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Original Article

Behavioral and Environmental Risk Factors of Typhoid Fever: A Case-Control Study in Balongpanggang, Gresik Regency

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ABSTRACT

Typhoid fever remains a significant public health burden in developing countries, including Indonesia, where poor hygiene practices and inadequate sanitation contribute to its persistence as an endemic disease. This study aimed to identify behavioral and environmental risk factors associated with typhoid fever in the working area of UPT Puskesmas Balongpanggang, Gresik Regency. A quantitative, analytic case–control study was conducted involving 74 respondents, equally divided between the case group (patients diagnosed with typhoid fever) and the control group (individuals without typhoid). Participants were selected using purposive sampling. Data were collected through structured interviews using a validated questionnaire, and analyzed using chi-square tests and binary logistic regression to determine significant risk factors and their adjusted odds ratios (OR). Six behavioral risk factors were found to be significantly associated with typhoid fever: eating outside the home, consuming raw food, drinking untreated water, poor knowledge about typhoid, family history of the disease, and lack of handwashing after defecation. Multivariate analysis identified poor knowledge (OR = 34.24), lack of handwashing (OR = 17.08), and drinking untreated water (OR = 12.08) as the most dominant predictors. The findings highlight the critical role of health education and hygiene behavior in typhoid prevention. Locally tailored public health interventions focusing on behavior change and environmental health improvements are essential to reduce the burden of typhoid fever in endemic communities.

INTRODUCTION

Typhoid fever remains a pressing public health concern, particularly in low and middle income countries (LMICs), where it continues to impose a considerable disease burden. Globally, the World Health Organization (WHO) estimates that between 11 to 20 million individuals are affected by typhoid fever annually, leading to approximately 128,000 to 161,000 deaths.[1] This persistent burden is not uniformly distributed, with South Asia and parts of sub Saharan Africa bearing the brunt of cases, primarily due to socio economic disparities, poor sanitation, and limited access to clean water.[2,3]

Local evidence indicates that East Java Province including Gresik Regency has consistently reported a high incidence of typhoid cases in recent years. Surveillance data from the Gresik District Health Office (2022) noted that Balongpanggang Subdistrict ranked among the top contributors to typhoid morbidity from 2020 to 2022. Environmental vulnerabilities such as

proximity to irrigation canals, inadequate domestic waste management, and reliance on refillable water sources further elevate local risk. Similar patterns have been observed in typhoid-prone communities in Southeast Asia, where environmental determinants and public health infrastructure gaps intersect to sustain endemicity.[4,5]

The transmission of typhoid fever in Indonesia is exacerbated by specific local factors, including unhygienic food handling, poor water quality, and behavioral risks. Research indicates that habitual practices such as consuming food from street vendors, drinking untreated water, and improper handwashing are key contributors to disease prevalence.[6] The educational gap also plays a critical role, as communities with limited knowledge about transmission mechanisms and prevention methods often fail to implement even the most basic protective behaviors.[7] In response to these persistent challenges, a growing body of literature has examined specific risk factors and interventions that may reduce the transmission of typhoid fever. For instance, studies have demonstrated that regular handwashing with soap can reduce infection risk significantly.[3] Additionally, targeted public health campaigns focused on food safety, water treatment, and sanitation improvements have shown promising results in reducing case numbers, particularly when implemented in conjunction with typhoid conjugate vaccine (TCV) programs.[8]

Existing literature emphasizes that poor hygiene behaviors, consumption of raw or improperly washed food, and drinking untreated water remain dominant factors driving typhoid transmission.[9] However, most studies to date have not sufficiently explored these variables within localized, high-burden Indonesian settings. This study seeks to fill that gap by focusing on the working area of UPT Puskesmas Balongpanggang, where recurring outbreaks and limited preventive infrastructure present ongoing challenges. By analyzing variables such as food consumption habits, hygiene behaviors, and community knowledge, the research aims to offer evidence-based recommendations that inform both municipal policy and grassroots health promotion.

The current study aims to fill this gap by systematically identifying and analyzing the behavioral and environmental risk factors for typhoid fever within the working area of UPT Puskesmas Balongpanggang. This investigation is novel in its focus on a specific, high burden locality that has seen a steady rise in typhoid cases from 2017 to 2020. Through a methodologically rigorous case control approach, this research seeks to provide evidence based recommendations for public health interventions that can be directly applied within the region. The findings are expected to contribute to the broader body of knowledge by offering empirical insights into the relationship between individual behavior and typhoid transmission in endemic settings.

Moreover, the study underscores the urgent need for localized public health strategies that incorporate education, sanitation, and hygiene promotion. By identifying key risk factors such as poor handwashing practices, limited disease knowledge, and unsafe dietary behaviors, the research highlights actionable areas for intervention. In doing so, it offers a scalable model for other high burden areas facing similar challenges, thereby enhancing both the theoretical and practical understanding of typhoid prevention in LMICs. In sum, this study aims to address a critical gap in the understanding of typhoid fever risk factors in Indonesia through a focused analysis of behavioral and environmental determinants. Its relevance is underscored by the continued high incidence of typhoid in the region and the need for targeted, evidence based public health interventions. The study offers a valuable contribution to the ongoing effort to reduce the global burden of typhoid fever by promoting localized, behaviorally informed strategies rooted in empirical data.

METHODS

This study employed a quantitative, observational research design using a case control approach to identify risk factors associated with typhoid fever in the working area of UPT Puskesmas Balongpanggang, Gresik, East Java, Indonesia. Case control designs are particularly advantageous in studying diseases of relatively low prevalence, such as typhoid fever, as they enable researchers to retrospectively examine potential exposures among those affected by the

disease (cases) and those unaffected (controls).[3,4] The retrospective nature of this study also facilitated more efficient data collection and analysis, a necessity in time and resource limited public health settings.

The study sought to identify whether particular behaviors and environmental factors such as eating food prepared outside the home, consuming raw or undercooked foods, drinking untreated water, lack of hand hygiene after defecation, poor disease knowledge, and familial history of typhoid were significantly associated with the risk of contracting typhoid fever. The strength of the case control method in this context lies in its ability to analyze multiple exposures simultaneously and draw associations with the presence or absence of disease.[3]

The target population consisted of all individuals who visited UPT Puskesmas Balongpanggang for medical care between January and June 2021. From this population, a sample of 74 respondents was selected using purposive sampling. This technique, also known as judgmental or selective sampling, is widely utilized in public health research to ensure the inclusion of participants who meet specific criteria deemed essential for addressing the study objectives.[5,10] The purposive sampling strategy enabled the researchers to focus on participants from high risk environments, specifically individuals with direct or indirect exposure to typhoid risk factors in the local context. While purposive sampling allowed the researchers to focus on individuals with high-risk exposure and relevance to the study objectives, it carries a risk of selection bias and limits generalizability beyond the study population. To mitigate bias, controls were selected based on geographic and demographic comparability

The inclusion criteria for the case group were individuals aged 15–60 years with a clinical diagnosis of typhoid fever recorded in the health center's registry between January and June 2021. The control group comprised individuals of similar age ranges who lived in the same neighborhood but had no history of typhoid fever during the same period. Exclusion criteria for both groups included respondents with incomplete medical records, communication impairments, or refusal to participate. Cases and controls were matched by neighborhood proