reported, with a median (IQR) of 110 (51-283). The diagnosis was confirmed predominantly through culture in 84.4% (92/109) of the articles, with approximately 9% (10/109) of articles using Widal and other serological tests and 6.4% (7/109) of the articles using polymerase chain reaction and other sequencing techniques. Age distribution data were available in 103 articles. Most of the articles (83/103, 80.6%) included participants of mixed ages, while approximately (14/103, 13.6%) of the articles focused exclusively on those aged ≤15 years and 5.8% (6/103) of the articles focused on those aged >15 years (Table S1 in Multimedia Appendix 3).

Table 1. Common and specific risk factors for typhoid fever.

Common risk factors	Specific risk factors
Waterborne transmission	
Water sources	Household sources of drinking water [24,58], having multiple drinking water sources [68], using water from other sources than the municipal water networks for bathing, brushing teeth or drinking [112], primary water sources with unpleasant smell [37], obtaining water from an outside tap [46], unsafe water source [53,115], obtaining water from municipal pipe for drinking [107], obtaining water from a river or stream [12,115]
Water supply	Water supplied by an outdated gravity-fed network [53], intermittent water availability [12], inadequate safe water supply [14], defective water systems [113], household water supply from public wells and boreholes or merchants [98], water from a community [34], water from government overhead tanks [43]
Contaminated or unsafe water	Drinking unsafe or contaminated water [28,33,63,79,95], using substandard water [83], *Escherichia coli* in stored drinking water [79], water sold in small plastic bags [80], use of ice cubes from a street vendor [29,123]
Untreated water	Drinking water from a well [96], untreated household drinking water [37,46-48,70,120], use of untreated public water after rains [32], drinking water from untreated open sources [12,27,89], drinking water at the work site [34], use of bore water [107], accidental ingestion of contaminated river water during swimming or bathing [28], cooking and cleaning with river water or an open dug well [68]
Water storage	Storing water in plastic containers without a lid [98], not storing water for drinking in a narrow-mouthed container [38], not using tipped containers to draw water [38], water sold in small plastic bags [80]
Foodborne transmission	
Street stall or restaurant food	Eating out from commercial food stalls, restaurants, or mobile food vendors in the street or outside home [26,34,45,91,101,122], eating outdoors at least once a week [29,30,117], eating food from a roadside cabin during the summer [34], mothers eating food from street vendors [70], eating cold beverages outside home [45], not dining at a tea-house [47], consuming French fries with sauce and poppadum from street vendors [107], eating commercially available foods or drinks [120], eating food at community market [97]
Poor food hygiene	Eating unwashed farm produce [12], unwashed guavas [38], not washing vegetables before eating [47]
Food handlers	Consuming food items from vendors [108,122], male food handlers [40], consuming food with the mother's or caregiver's assistance [30], drinking orange juice with hand contact [50], poor or unhygienic food handling practices or procedures [14,100], eating food prepared at home [97]
Salads or other contaminated food	Eating contaminated foods [63], including cucumber salad [94], potato salad [114], lettuce salad [31], and raw salads (onion, cucumber, and tomato) [103]
Uncooked or raw food	Eating raw traditional foods such as cig kofte [31], raw onions and cabbage [38], raw milk and meat [58], uncooked shellfish [118], papaya [37], and unwashed guava [38]
Frozen food	Eating ice cream [30,34,49], ice cubes in beverages [29], frozen tropical fruit (mamey) shakes [84], and fresh ice cream during the hot season [13]
Milk products	Eating butter and yogurt [38], fresh yogurt made from cow and sheep in the summer [13], and homemade cheese [13]
Local or traditional food	consuming locally made beverages [80], eating locally prepared popsicles [103], and consuming locally prepared flavored beverages [103]
Other	Eating food brought by relatives from endemic areas [91], sharing food from the same plate [123], and sharing food plates [53]
Demographic, socioeconomic, hygiene, and sanitation factors	
Demographic background	Age [25,58,87,126], older age [39,86], younger age [33,42,59,82,108,109], sex of the individual [102,126], being female [108,121] or male [87,101], presence of preschool children in the household [103], young adult [121], demographic status [56], and low BMI [128]
Socioeconomic status	Poor or low socioeconomic status [25,56,76,83,104], attending a gathering [96], per capita disposable income of all residents, and per capita gross domestic product [102], unemployment or part-time work [29,128], being part of a nuclear family [49], wealth index [90], being a student [47], and attending school or daycare [68]
Education level	No or low educational level [27,48,120], educational level [58], years of schooling [90], students in conventional institutions of higher learning [102], and illiteracy rate [49,104,105]
Occupational risk	Mishandling of *S* Typhi samples by clinical microbiology laboratory staff [72]; medical and laboratory personnel and sewage workers occupationally exposed to *Salmonella* bacteria [91]; household member growing crops [68]; farmers [87,128]; rearing chicken or goats [92]; job-related cause [63]
Population growth and overcrowding	Rising or bigger household size [104,127], living in a crowded household [31], crowding poor living conditions [63], and increased population density [33,113]
Housing system or condition	Poor housing conditions [79]

Common risk factors	Specific risk factors
Hygiene and behavioral factors	Scarcity of soap near a hand washing facility [127], nonuse of soap for handwashing [12,49,69,108], nonuse of medicated soap [127], nonavailability of soap to wash hands after toilet use [68,104], a habit of not washing hands before cooking or after defecating [53], infrequent hand washing after latrine use [12,97], poor hand washing practices [105], occasionally or never washing hand with water and soap [26,122], never or rarely washing hands before preparing or handling food, and eating or feeding [29,30,120]
Water, sanitation, and hygiene (WASH) practices	Poor WASH practices [74], not living in a better WASH household [75,106]
Sanitation and sewage systems	Use of pit latrine [27,92], open defecation [92], improper disposal of solid waste [27], burst sewer pipes at home [96], living in houses with open sewers [29], visible urine or feces [53], poor sanitary practice [14,63,95,98,113], having home latrines [38], no toilets in the residence [108,115], poor excreta disposal [79], having unimproved or malfunctioning sanitation infrastructure [12], unsterilized water from the hospital disposal and residential sewage used to irrigate vegetable farmlands [110], inadequate public sewerage system [90], and poor toilet drainage soil [79].
Other	
Antimicrobial use	Frequent use of antimicrobials or history of antimicrobial use [34,47,55,62,63,76,81,101], chloramphenicol-resistant *S* Typhi strain [44,79], ceftriaxone-resistant *S* Typhi strain [119], multidrug resistant or extensively drug-resistant *S* Typhi strains [121], circulation of virulent *S* Typhi strain (H58-lineage) [60,103]
Host risk factors	Polymorphism in intronic variable number tandem repeat of IL-4 [35], presence of serum anti–*Helicobacter pylori* immunoglobulin G antibodies [49,109], history of chronic underlying disease [69], HIV infections [71], and haplotype of tumor necrosis factor locus from single nucleotide polymorphisms [124]
Typhoid carriers	Recent or close contact with a patient with confirmed or active typhoid fever [32,48,63,88,101,105], hospitalization of household member with febrile illness [68], history of typhoid fever infections [69], having typhoid carrier at home [65], recent typhoid fever case in the household [108], and having a housekeeper (a boy or girl) [120]
Vaccination	No or lack of vaccination [63,75,106], vaccine hesitancy [120], vaccine ineffectiveness [94], and poor vaccination coverage [103]
Health education	Lack of knowledge regarding typhoid fever contact [127] and poor awareness of typhoid fever disease [97]
Travel-related risk	Longer duration of stay in the endemic area [39]; returning from or visiting endemic countries [76,86,116,126]; visiting friends and relatives in endemic areas [39,73]; travel destination [64]; travel outside the United States, Sweden, or United Kingdom (international travel) [41,59,93,129]; Asian travelers [52]; children visiting friends and relatives in endemic places (particularly South Asia) [61,99]; recent travel to endemic areas [85,125]; transient male workers [82]; living in a metropolitan area [86]; urbanization [90]; and number of foreign tourists received (tourism) [102]
Environmental conditions or factors	Living in geographically lower elevation areas [42], neighbors to a typhoid fever case [54], potentially floodable areas [57], proximity to major rivers and creeks [57], housing (external condition) [79], a lack of agricultural land [115], hydrological catchment areas [119], residing closer to waterbodies, residing near typhoid study treatment centers [104], anthropogenic alteration of land cover and hydrology [78], and environmental factors [56]
Climate or meteorological factors	Seasonal variation or fluctuations [25,82,102,110], high temperatures during summer [103], rainfall [57,115], temperature and precipitation [111,115,126], high vapor pressure [115], rainy and harmattan seasons [36], extreme weather conditions [77], higher or hot temperatures [66,86], flooding [87], and wind speed [90]

Discussion

Principal Findings

This study synthesizes typhoid fever risk factors from 1928 to 2024; however, the included studies span from 1972 to 2024, as few earlier publications met the inclusion criteria. We have identified demographic and socioeconomic factors as the predominant pathways for typhoid fever transmission, with additional contributions from waterborne and foodborne routes, hygiene and sanitation, travel-related exposures, antimicrobial use, and typhoid carriers. These findings highlight the multifaceted nature of typhoid fever transmission and underscore the importance of targeted interventions. This evidence is crucial for clinicians, public health experts, and policy makers in designing effective control strategies and optimizing resource allocation, particularly in endemic regions.

Approximately 70.6% (77/109) of the reviewed articles collected data from Asia and Africa, where most developing countries are located. This aligns with the global burden of typhoid fever estimation, which shows that Asian and African countries bear the greatest burden [130]. The low number of articles in Europe, North America, and Australia can be attributed to the introduction of control programs such as the treatment of municipal water, pasteurization of dairy products, and strict food safety regulations [1,131]. Similarly, the lack of studies from South America can be attributed to the decline in typhoid burden, given the economic transition with improved water and sanitation in the area [1]. Despite the lower disease burden in these underrepresented regions (Europe, North and South America, and Australia), the risk factors identified in this study, such as socioeconomic, foodborne and waterborne transmission, and antimicrobial use, remain relevant to these regions. Emerging threats, including climate change, urbanization, and increased global travel, may contribute to the reemergence of typhoid in areas where it was previously controlled. In addition, the rise of antibiotic-resistant strains presents an ongoing challenge, underscoring the need for public health preparedness in these regions.

Waterborne Transmission

Water sources greatly impact the spread of typhoid fever, with protected wells and piped water classified as safe, while rivers, streams, and other unprotected sources are deemed unsafe [132]. This study identified several specific risk factors associated with typhoid fever and water sources, including having multiple drinking water sources [68], use of nonmunicipal water sources for various purposes [29,68,107], and main water sources with a foul smell [37]. Households with access to multiple water sources may be at increased risk of typhoid fever, particularly when they face challenges with potable water access such as limited supply hours, high tariffs, low-pressure, and long distances to collection points. These challenges often impede their ability to meet daily needs. Consequently, some households, particularly those located close to open dug wells, rivers, or streams, may use these alternative sources for bathing, cooking, or even drinking [115]. Although such sources offer convenience, they often lack chlorination and may be contaminated with fecal matter, thereby posing a risk for typhoid fever transmission.

A water supply system defect can facilitate the transmission of typhoid fever. Our study discovered a typhoid fever outbreak associated with a gravity-fed network [53], indicating a probable spread through an outdated mains system. This was attributed to low water pressure, insufficient chlorination, and fecal infiltration [12].

Furthermore, we uncovered an intermittent piped water supply as a risk factor for typhoid transmission. Intermittent piped water supply is a common challenge in many developing countries, potentially compromising water supply quality by allowing contaminants in nonpressurized pipes and creating negative pressure conditions that enable pathogens such as *S* Typhi to infiltrate the system [12,133]. Such interruptions often compel households to rely on water storage, which may introduce additional contamination risks, and to seek alternative sources that may not be microbiologically safe [12,29]. Sources such as government overhead tanks [43], community or public taps, and protected wells [34,115], which are often considered safe, can become contaminated due to environmental exposures, including industrial activities, sewage discharges, agricultural runoff, and animal waste [28,80]. Under these conditions, the presence of *Escherichia coli* (*E coli*) in drinking water is commonly regarded as an indicator of fecal contamination and, by extension, a potential risk factor for typhoid fever due to the possible presence of enteric pathogens [79]. However, the relationship between *E coli* and typhoid fever risk remains inconclusive. For instance, Karkey et al [134] observed a link between high *E coli* concentrations and the presence of *S* Typhi nucleic acids in drinking water, suggesting that *E coli* contamination may serve as a proxy for typhoid transmission risk. In contrast, Luby et al [34] found no significant difference in the levels of *E coli* in water samples between households with typhoid cases and control households, challenging the consistency of this connection. These discrepancies may stem from environmental conditions, regional differences in water treatment practices, and microbial competition. For instance, in settings with inadequate chlorination, *E coli* presence may serve as a proxy for recent fecal contamination, thereby increasing typhoid risk. Conversely, in areas with intermittent water supply and biofilm formation within pipes, *S* Typhi may persist independently of *E coli*, complicating its use as a universal indicator.

In addition, water storage practices emerged as a risk factor for typhoid fever in our study. Evidence suggests that the microbiological quality of water often deteriorates after collection, particularly during storage and handling [98]. The risk of contamination is influenced by the type of vessel used for storing or drawing drinking water. Wide-mouthed containers, in particular, are associated with a higher risk of infection due to their larger open surface area, which increases exposure to environmental contaminants and the likelihood of fecal contamination, compared to narrow-tipped or covered containers [38,98].

Moreover, the use of untreated water, both inside and outside the home, poses significant risks for typhoid fever transmission [27,32,48,89]. Although municipal water systems may incorporate filtration and chlorination, cross-contamination with *S* Typhi through wastewater intrusion remains a concern [46]. In such contexts, household-level water disinfection may be necessary to enhance water quality [37]. However, some households opt out of water treatment due to the perceived reliability of their water sources [98]. While water from piped or otherwise protected sources may contain insufficient bacteria to cause typhoid fever, untreated water from unprotected sources may carry high *S* Typhi levels, sufficient to cause clinical disease [28,34,47]. All the aforementioned risk factors are listed in Textbox 1.

Foodborne Transmission

Food serves as a highly efficient medium for the growth of *S* Typhi compared to water [34]. This study revealed specific risk factors indicating potential foodborne transmission of typhoid fever, with street stalls (restaurants) emerging as a major factor in this category. Street food stalls are typically small, with outdoor seating and without refrigerators or easy access to potable water or adequate facilities for washing food and utensils [29,34,45]. Therefore, persons who frequently consume food from such establishments are at increased risk of developing typhoid fever [29]. This increased risk may stem from using untreated or tap water stored or served in contaminated containers for food preparation and drinking purposes [45]. In addition, poor hygiene practices among street food vendors, including irregular handwashing [122], and the potential exposure to carriers of *S* Typhi further contribute to the risk of infection [135]. In addition, many of these food preparers and handlers in the street eateries lack adequate knowledge of safe food handling practices necessary to avert *S* Typhi infection transmission. Often, they operate without licenses or registration from food safety authorities; as a result, they are neither trained nor subject to regular inspections. Consequently, they may unknowingly share food and drinks using poorly cleaned cups and utensils among multiple clients [97,120]. Furthermore, this study discovered a relationship between the consumption of frozen foods, including ice cream [13,30,49], fruit shakes [84], and iced beverages [29], and typhoid fever. A potential source of contamination lies in the ice used by street vendors, who often purchase large blocks of ice produced from untreated water, typically intended for industrial use, such as fisheries, rather than for human consumption. Despite this, the ice is commonly served in drinks for customers. Notably, research has shown that *S* Typhi can survive in ice for extended periods, underscoring its potential role as a vehicle for transmission [29,45,122]. Moreover, iced drinks may be further contaminated by street vendors who are asymptomatic carriers of *S* Typhi during the distribution chain [29]. In contrast, dining at tea houses decreases the risk of typhoid fever, as customers are typically served boiled water and tea, practices that limit exposure to *S* Typhi through thermal inactivation of the pathogen [47]. In addition, consumption of uncooked or raw foods such as onions, milk, meat, shellfish, papaya, cabbage, and other traditional raw ingredients poses a considerable risk, as these items may harbor *S* Typhi if not properly handled or sourced [31,37,38,58,118]. For instance, failure to wash fruits and vegetables before consumption increases the risk of infection due to surface contamination [12,38,47]. Cross-contamination during meat handling is another concern; for example, using the same knives and cutting boards for both infected and uninfected meat in butcheries and restaurants. Similarly, if contaminated water is used to wash carcasses or clean food-contact surfaces, *S* Typhi may be introduced during processing [58]. Moreover, inadequate hygiene practices during milk processing may contribute to the contamination of dairy products, including butter, yogurt, and homemade cheese [13,38,58]. Although dairy animals do not harbor *S* Typhi [136], improperly handled dairy products can serve as effective growth media for the pathogen [58].

Demographic and Socioeconomic Factors

This study identified mixed findings regarding sex-based susceptibility to typhoid fever. While a study suggests that men face greater exposure due to occupational differences, mobility patterns, dietary factors, or a lack of immunity [82], other studies indicate that women, influenced by their physiological status, hormonal imbalance, and gender-specific activities, are more susceptible [120,121]. Building on this, we propose the hypothesis that occupational exposure may explain the higher risk in men, whereas caregiving roles could contribute to increased susceptibility among women. Nonetheless, a study by Rasul et al [137] concludes that typhoid fever incidence is independent of gender, affecting men and women equally across all age groups. Age serves as a significant factor in typhoid transmission, with both young children and older adults identified as vulnerable groups [121,138]. Young children, characterized by their underdeveloped immune systems [33,42,87] and a limited understanding of disease transmission [58,87], face heightened risks of infection. While younger adults are predisposed to infections due to their adventurous lifestyle or unsanitary activities, such as eating junk food, and an increased number of social gatherings [25,42,58], older adults are more likely to be *S* Typhi resistant due to continual immune boosting [138]. Conversely, older adults may experience susceptibility due to a waning immune system or increased exposure to occupational and environmental risks. These exposures may include involvement in farming-related water contact activities [58,68], rearing chicken or goats [68], handling *S* Typhi specimens in clinical settings [72,91], and working in sewage management [91]. Although *S* Typhi is a human-adapted pathogen and not naturally harbored by animals, the association with poultry and livestock rearing may act as a confounder, reflecting underlying poor sanitary and hygienic conditions within the household rather than direct transmission from animals [92].

Our investigation further revealed that socioeconomic status correlates with an increased likelihood of *S* Typhi infection [96]. While studies suggest that typhoid fever is more common in low-income countries and is connected to poor public health and low socioeconomic indicators [25,83], one study [90] identified a protective effect of the wealth index. This suggests that residing in affluent districts within low- or middle-income countries may significantly mitigate the risk. This may be attributed to the per capita gross domestic product and individual disposable income within a community [102]. Wealthier households are more likely to afford preventive measures such as clean drinking water, improved sanitation, and timely medical consultations, thereby reducing the risk of infection. Conversely, individuals in lower socioeconomic brackets often face health care barriers, leading to underdiagnosis and delayed treatment. The protective effect of a higher wealth index underscores the need for targeted interventions. Public health strategies should prioritize health care accessibility and sanitation improvements in economically disadvantaged areas. Investments in water and sanitation infrastructure, subsidized vaccination programs, and awareness campaigns tailored to low-income communities could help reduce the disproportionate burden of typhoid fever. In addition, strengthening diagnostic capacity in resource-limited settings can improve case detection, ensure timely treatment, and curb typhoid transmission while enhancing health outcomes.

In the context of education, our research highlights the lack of certificate education as a significant risk factor influencing the perception of typhoid fever. Individuals who have never attended school tend to possess limited knowledge about the disease and its modes of transmission, highlighting a strong link between lower educational attainment and reduced awareness [102,120]. Previous studies [90,104,105] emphasize that formal education increases understanding, with uneducated individuals more likely to contract typhoid fever. Interestingly, being a student [47] or attending school (daycare) [68] may also pose risks, likely due to certain exposures in educational settings. While essential health knowledge, such as WHO-recommended practices of handwashing with soap, can be acquired outside formal education, a general lack of awareness significantly increases the risk of infection. Individuals who do not recognize the risks are less likely to take preventive actions [97,127]. Another significant factor for typhoid transmission, besides knowledge, is awareness of the presence of a patient with typhoid at home [120]. Individuals who are unsure of the presence of a patient with chronic or current typhoid at home are more likely to have typhoid or a recurrence than those with full awareness. This may be attributed to the continued shedding of *S* Typhi in the stool and urine of infected individuals, even after initial antimicrobial treatment. Up to 10% of patients may continue shedding the bacteria for as long as 3 months, with some proceeding to become long-term asymptomatic carriers [1]. These transient or chronic carriers can be sources of infection within households [139,140]. In contrast, household members who are well informed of such cases are more likely to acquire knowledge about the disease, its transmission routes, and effective preventive measures. Recent contact with patients with typhoid has also been observed as a potential risk factor, further emphasizing the role of household-level awareness in reducing transmission [48,88]. In many communities, traditional practices of visiting the sick can increase interpersonal contact and inadvertently raise the risk of exposure. Close contacts are often residents of the same area and may share communal water sources, suggesting that transmission could still occur via water contamination (broader environment) rather than direct person-to-person spread. Therefore, health education initiatives should consider addressing the risks associated with visiting infected individuals, alongside broader messaging on water hygiene and disease prevention.

Hygiene and Sanitation Risk Factors

This study further identified risk factors that underscore the significant impact of hygiene and sanitation on the spread of typhoid fever. Poor handwashing practice is a critical risk factor, given the crucial role hands play in transmitting *S* Typhi through the fecal-oral cycle [26,30,120,123]. While handwashing with soap and clean water effectively removes pathogens [29], inadequacies in technique, such as rinsing without soap [53,122] or neglecting handwashing after defecation [12,97], can increase the risk of bacterial spread [106]. Furthermore, using medicated soaps is an added advantage because it is more effective in eliminating bacteria from hands compared to regular soaps [127].

In addition, the condition of the sewerage system in the house has an important impact on typhoid fever incidence. According to Prasad et al [12], people lacking access to improved sanitation facilities or with damaged improved sewerage systems are particularly vulnerable to infections. In many cases, household toilets are built without professional expertise, often on permeable soil, and in flood-prone areas, increasing the likelihood of leakage and pollution of surface water and crops with human waste [79]. Strengthening the construction and maintenance of sanitary excreta disposal facilities, alongside effective solid waste management, is essential for preventing typhoid fever transmission. Studies have shown that poor sanitation, including improper disposal of solid waste and excreta in residential settings, is directly correlated with higher typhoid prevalence [27,79]. Inadequate waste disposal infrastructure, such as pit latrines, open defecation sites, burst sewer pipes, and the presence of visible feces or urine, has been consistently identified as a significant risk factor [29,53,92,96]. Notably, preventing human excreta from entering the domestic arena has a greater impact on interrupting typhoid transmission than behaviors preventing pathogens in the environment from being ingested by humans (eg, hand washing).

Finally, the discharge of unsterilized water from hospitals and residential areas into rainwater canal systems, often used for irrigating farmlands, contributes to the contamination of vegetables cultivated in these areas [110]. These contaminated crops are frequently consumed without thorough washing, thereby increasing the risk of typhoid fever. Particularly, the risk is pronounced during the rainy season, when heavily polluted irrigation water is more commonly used, and runoff from farms mixed with garbage is more likely to spread into residential zones, further endangering public health.

Other Risk Factors for Typhoid Fever

Other typhoid risk factors identified in this study include antimicrobial exposure, host-related factors, vaccination status, travel history, and environmental or climate conditions. Among these, antimicrobial use has the greatest impact on *S* Typhi infection. Several studies have shown that prior or recent use of antibiotics, particularly within 4 weeks before disease onset, is associated with an increased risk of typhoid fever, particularly in cases involving multidrug resistant or extensively drug-resistant strains [63,81,101]. Antimicrobial exposure can induce prolonged alterations in gut flora and compromise the barrier against bacterial colonization, thereby reducing the threshold of *S* Typhi required for infection [47]. Studies by Yousafzai et al [119], Srinivasan et al [103], and Kamal et al [81], further highlight antimicrobial resistance as a major contributor to typhoid fever, with certain resistant strains capable of causing epidemics. This resistance is largely caused by the routine presence of *S* Typhi in the human intestine and the indiscriminate use of antibiotics [44,63]. Consequently, drug-resistant *S* Typhi strains, often carrying multiple virulence factors, are becoming increasingly prevalent worldwide. Notably, this study also identified specific risk factors associated with *S* Typhi–resistant strains harboring virulence genes, including those within the H58 lineage, which enhance their ability to infect and interact with host cells [60,62,103,121].

Host-Related Factors

Host genetic factors influence susceptibility to infectious diseases in humans. This study referenced research by Manal et al [35], which explored the relationship between genetic polymorphisms and typhoid fever risk. Their findings suggested that individuals carrying the 2R3R heterozygote of the intronic variable number tandem repeat in the *IL4* gene may have a genetic predisposition to typhoid fever. However, a study by Dunstan et al [124] reported that a specific haplotype within the tumor necrosis factor gene locus offers protection from typhoid. These associations may be explained by the influence of genetic variation on immune response pathways. Another study [49] found a link between serum anti *H pylori* immunoglobulin G (IgG) levels and an increased risk of typhoid fever. Serum IgG antibodies indicate either prior or active *H pylori* infection, as these antibodies can persist even after infection clearance [49,141,142]. A possible explanation for this association lies in the role of the gastric acid barrier as a crucial defense mechanism against ingested pathogens such as *S* Typhi. *H pylori* infection has been associated with hypochlorhydria, a condition characterized by reduced stomach acid production, which weakens this protective barrier [49,109].

This impairment may facilitate the survival and subsequent colonization of *S* Typhi in the gastrointestinal tract, thereby increasing susceptibility to typhoid fever.

In addition, this review identified a significant association between typhoid fever and the presence of chronic underlying conditions [69]. A plausible explanation is that chronic illnesses can weaken the immune system, impairing the body's ability to clear *S* Typhi and increasing the risk of persistent or severe infection. For instance, although *S* Typhi is not widely associated with AIDS in developed countries, studies from endemic areas suggest a different pattern. We uncovered a study by Gotuzzo et al [71] that reported an increased risk of typhoid in patients infected with HIV from typhoid-endemic areas. In addition, the study noted that a large proportion of HIV-positive participants were men who have sex with men, raising the possibility that direct fecal-oral transmission may contribute to increased incidence in this subgroup. However, further research is needed to clarify the specific transmission dynamics within this population and to distinguish the role of immunosuppression from that of behavioral factors.

Travel-Related Risk

Typhoid fever, once prevalent in industrialized countries, is now effectively controlled [91,93]; however, imported infections remain a significant public health concern [39,52,85]. The risk of infection among travelers varies depending on factors such as age, destination, duration, and purpose of travel [99]. Travelers visiting friends or relatives are in a high-risk category for typhoid fever [39,61,73]. As they are much less likely than other travelers to seek pretravel counseling, they may visit more rural, remote areas and engage closely with local people as well as eat high-risk foods and beverages [51]. Children and young adolescents who are visiting friends or relatives are also at high risk of contracting typhoid fever due to a lack of immunity or the possibility of traveling under unhygienic conditions [61,82,99]. We also discovered that traveling to endemic locations increases the risk of contracting typhoid [52,59,86,93]. According to Lin et al [86], more than half of all travelers with typhoid returning to developed countries have visited Asia or Africa, where the disease is widespread. This trend likely reflects increased exposure associated with travel to these endemic areas, particularly during extended stays. In contrast, short-term visitors to endemic areas face a comparatively lower risk of infection [39]. Furthermore, increasing global mobility driven by economic globalization has facilitated the movement of travelers for business, tourism, or labor migration, thereby contributing to disease spread. This growing influx of individuals, often without adequate vaccination or awareness of preventive measures, contributes to the continued transmission and global spread of typhoid fever [82,102].

Vaccination

Vaccination is essential for the control of typhoid fever in endemic and epidemic settings as well as among travelers moving between nonendemic and endemic areas. The WHO recommends the programmatic use of typhoid fever vaccines in endemic areas [4]. We retrieved 2 studies [75,106] that demonstrated a reduced risk of typhoid fever among individuals who received effective typhoid vaccines and resided in households with improved water. Conversely, poor vaccination coverage, particularly when combined with inadequate WASH infrastructure, can exacerbate typhoid transmission in a given area [63,103]. Moreover, the effectiveness of vaccination may also be compromised by factors, including defective vaccine batches, incorrect immunization procedures, or the interval since vaccination. Evidence from this study suggests that individuals vaccinated more than 3 years prior may face a heightened risk of infection, likely due to waning immunity [94]. This is particularly relevant for polysaccharide vaccines, which have an estimated cumulative efficacy of approximately 55% over 3 years, with the strongest protection occurring within the first 2 years after immunization.

Environmental, Seasonal, and Climate Factors

Typhoid fever transmission exhibits distinct seasonal patterns influenced by environmental and climatic factors such as temperature, humidity, and precipitation. This study identified diverse peak periods across different endemic regions. For example, Taiwan experiences a surge in cases during the fall (September-November) and winter seasons (December-February) [86], whereas in India, the peak occurs in June in Allahabad [25], and during the monsoon season (July-November) in Ahmedabad [77]. A study by Corner et al [56] discovered that approximately half of the yearly typhoid cases in the Dhaka Metropolitan Area, reaching up to 11 per 100,000 individuals, occurred during summer and fall (July-October). Similarly, Srinivasan et al [103] found a positive correlation between summer temperatures (June-August) and increased typhoid cases. These seasonal fluctuations may stem from a complex interplay of climatic conditions, hygiene practices, and local cultural dynamics [86,143]. In warmer climates or during summer, elevated temperatures enhance the proliferation of *S* Typhi in contaminated foods [103]. Conversely, in colder and more humid conditions, *S* Typhi survive longer in water and soil, thereby increasing the likelihood of environmental transmission [144]. In addition, heavy rainfall during the rainy season can trigger flooding and sewage overflows, leading to contamination of water sources and an increase in typhoid incidences [25,66]. This risk is particularly high in low-lying or flood-prone areas where surface water is commonly used for drinking, cooking, and cleaning [42,56,57]. Settlements in hydrologically vulnerable terrains, such as river floodplains, face particularly heightened risks during these periods due to increased sewage runoff and widespread contamination of water and food supplies [67,78].

Study Limitations

This study has some limitations. First, publication bias may be present, as studies with significant findings are more likely to be published, potentially underrepresenting negative or null results and skewing risk factor assessments. Second, the lack of formal risk-of-bias assessments may also affect the reliability of findings. In addition, excluding gray literature and non-English studies may have limited the scope, as multilingual and unpublished data could provide further insights. Furthermore, although the review highlights sex-based differences in susceptibility to typhoid fever, the underlying mechanisms remain unclear due to mixed findings, making the proposed explanation, such as occupational exposure in men versus caregiving roles in women, speculative.

Conclusions

This review combines current knowledge of typhoid fever risk factors and identifies critical areas for targeted intervention. While food and water have been traditionally recognized as the primary transmission pathways for typhoid fever, this review identifies demographic and socioeconomic factors as predominant drivers for transmission. This shift in understanding underscores the need to move beyond conventional mitigation strategies and adopt targeted interventions that address demographic and socioeconomic disparities, which may play a more significant role in typhoid transmission than previously acknowledged. Considering all identified risk factors, mitigation strategies should be prioritized based on regional transmission dynamics and resource availability. In urban Asia, street food regulation should take precedence, while in rural Africa, investment in water infrastructure is equally critical. A combined approach integrating WASH and vaccination programs, particularly in schools and high-risk communities, remains a key priority for long-term disease control in endemic regions. In addition, addressing environmental and climate-related risks, such as flooding and poor waste management, should be incorporated into prevention strategies.

While this review provides a broad synthesis, key knowledge gaps remain. The absence of longitudinal studies limits the understanding of causality and the temporal dynamics of typhoid risk factors. Methodologically, while this review allows a flexible and wide-range synthesis, it lacks the rigor of systematic reviews and meta-analyses, particularly in terms of risk-of-bias assessments and standardized inclusion criteria.

Future studies should focus on longitudinal and case-control methodologies to establish causality in typhoid risk factors, particularly regarding sex, occupation, and disease susceptibility. In addition, structured bias evaluations and quantitative meta-analyses should be incorporated where possible to improve the reliability and comparability of findings. Future research should also investigate the impact of demographic, socioeconomic, and climate variability on typhoid transmission dynamics, given their increasing relevance. Moreover, TCVs are an important tool in reducing *S* Typhi transmission and should be prioritized for introduction in endemic areas to strengthen prevention and control efforts.

By addressing these gaps and priority key areas, future research can strengthen the empirical foundations for typhoid control strategies, enabling policy makers and public health professionals to develop more targeted, evidence-based interventions for effective typhoid fever prevention and control.

Acknowledgments

The authors would like to thank the EOD project team at Kwame Nkrumah University of Science, in collaboration with the International Vaccine Institute, for their support. The authors received no specific funding for this study.

Conflicts of Interest

None declared.

Multimedia Appendix 1

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist.
[DOCX File , 270 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Data extraction entities for the systematic review of typhoid fever risk factors.
[XLSX File (Microsoft Excel File), 108 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Summary of study characteristics and query strings for article search.
[DOCX File , 25 KB-Multimedia Appendix 3]

References

1. Crump JA, Sjölund-Karlsson M, Gordon MA, Parry CM. Epidemiology, clinical presentation, laboratory diagnosis, antimicrobial resistance, and antimicrobial management of invasive salmonella infections. Clin Microbiol Rev. Oct 2015;28(4):901-937. [FREE Full text] [doi: 10.1128/CMR.00002-15] [Medline: 26180063]
2. Cunha BA. Osler on typhoid fever: differentiating typhoid from typhus and malaria. Infect Dis Clin North Am. Mar 2004;18(1):111-125. [doi: 10.1016/S0891-5520(03)00094-1] [Medline: 15081508]
3. Parry CM, Wijedoru L, Arjyal A, Baker S. The utility of diagnostic tests for enteric fever in endemic locations. Expert Rev Anti Infect Ther. Jun 10, 2011;9(6):711-725. [doi: 10.1586/eri.11.47] [Medline: 21692675]
4. Typhoid vaccines: WHO position paper - March 2018. World Health Organization. Mar 30, 2018. URL: https://www.who.int/publications/i/item/typhoid-vaccines-who-position-paper-march-2018 [accessed 2024-07-28]

5. Marks F, Im J, Park SE, Pak GD, Jeon HJ, Wandji Nana LR, et al. Incidence of typhoid fever in Burkina Faso, Democratic Republic of the Congo, Ethiopia, Ghana, Madagascar, and Nigeria (the Severe Typhoid in Africa programme): a population-based study. Lancet Glob Health. Apr 2024;12(4):e599-e610. [doi: 10.1016/S2214-109x(24)00007-x]
6. Stuart BM, Pullen RL. Typhoid; clinical analysis of 360 cases. Arch Intern Med (Chic). Dec 01, 1946;78(6):629-661. [doi: 10.1001/archinte.1946.00220060002001] [Medline: 20278487]
7. Crump JA, Luby SP, Mintz ED. The global burden of typhoid fever. Bull World Health Organ. May 2004;82(5):346-353. [FREE Full text] [Medline: 15298225]
8. Buckle GC, Walker CL, Black RE. Typhoid fever and paratyphoid fever: systematic review to estimate global morbidity and mortality for 2010. J Glob Health. Jun 2012;2(1):1-9. [FREE Full text] [doi: 10.7189/jogh.01.010401]
9. GBD 2017 Typhoid and Paratyphoid Collaborators. The global burden of typhoid and paratyphoid fevers: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Infect Dis. Apr 2019;19(4):369-381. [FREE Full text] [doi: 10.1016/S1473-3099(18)30685-6] [Medline: 30792131]
10. Wang H, Zhang P, Zhao Q, Ma W. Global burden, trends and inequalities for typhoid and paratyphoid fever among children younger than 15 years over the past 30 years. J Travel Med. Dec 10, 2024;31(8):e140. [doi: 10.1093/jtm/taae140] [Medline: 39450993]
11. World Health Organization. Typhoid vaccines: WHO position paper, March 2018 - recommendations. Vaccine. Jan 07, 2019;37(2):214-216. [doi: 10.1016/j.vaccine.2018.04.022] [Medline: 29661581]
12. Prasad N, Jenkins AP, Naucukidi L, Rosa V, Sahu-Khan A, Kama M, et al. Epidemiology and risk factors for typhoid fever in Central Division, Fiji, 2014-2017: a case-control study. PLoS Negl Trop Dis. Jun 8, 2018;12(6):e0006571. [FREE Full text] [doi: 10.1371/journal.pntd.0006571] [Medline: 29883448]
13. Zubair OA, Mohammad MY. Prevalent sources of enteric fevers among women in Mosul City. Ann Trop Med Public Health. 2020;23(13B). [FREE Full text] [doi: 10.36295/ASRO.2020.231355]
14. Meftahuddin T. Review of the trends and causes of food borne outbreaks in Malaysia from 1988 to 1997. Med J Malaysia. Mar 2002;57(1):70-79. [FREE Full text] [Medline: 14569721]
15. Lee JS, Mogasale VV, Mogasale V, Lee K. Geographical distribution of typhoid risk factors in low and middle income countries. BMC Infect Dis. Dec 05, 2016;16(1):732. [FREE Full text] [doi: 10.1186/s12879-016-2074-1] [Medline: 27919235]
16. Kim JH, Choi J, Kim C, Pak GD, Parajulee P, Haselbeck A, et al. Mapping the incidence rate of typhoid fever in sub-Saharan Africa. PLoS Negl Trop Dis. Feb 26, 2024;18(2):e0011902. [doi: 10.1371/journal.pntd.0011902] [Medline: 38408128]
17. Brockett S, Wolfe MK, Hamot A, Appiah GD, Mintz ED, Lantagne D. Associations among water, sanitation, and hygiene, and food exposures and typhoid fever in case-control studies: a systematic review and meta-analysis. Am J Trop Med Hyg. Sep 2020;103(3):1020-1031. [FREE Full text] [doi: 10.4269/ajtmh.19-0479] [Medline: 32700668]
18. Mogasale VV, Ramani E, Mogasale V, Park JY, Wierzba TF. Estimating typhoid fever risk associated with lack of access to safe water: a systematic literature review. J Environ Public Health. 2018;2018:9589208. [FREE Full text] [doi: 10.1155/2018/9589208] [Medline: 30174699]
19. Wang Z, Zhou H, Liu Y, Huang C, Chen J, Siddique A, et al. Nationwide trends and features of human salmonellosis outbreaks in China. Emerg Microbes Infect. Dec 18, 2024;13(1):2372364. [FREE Full text] [doi: 10.1080/22221751.2024.2372364] [Medline: 38923510]
20. Ma PY, Tan JE, Hee EW, Yong DW, Heng YS, Low WX, et al. Human genetic variation influences enteric fever progression. Cells. Feb 06, 2021;10(2):345. [FREE Full text] [doi: 10.3390/cells10020345] [Medline: 33562108]
21. Levantesi C, Bonadonna L, Briancesco R, Grohmann E, Toze S, Tandoi V. Salmonella in surface and drinking water: occurrence and water-mediated transmission. Food Res Int. Mar 27, 2012;45(2):587-602. [FREE Full text] [doi: 10.1016/j.foodres.2011.06.037]
22. Okyere PB, Twumasi-Ankrah S, Newton S, Owusu-Dabo E. Protocol for a desk review on risk factors for typhoid fever. Open Science Framework Registries. 2024. URL: https://osf.io/87jv9 [accessed 2024-09-07]
23. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev. Dec 05, 2016;5(1):210. [FREE Full text] [doi: 10.1186/s13643-016-0384-4] [Medline: 27919275]
24. Akwa TE, Nguimbous SP. Investigation of typhoid fever and their associated risk factors in children attending “Deo Gratias” hospital in Douala, Littoral, Cameroon. Eur J Med Educ Technol. 2021;14(2):em2107. [doi: 10.30935/ejmets/10910]
25. Alajeely AA, Lawrence R, Jeyakumar E, Maurice NG. Risk factors of typhoid fever amongst patients in the Allahabad region, India. Int J Curr Res. 2014;6(11). [FREE Full text]
26. Alba S, Bakker MI, Hatta M, Scheelbeek PF, Dwiyanti R, Usman R, et al. Risk factors of typhoid infection in the Indonesian archipelago. PLoS One. Jun 9, 2016;11(6):e0155286. [FREE Full text] [doi: 10.1371/journal.pone.0155286] [Medline: 27281311]
27. Eba K, Bekele D. Prevalence of typhoid fever and its risk factors in Lalo Assabi District, West Wollega, Oromiya, Ethiopia. J Bacteriol Parasitol. 2019;10:365. [FREE Full text]
28. Anita S, Amir KM, Fadzilah K, Ahamad J, Noorhaida U, Marina K, et al. Risk factors for typhoid outbreak in Sungai Congkak Recreational Park, Selangor 2009. Med J Malaysia. Feb 2012;67(1):12-16. [FREE Full text] [Medline: 22582542]

29. Gasem MH, Dolmans WM, Keuter MM, Djokomoeljanto RR. Poor food hygiene and housing as risk factors for typhoid fever in Semarang, Indonesia. Trop Med Int Health. Jun 21, 2001;6(6):484-490. [FREE Full text] [doi: 10.1046/j.1365-3156.2001.00734.x] [Medline: 11422963]
30. Halder S, Rahman ME, Sarker MM, Mone FH, Roy K, Tajkia G. Identification of risk factors for typhoid fever in children admitted in a tertiary care hospital. J Health Med Sci. Jun 2021;4(2):158-162. [doi: 10.31014/aior.1994.04.02.168]
31. Hosoglu S, Celen MK, Geyik MF, Akalin S, Ayaz C, Acemoglu H, et al. Risk factors for typhoid fever among adult patients in Diyarbakir, Turkey. Epidemiol Infect. Jun 2006;134(3):612-616. [doi: 10.1017/S0950268805005583] [Medline: 16288686]
32. Javed N, Abbasi S, Tahir M, Bashir F. Identifying the risk factors for typhoid fever among the residents of rural Islamabad. Pak J Med Res. 2017;56(2). [FREE Full text]
33. Khan MI, Ochiai RL, Soofi SB, Von-seidlein L, Khan MJ, Sahito SM, et al. Risk factors associated with typhoid fever in children aged 2–16 years in Karachi, Pakistan. Epidemiol Infect. May 31, 2011;140(4):665-672. [FREE Full text] [doi: 10.1017/s0950268811000938]
34. Luby SP, Faizan MK, Fisher-Hoch SP, Syed A, Mintz ED, Bhutta ZA, et al. Risk factors for typhoid fever in an endemic setting, Karachi, Pakistan. Epidemiol Infect. Mar 1998;120(2):129-138. [doi: 10.1017/s0950268897008558] [Medline: 9593481]
35. Fadl MA, Aydarous MA, Mao C, Yasmeen A. An association of VNTR polymorphism in intron3 of IL-4 gene with susceptibility to typhoid fever in Khartoum State, Sudan. Kuwait J Sci. 2016;43(1). [FREE Full text]
36. Rabasa AI, Mava Y, Pius S, Timothy SY, Baba UA. Typhoid fever in children: clinical presentation and risk factors. Niger J Paediatr. Dec 04, 2012;40(1):2013. [FREE Full text] [doi: 10.4314/njp.v40i1.11]
37. Ram PK, Naheed A, Brooks WA, Hossain MA, Mintz ED, Breiman RF, et al. Risk factors for typhoid fever in a slum in Dhaka, Bangladesh. Epidemiol Infect. Apr 08, 2007;135(3):458-465. [doi: 10.1017/S0950268806007114] [Medline: 16893490]
38. Sharma PK, Ramakrishnan R, Hutin Y, Manickam P, Gupte MD. Risk factors for typhoid in Darjeeling, West Bengal, India: evidence for practical action. Trop Med Int Health. Jun 23, 2009;14(6):696-702. [FREE Full text] [doi: 10.1111/j.1365-3156.2009.02283.x] [Medline: 19392739]
39. Jelinek T, Nothdurft HD, von Sonnenburg F, Löscher T. Risk factors for typhoid fever in travelers. J Travel Med. Dec 01, 1996;3(4):200-203. [FREE Full text] [doi: 10.1111/j.1708-8305.1996.tb00746.x] [Medline: 9815456]
40. Abera B, Yitayew G, Amare H. Salmonella serotypeTyphi, Shigella, and intestinal parasites among food handlers at Bahir Dar University, Ethiopia. J Infect Dev Ctries. Feb 28, 2016;10(2):121-126. [FREE Full text] [doi: 10.3855/jidc.6890] [Medline: 26927451]
41. Ackers ML, Puhr ND, Tauxe RV, Mintz ED. Laboratory-based surveillance of Salmonella serotype Typhi infections in the United States: antimicrobial resistance on the rise. JAMA. May 24, 2000;283(20):2668-2673. [doi: 10.1001/jama.283.20.2668] [Medline: 10819949]
42. Akullian A, Ng'eno E, Matheson AI, Cosmas L, Macharia D, Fields B, et al. Environmental transmission of typhoid fever in an urban slum. PLoS Negl Trop Dis. Dec 3, 2015;9(12):e0004212. [FREE Full text] [doi: 10.1371/journal.pntd.0004212] [Medline: 26633656]
43. Anand PK, Ramakrishnan R. Investigation of the outbreak of typhoid in a village of Thar Desert Rajasthan, India. Indian J Med Res. Jun 2010;131:799-803. [FREE Full text] [Medline: 20571169]
44. Anderson ES, Smith HR. Chloramphenicol resistance in the typhoid bacillus. Br Med J. Aug 05, 1972;3(5822):329-331. [FREE Full text] [doi: 10.1136/bmj.3.5822.329] [Medline: 4558307]
45. Batool R, Qureshi S, Yousafzai M, Kazi MT, Ali M, Qamar FN. Risk factors associated with extensively drug-resistant typhoid in an outbreak setting of Lyari Town Karachi, Pakistan. Am J Trop Med Hyg. Mar 28, 2022;106(5):1379-1383. [FREE Full text] [doi: 10.4269/ajtmh.21-1323] [Medline: 35344928]
46. Centers for Disease Control and Prevention (CDC). Epidemic typhoid fever--Dushanbe, Tajikistan, 1997. MMWR Morb Mortal Wkly Rep. Sep 18, 1998;47(36):752-756. [FREE Full text] [Medline: 9756457]
47. Srikantiah P, Vafokulov S, Luby SP, Ishmail T, Earhart K, Khodjaev N, et al. Epidemiology and risk factors for endemic typhoid fever in Uzbekistan. Trop Med Int Health. Jul 25, 2007;12(7):838-847. [FREE Full text] [doi: 10.1111/j.1365-3156.2007.01853.x] [Medline: 17596250]
48. Tran HH, Bjune G, Nguyen BM, Rottingen JA, Grais RF, Guerin PJ. Risk factors associated with typhoid fever in Son La province, northern Vietnam. Trans R Soc Trop Med Hyg. Nov 2005;99(11):819-826. [doi: 10.1016/j.trstmh.2005.05.007] [Medline: 16099488]
49. Bhan MK, Bahl R, Sazawal S, Sinha A, Kumar R, Mahalanabis D, et al. Association between Helicobacter pylori infection and increased risk of typhoid fever. J Infect Dis. Dec 15, 2002;186(12):1857-1860. [doi: 10.1086/345762] [Medline: 12447776]
50. Birkhead GS, Morse DL, Levine WC, Fudala JK, Kondracki SF, Chang H, et al. Typhoid fever at a resort hotel in New York: a large outbreak with an unusual vehicle. J Infect Dis. May 01, 1993;167(5):1228-1232. [doi: 10.1093/infdis/167.5.1228] [Medline: 8486960]

51. Boggild AK, Castelli F, Gautret P, Torresi J, von Sonnenburg F, Barnett ED, et al. Vaccine preventable diseases in returned international travelers: results from the GeoSentinel Surveillance Network. Vaccine. Oct 28, 2010;28(46):7389-7395. [doi: 10.1016/j.vaccine.2010.09.009] [Medline: 20851081]
52. Braddick MR, Sharp JC. Enteric fever in Scotland 1975-1990. Public Health. May 1993;107(3):193-198. [doi: 10.1016/s0033-3506(05)80441-x] [Medline: 8511239]
53. Brainard J, D'hondt R, Ali E, Van den Bergh R, De Weggheleire A, Baudot Y, et al. Typhoid fever outbreak in the Democratic Republic of Congo: case control and ecological study. PLoS Negl Trop Dis. Oct 3, 2018;12(10):e0006795. [FREE Full text] [doi: 10.1371/journal.pntd.0006795] [Medline: 30281598]
54. Chao DL, Park JK, Marks F, Ochiai RL, Longini IM, Halloran ME. The contribution of neighbours to an individual's risk of typhoid outcome. Epidemiol Infect. Dec 04, 2015;143(16):3520-3527. [FREE Full text] [doi: 10.1017/S0950268815000692] [Medline: 25936682]
55. Clark ST, Cronin K, Corbeil AJ, Patel SN. A ten-year retrospective survey of antimicrobial susceptibility patterns among salmonella enterica subsp. enterica Serovar Typhi Isolates in Ontario, Canada. Microbiol Spectr. Feb 14, 2023;11(1):e0482822. [FREE Full text] [doi: 10.1128/spectrum.04828-22] [Medline: 36622222]
56. Corner RJ, Dewan AM, Hashizume M. Modelling typhoid risk in Dhaka metropolitan area of Bangladesh: the role of socio-economic and environmental factors. Int J Health Geogr. Mar 16, 2013;12:13. [FREE Full text] [doi: 10.1186/1476-072X-12-13] [Medline: 23497202]
57. de Alwis R, Watson C, Nikolay B, Lowry JH, Thieu NT, Van TT, et al. Role of environmental factors in shaping spatial distribution of Salmonella enterica Serovar Typhi, Fiji. Emerg Infect Dis. Feb 2018;24(2):284-293. [FREE Full text] [doi: 10.3201/eid2402.170704] [Medline: 29350150]
58. Deksissa T, Gebremedhin EZ. A cross-sectional study of enteric fever among febrile patients at Ambo hospital: prevalence, risk factors, comparison of Widal test and stool culture and antimicrobials susceptibility pattern of isolates. BMC Infect Dis. Mar 27, 2019;19(1):288. [FREE Full text] [doi: 10.1186/s12879-019-3917-3] [Medline: 30917795]
59. Ekdahl K, de Jong B, Andersson Y. Risk of travel-associated typhoid and paratyphoid fevers in various regions. J Travel Med. 2005;12(4):197-204. [FREE Full text] [doi: 10.2310/7060.2005.12405] [Medline: 16086894]
60. Elemfareji OI, Thong KL. Comparative virulotyping of Salmonella typhi and Salmonella enteritidis. Indian J Microbiol. Dec 23, 2013;53(4):410-417. [FREE Full text] [doi: 10.1007/s12088-013-0407-y] [Medline: 24426144]
61. Farmakiotis D, Varughese J, Sue P, Andrews P, Brimmage M, Dobroszycki J, et al. Typhoid fever in an inner city hospital: a 5-year retrospective review. J Travel Med. Jan 01, 2013;20(1):17-21. [FREE Full text] [doi: 10.1111/j.1708-8305.2012.00665.x] [Medline: 23279226]
62. Feasey NA, Masesa C, Jassi C, Faragher EB, Mallewa J, Mallewa M, et al. Three epidemics of invasive multidrug-resistant Salmonella bloodstream infection in Blantyre, Malawi, 1998-2014. Clin Infect Dis. Nov 01, 2015;61 Suppl 4(Suppl 4):S363-S371. [FREE Full text] [doi: 10.1093/cid/civ691] [Medline: 26449953]
63. Fida S, Mansoor H, Saif S, Iqbal J, Khan AQ. Clinical perspectives of multiple and extensively drug-resistant typhoid; result from a tertiary care hospital from Pakistan. J Infect Dev Ctries. Apr 30, 2021;15(4):530-537. [doi: 10.3855/jidc.13539] [Medline: 33956653]
64. Forster DP, Leder K. Typhoid fever in travellers: estimating the risk of acquisition by country. J Travel Med. Dec 29, 2021;28(8):taab150. [FREE Full text] [doi: 10.1093/jtm/taab150] [Medline: 34619766]
65. Forsyth JR, Bennett NM, Hogben S, Hutchinson EM, Rouch G, Tan A, et al. The year of the Salmonella seekers--1977. Aust N Z J Public Health. Aug 2003;27(4):385-389. [FREE Full text] [doi: 10.1111/j.1467-842x.2003.tb00414.x] [Medline: 14705299]
66. Gao Q, Liu Z, Xiang J, Zhang Y, Tong MX, Wang S, et al. Impact of temperature and rainfall on typhoid/paratyphoid fever in Taizhou, China: effect estimation and vulnerable group identification. Am J Trop Med Hyg. Dec 06, 2021;106(2):532-542. [FREE Full text] [doi: 10.4269/ajtmh.20-1457] [Medline: 34872055]
67. Gauld JS, Olgemoeller F, Heinz E, Nkhata R, Bilima S, Wailan AM, et al. Spatial and genomic data to characterize endemic typhoid transmission. Clin Infect Dis. Jun 10, 2022;74(11):1993-2000. [FREE Full text] [doi: 10.1093/cid/ciab745] [Medline: 34463736]
68. Gauld JS, Olgemoeller F, Nkhata R, Li C, Chirambo A, Morse T, et al. Domestic river water use and risk of typhoid fever: results from a case-control study in Blantyre, Malawi. Clin Infect Dis. Mar 17, 2020;70(7):1278-1284. [FREE Full text] [doi: 10.1093/cid/ciz405] [Medline: 31144715]
69. Geteneh A, Tadesse S, Biset S, Girma L, Fissiha P. Rapid stool antigenic test for typhoid fever among suspected cases, Northeast, Ethiopia. Sci Rep. Jan 12, 2023;13(1):649. [FREE Full text] [doi: 10.1038/s41598-023-27909-5] [Medline: 36635427]
70. Giri S, Mohan VR, Srinivasan M, Kumar N, Kumar V, Dhanapal P, et al. Case-control study of household and environmental transmission of typhoid fever in India. J Infect Dis. Nov 23, 2021;224(Supple 5):S584-S592. [FREE Full text] [doi: 10.1093/infdis/jiab378] [Medline: 35238355]
71. Gotuzzo E, Frisancho O, Sanchez J, Liendo G, Carrillo C, Black RE, et al. Association between the acquired immunodeficiency syndrome and infection with Salmonella typhi or Salmonella paratyphi in an endemic typhoid area. Arch Intern Med. Feb 1991;151(2):381-382. [Medline: 1899554]

72. Grist NR, Emslie JA. Infections in British clinical laboratories, 1988-1989. J Clin Pathol. Aug 1991;44(8):667-669. [FREE Full text] [doi: 10.1136/jcp.44.8.667] [Medline: 1890201]
73. Gunaratnam P, Tobin S, Seale H, McAnulty JM. Infectious diseases in returned travellers, NSW, 2010-2011. N S W Public Health Bull. Jun 2014;24(4):171-175. [doi: 10.1071/NB13005] [Medline: 24939227]
74. Im J, Islam MT, Ahmmed F, Kim DR, Islam Khan A, Zaman K, et al. Can existing improvements of water, sanitation, and hygiene (WASH) in urban slums reduce the burden of typhoid fever in these settings? Clin Infect Dis. Jun 01, 2021;72(11):e720-e726. [doi: 10.1093/cid/ciaa1429] [Medline: 32964216]
75. Im J, Khanam F, Ahmmed F, Kim DR, Kang S, Tadesse BT, et al. Prevention of typhoid fever by existing improvements in household water, sanitation, and hygiene, and the use of the Vi polysaccharide typhoid vaccine in poor urban slums: results from a cluster-randomized trial. Am J Trop Med Hyg. Mar 07, 2022;106(4):1149-1155. [FREE Full text] [doi: 10.4269/ajtmh.21-1034] [Medline: 35385827]
76. Issack MI. Epidemiology of typhoid fever in Mauritius. J Travel Med. 2005;12(5):270-274. [FREE Full text] [doi: 10.2310/7060.2005.12506] [Medline: 16256051]
77. Iyer V, Sharma A, Nair D, Solanki B, Umrigar P, Murtugudde R, et al. Role of extreme weather events and El Niño Southern Oscillation on incidence of Enteric Fever in Ahmedabad and Surat, Gujarat, India. Environ Res. May 2021;196:110417. [doi: 10.1016/j.envres.2020.110417] [Medline: 33217433]
78. Jenkins AP, Jupiter S, Mueller U, Jenney A, Vosaki G, Rosa V, et al. Health at the sub-catchment scale: typhoid and its environmental determinants in Central Division, Fiji. Ecohealth. Dec 24, 2016;13(4):633-651. [doi: 10.1007/s10393-016-1152-6] [Medline: 27557784]
79. Jenkins AP, Jupiter SD, Jenney A, Naucukidi A, Prasad N, Vosaki G, et al. Environmental foundations of typhoid fever in the Fijian residential setting. Int J Environ Res Public Health. Jul 06, 2019;16(13):2407. [FREE Full text] [doi: 10.3390/ijerph16132407] [Medline: 31284613]
80. Kabwama SN, Bulage L, Nsubuga F, Pande G, Oguttu DW, Mafigiri R, et al. A large and persistent outbreak of typhoid fever caused by consuming contaminated water and street-vended beverages: Kampala, Uganda, January - June 2015. BMC Public Health. Jan 05, 2017;17(1):23. [FREE Full text] [doi: 10.1186/s12889-016-4002-0] [Medline: 28056940]
81. Kamal R, Ching C, Zaman MH, Sultan F, Abbas S, Khan E, et al. Identification of multiple variant extensively drug-resistant typhoid infections across Pakistan. Am J Trop Med Hyg. Feb 01, 2023;108(2):278-284. [FREE Full text] [doi: 10.4269/ajtmh.22-0071] [Medline: 36623485]
82. Karkey A, Arjyal A, Anders KL, Boni MF, Dongol S, Koirala S, et al. The burden and characteristics of enteric fever at a healthcare facility in a densely populated area of Kathmandu. PLoS One. Nov 15, 2010;5(11):e13988. [FREE Full text] [doi: 10.1371/journal.pone.0013988] [Medline: 21085575]
83. Karkey A, Thompson CN, Tran Vu Thieu N, Dongol S, Le Thi Phuong T, Voong Vinh P, et al. Differential epidemiology of Salmonella Typhi and Paratyphi A in Kathmandu, Nepal: a matched case control investigation in a highly endemic enteric fever setting. PLoS Negl Trop Dis. Aug 22, 2013;7(8):e2391. [FREE Full text] [doi: 10.1371/journal.pntd.0002391] [Medline: 23991240]
84. Katz DJ, Cruz MA, Trepka MJ, Suarez JA, Fiorella PD, Hammond RM. An outbreak of typhoid fever in Florida associated with an imported frozen fruit. J Infect Dis. Jul 15, 2002;186(2):234-239. [doi: 10.1086/341208] [Medline: 12134260]
85. Keller A, Frey M, Schmid H, Steffen R, Walker T, Schlagenhauf P. Imported typhoid fever in Switzerland, 1993 to 2004. J Travel Med. Jul 01, 2008;15(4):248-251. [FREE Full text] [doi: 10.1111/j.1708-8305.2008.00216.x] [Medline: 18666925]
86. Lin FH, Chen BC, Chou YC, Hsieh CJ, Yu CP. Incidence and risk factors for notifiable typhoid and paratyphoid in Taiwan during the period 2011-2020. Healthcare (Basel). Oct 01, 2021;9(10):1316. [FREE Full text] [doi: 10.3390/healthcare9101316] [Medline: 34682996]
87. Liu Z, Lao J, Zhang Y, Liu Y, Zhang J, Wang H, et al. Association between floods and typhoid fever in Yongzhou, China: effects and vulnerable groups. Environ Res. Nov 2018;167:718-724. [doi: 10.1016/j.envres.2018.08.030] [Medline: 30241731]
88. Luxemburger C, Chau MC, Mai NL, Wain J, Tran TH, Simpson JA, et al. Risk factors for typhoid fever in the Mekong delta, southern Viet Nam: a case-control study. Trans R Soc Trop Med Hyg. Jan 2001;95(1):19-23. [doi: 10.1016/s0035-9203(01)90318-9] [Medline: 11280056]
89. Makungo UB, Ramutshila TE, Mabotja MC, Thomas J, Lekalakala-Mokaba R, Smith AM, et al. Epidemiological investigation of a typhoid fever outbreak in Sekhukhune District, Limpopo province, South Africa - 2017. S Afr J Infect Dis. Nov 16, 2020;35(1):107. [FREE Full text] [doi: 10.4102/sajid.v35i1.107] [Medline: 34485467]
90. Masinaei M, Eshrati B, Yaseri M. Spatial and spatiotemporal patterns of typhoid fever and investigation of their relationship with potential risk factors in Iran, 2012-2017. Int J Hyg Environ Health. Mar 2020;224:113432. [doi: 10.1016/j.ijheh.2019.113432] [Medline: 31978729]
91. Mathieu JJ, Henning KJ, Bell E, Frieden TR. Typhoid fever in New York City, 1980 through 1990. Arch Intern Med. Aug 08, 1994;154(15):1713-1718. [Medline: 8042888]
92. Mbae C, Mwangi M, Gitau N, Irungu T, Muendo F, Wakio Z, et al. Factors associated with occurrence of salmonellosis among children living in Mukuru slum, an urban informal settlement in Kenya. BMC Infect Dis. Jun 17, 2020;20(1):422. [FREE Full text] [doi: 10.1186/s12879-020-05134-z] [Medline: 32552753]

93. Mermin JH, Townes JM, Gerber M, Dolan N, Mintz ED, Tauxe RV. Typhoid fever in the United States, 1985-1994: changing risks of international travel and increasing antimicrobial resistance. Arch Intern Med. Mar 23, 1998;158(6):633-638. [doi: 10.1001/archinte.158.6.633] [Medline: 9521228]
94. Michel R, Garnotel E, Spiegel A, Morillon M, Saliou P, Boutin J. Outbreak of typhoid fever in vaccinated members of the French Armed Forces in the Ivory Coast. Eur J Epidemiol. Jul 2005;20(7):635-642. [doi: 10.1007/s10654-005-7454-6] [Medline: 16119438]
95. Mohan VR, Srinivasan M, Sinha B, Shrivastava A, Kanungo S, Natarajan Sindhu K, et al. Geographically weighted regression modeling of spatial clustering and determinants of focal typhoid fever incidence. J Infect Dis. Nov 23, 2021;224(Supple 5):S601-S611. [FREE Full text] [doi: 10.1093/infdis/jiab379] [Medline: 35238357]
96. Muti M, Gombe N, Tshimanga M, Takundwa L, Bangure D, Mungofa S, et al. Typhoid outbreak investigation in Dzivaresekwa, suburb of Harare City, Zimbabwe, 2011. Pan Afr Med J. 2014;18:309. [FREE Full text] [doi: 10.11604/pamj.2014.18.309.4288] [Medline: 25469202]
97. Nyamusore J, Nahimana MR, Ngoc CT, Olu O, Isiaka A, Ndahindwa V, et al. Risk factors for transmission of Salmonella Typhi in Mahama refugee camp, Rwanda: a matched case-control study. Pan Afr Med J. 2018;29:148. [doi: 10.11604/pamj.2018.29.148.12070] [Medline: 30050612]
98. Okpasuo O, Aguzie IO, Joy AT, Okafor FC. Risk assessment of waterborne infections in Enugu State, Nigeria: implications of household water choices, knowledge, and practices. AIMS Public Health. 2020;7(3):634-649. [FREE Full text] [doi: 10.3934/publichealth.2020050] [Medline: 32968683]
99. Pommelet V, Mariani P, Basmaci R, Tourdjman M, Morin L, Gaschignard J, et al. Enteric fever among children: 50 cases in a French tertiary care centre. J Travel Med. Jan 01, 2018;25(1):059. [doi: 10.1093/jtm/tay059] [Medline: 30060197]
100. Pradier C, Keita-Perse O, Bernard E, Gisbert C, Vezolles MJ, Armengaud A, et al. Outbreak of typhoid fever on the French Riviera. Eur J Clin Microbiol Infect Dis. Jun 4, 2000;19(6):464-467. [doi: 10.1007/s100960000300] [Medline: 10947223]
101. Qamar FN, Yousafzai MT, Khalid M, Kazi AM, Lohana H, Karim S, et al. Outbreak investigation of ceftriaxone-resistant Salmonella enterica serotype Typhi and its risk factors among the general population in Hyderabad, Pakistan: a matched case-control study. Lancet Infect Dis. Dec 2018;18(12):1368-1376. [doi: 10.1016/S1473-3099(18)30483-3] [Medline: 30507460]
102. Ren X, Zhang S, Luo P, Zhao J, Kuang W, Ni H, et al. Spatial heterogeneity of socio-economic determinants of typhoid/paratyphoid fever in one province in central China from 2015 to 2019. BMC Public Health. May 22, 2023;23(1):927. [FREE Full text] [doi: 10.1186/s12889-023-15738-0] [Medline: 37217879]
103. Srinivasan M, Sindhu K, Kumar JS, Ramasamy RK, Pragasam AK, Aasaithampi P, et al. Outbreak of typhoid fever in children of urban Vellore: a report from the surveillance for enteric fever in India cohort. Am J Trop Med Hyg. Jul 13, 2022;107(1):82-85. [doi: 10.4269/ajtmh.21-0593] [Medline: 35895361]
104. Sur D, Ali M, von Seidlein L, Manna B, Deen JL, Acosta CJ, et al. Comparisons of predictors for typhoid and paratyphoid fever in Kolkata, India. BMC Public Health. Oct 12, 2007;7(1):289. [FREE Full text] [doi: 10.1186/1471-2458-7-289] [Medline: 17935611]
105. Sutiono AB, Qiantori A, Suwa H, Ohta T. Characteristics and risk factors for typhoid fever after the tsunami, earthquake and under normal conditions in Indonesia. BMC Res Notes. Apr 17, 2010;3:106. [FREE Full text] [doi: 10.1186/1756-0500-3-106] [Medline: 20398409]
106. Tadesse BT, Khanam F, Ahmmed F, Im J, Islam MT, Kim DR, et al. Prevention of typhoid by Vi conjugate vaccine and achievable improvements in household water, sanitation, and hygiene: evidence from a cluster-randomized trial in Dhaka, Bangladesh. Clin Infect Dis. Nov 14, 2022;75(10):1681-1687. [FREE Full text] [doi: 10.1093/cid/ciac289] [Medline: 35412603]
107. Vighio A, Syed MA, Hussain I, Zia SM, Fatima M, Masood N, et al. Risk factors of extensively drug resistant typhoid fever among children in Karachi: case-control study. JMIR Public Health Surveill. May 11, 2021;7(5):e27276. [FREE Full text] [doi: 10.2196/27276] [Medline: 33973861]
108. Vollaard AM, Ali S, van Asten HA, Ismid IS, Widjaja S, Visser LG, et al. Risk factors for transmission of foodborne illness in restaurants and street vendors in Jakarta, Indonesia. Epidemiol Infect. Oct 2004;132(5):863-872. [doi: 10.1017/s0950268804002742] [Medline: 15473149]
109. Vollaard AM, Verspaget HW, Ali S, Visser LG, Veenendaal RA, Van Asten HA, et al. Helicobacter pylori infection and typhoid fever in Jakarta, Indonesia. Epidemiol Infect. Feb 22, 2006;134(1):163-170. [doi: 10.1017/S0950268805004875] [Medline: 16409664]
110. Wang JF, Wang Y, Zhang J, Christakos G, Sun JL, Liu X, et al. Spatiotemporal transmission and determinants of typhoid and paratyphoid fever in Hongta District, Yunnan Province, China. PLoS Negl Trop Dis. 2013;7(3):e2112. [FREE Full text] [doi: 10.1371/journal.pntd.0002112] [Medline: 23516653]
111. Wang LX, Li XJ, Fang LQ, Wang DC, Cao WC, Kan B. Association between the incidence of typhoid and paratyphoid fever and meteorological variables in Guizhou, China. Chin Med J (Engl). Feb 2012;125(3):455-460. [Medline: 22490402]
112. Afifi S, Earhart K, Azab MA, Youssef FG, El Sakka H, Wasfy M, et al. Hospital-based surveillance for acute febrile illness in Egypt: a focus on community-acquired bloodstream infections. Am J Trop Med Hyg. Aug 2005;73(2):392-399. [Medline: 16103611]

113. Bendib A, Dridi H, Kalla M, Baziz N. Spatial analysis of typhoid fever vulnerability in the city of Batna (eastern Algeria). Environ Risques Santé. 2016;15(3):228-237. [FREE Full text]
114. Coté TR, Convery H, Robinson D, Ries A, Barrett T, Frank L, et al. Typhoid fever in the park: epidemiology of an outbreak at a cultural interface. J Community Health. Dec 1995;20(6):451-458. [doi: 10.1007/BF02277062] [Medline: 8568020]
115. Kelly-Hope LA, Alonso WJ, Thiem VD, Anh DD, Canh DG, Lee H, et al. Geographical distribution and risk factors associated with enteric diseases in Vietnam. Am J Trop Med Hyg. Apr 2007;76(4):706-712. [Medline: 17426175]
116. Khatami A, Khan F, Macartney KK. Enteric fever in children in Western Sydney, Australia, 2003-2015. Pediatr Infect Dis J. Dec 2017;36(12):1124-1128. [doi: 10.1097/INF.0000000000001606] [Medline: 28445250]
117. Salama RI, Emara MH, Mostafa HM, Abd-Elsalam S, Alnabawy S, Elshweikh SA, et al. Helicobacter pylori infection and risk of salmonella infection. Medicine (Baltimore). Feb 2019;98(6):e14335. [FREE Full text] [doi: 10.1097/MD.0000000000014335] [Medline: 30732157]
118. Stroffolini T, Manzillo G, De Sena R, Manzillo E, Pagliano P, Zaccarelli M, et al. Typhoid fever in the Neapolitan area: a case-control study. Eur J Epidemiol. Jul 1992;8(4):539-542. [doi: 10.1007/BF00146373] [Medline: 1397222]
119. Yousafzai MT, Qamar FN, Shakoor S, Saleem K, Lohana H, Karim S, et al. Ceftriaxone-resistant salmonella typhi outbreak in Hyderabad City of Sindh, Pakistan: high time for the introduction of typhoid conjugate vaccine. Clin Infect Dis. Feb 15, 2019;68(Suppl 1):S16-S21. [FREE Full text] [doi: 10.1093/cid/ciy877] [Medline: 30767003]
120. Abdullahi Tawfiq U, Shohaimi S, Mohd Nadzir MN, Amin Nordin S, Ab Rahman AH, Salari N. Epidemiology and risk factors for typhoid fever in Gombe metropolis, Gombe State, Nigeria. Malays J Public Health Med. 2022;22(2):110-121. [FREE Full text] [doi: 10.37268/mjphm/vol.22/no.2/art.1656]
121. Titus I, Iliyasu MY, Sahal MR, Umar RD, Wali MM, Ismai'l S, et al. Phenotypic characterization of virulence factors in multidrug-resistant Salmonella Typhi serovars isolated from clinical specimens in Bauchi metropolis. South Asian J Res Microbiol. 2023;15(3):10-20. [FREE Full text] [doi: 10.9734/sajrm/2023/v15i3287]
122. Velema JP, van Wijnen G, Bult P, van Naerssen T, Jota S. Typhoid fever in Ujung Pandang, Indonesia--high-risk groups and high-risk behaviours. Trop Med Int Health. Nov 03, 1997;2(11):1088-1094. [FREE Full text] [doi: 10.1046/j.1365-3156.1997.d01-179.x] [Medline: 9391512]
123. Vollaard AM, Ali S, van Asten HA, Widjaja S, Visser LG, Surjadi C, et al. Risk factors for typhoid and paratyphoid fever in Jakarta, Indonesia. JAMA. Jun 02, 2004;291(21):2607-2615. [doi: 10.1001/jama.291.21.2607] [Medline: 15173152]
124. Dunstan SJ, Nguyen TH, Rockett K, Forton J, Morris AP, Diakite M, et al. A TNF region haplotype offers protection from typhoid fever in Vietnamese patients. Hum Genet. Aug 15, 2007;122(1):51-61. [FREE Full text] [doi: 10.1007/s00439-007-0372-9] [Medline: 17503085]
125. Steinberg EB, Bishop R, Haber P, Dempsey AF, Hoekstra RM, Nelson JM, et al. Typhoid fever in travelers: who should be targeted for prevention? Clin Infect Dis. Jul 15, 2004;39(2):186-191. [doi: 10.1086/421945] [Medline: 15307027]
126. Feng Y, Pan H, Zheng B, Li F, Teng L, Jiang Z, et al. An integrated nationwide genomics study reveals transmission modes of typhoid fever in China. mBio. Oct 31, 2023;14(5):e0133323. [FREE Full text] [doi: 10.1128/mbio.01333-23] [Medline: 37800953]
127. Siddiqui FJ, Haider SR, Bhutta ZA. Risk factors for typhoid fever in children in squatter settlements of Karachi: a nested case-control study. J Infect Public Health. 2008;1(2):113-120. [FREE Full text] [doi: 10.1016/j.jiph.2008.10.003] [Medline: 20701852]
128. Muche G, Tesfaw A, Bayou FD. Prevalence of typhoid fever and its associated factors among febrile patients visiting Arerti Primary Hospital, Amhara Region, north east Ethiopia. Front Public Health. Aug 16, 2024;12:1357131. [FREE Full text] [doi: 10.3389/fpubh.2024.1357131] [Medline: 39220452]
129. Herdman MT, Karo B, Dave J, Katwa P, Freedman J, Do Nascimento V, et al. Increasingly limited options for the treatment of enteric fever in travellers returning to England, 2014-2019: a cross-sectional analytical study. J Med Microbiol. Aug 2021;70(8):1359. [FREE Full text] [doi: 10.1099/jmm.0.001359] [Medline: 34351258]
130. Antillón M, Warren JL, Crawford FW, Weinberger DM, Kürüm E, Pak GD, et al. The burden of typhoid fever in low- and middle-income countries: a meta-regression approach. PLoS Negl Trop Dis. Feb 27, 2017;11(2):e0005376. [FREE Full text] [doi: 10.1371/journal.pntd.0005376] [Medline: 28241011]
131. Anonymous. Typhoid in the large cities of the United States in 1919. JAMA. Mar 06, 1920;74(10):672-675. [FREE Full text] [doi: 10.1001/jama.1920.26210100002011]
132. Progress on drinking water and sanitation: Joint Monitoring Programme update 2012. World Health Organization. Mar 06, 2012. URL: https://www.who.int/publications/i/item/9789280646320 [accessed 2024-02-08]
133. Ercumen A, Arnold BF, Kumpel E, Burt Z, Ray I, Nelson K, et al. Upgrading a piped water supply from intermittent to continuous delivery and association with waterborne illness: a matched cohort study in urban India. PLoS Med. Oct 27, 2015;12(10):e1001892. [FREE Full text] [doi: 10.1371/journal.pmed.1001892] [Medline: 26505897]
134. Karkey A, Jombart T, Walker AW, Thompson CN, Torres A, Dongol S, et al. The ecological dynamics of fecal contamination and Salmonella Typhi and Salmonella Paratyphi A in municipal Kathmandu drinking water. PLoS Negl Trop Dis. Jan 6, 2016;10(1):e0004346. [FREE Full text] [doi: 10.1371/journal.pntd.0004346] [Medline: 26735696]
135. Feglo PK, Frimpong EH, Essel-Ahun M. Salmonellae carrier status of food vendors in Kumasi, Ghana. East Afr Med J. Jul 22, 2004;81(7):358-361. [doi: 10.4314/eamj.v81i7.9191] [Medline: 15490708]

136. Parry CM. Epidemiological and clinical aspects of human typhoid fever. In: Maskell D, Mastroeni P, editors. Salmonella Infections: Clinical, Immunological and Molecular Aspects. Cambridge, UK. Cambridge University Press; 2006.
137. Rasul F, Sughra K, Mushtaq A, Zeeshan N, Mehmood S, Rashid U. Surveillance report on typhoid fever epidemiology and risk factor assessment in district Gujrat, Punjab, Pakistan. Biomed Res. 2017;28(8):1-6. [FREE Full text]
138. Parry CM, Karunanayake L, Coulter JB, Beeching NJ. Test for quinolone resistance in typhoid fever. BMJ. Jul 29, 2006;333(7561):260-261. [FREE Full text] [doi: 10.1136/bmj.333.7561.260-b] [Medline: 16873871]
139. Gunn JS, Marshall JM, Baker S, Dongol S, Charles RC, Ryan ET. Salmonella chronic carriage: epidemiology, diagnosis, and gallbladder persistence. Trends Microbiol. Nov 2014;22(11):648-655. [FREE Full text] [doi: 10.1016/j.tim.2014.06.007] [Medline: 25065707]
140. Gupta V, Kaur M, Datta P, Chander J. Chronic urinary carrier state due to Salmonella Typhi causing urinary tract infection in an immunocompetent healthy woman. Trop Doct. Jul 07, 2018;48(3):236-238. [doi: 10.1177/0049475517752205] [Medline: 29307275]
141. Clemens J, Albert MJ, Rao M, Qadri F, Huda S, Kay B, et al. Impact of infection by Helicobacter pylori on the risk and severity of endemic cholera. J Infect Dis. Jun 01, 1995;171(6):1653-1656. [doi: 10.1093/infdis/171.6.1653] [Medline: 7769312]
142. Passaro DJ, Taylor DN, Meza R, Cabrera L, Gilman RH, Parsonnet J. Acute Helicobacter pylori infection is followed by an increase in diarrheal disease among Peruvian children. Pediatrics. Nov 2001;108(5):E87. [doi: 10.1542/peds.108.5.e87] [Medline: 11694671]
143. Saad NJ, Lynch VD, Antillón M, Yang C, Crump JA, Pitzer VE. Seasonal dynamics of typhoid and paratyphoid fever. Sci Rep. May 02, 2018;8(1):6870. [FREE Full text] [doi: 10.1038/s41598-018-25234-w] [Medline: 29720736]
144. Butler T, Mahmoud AA, Warren KS. Algorithms in the diagnosis and management of exotic diseases. XXIII. Typhoid fever. J Infect Dis. Jun 01, 1977;135(6):1017-1020. [doi: 10.1093/infdis/135.6.1017] [Medline: 864284]

Abbreviations

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TCV: typhoid conjugate vaccine
WASH: water, sanitation, and hygiene
WHO: World Health Organization

Edited by A Mavragani; submitted 14.10.24; peer-reviewed by I Friesema, M Yue; comments to author 13.02.25; revised version received 07.05.25; accepted 04.06.25; published 28.08.25

Please cite as:
Boakye Okyere P, Twumasi-Ankrah S, Newton S, Nkansah Darko S, Owusu Ansah M, Darko E, Agyapong F, Jeon HJ, Adu-Sarkodie Y, Marks F, Owusu-Dabo E
Risk Factors for Typhoid Fever: Systematic Review
JMIR Public Health Surveill 2025;11:e67544
URL: https://publichealth.jmir.org/2025/1/e67544
doi: 10.2196/67544
PMID: 40875987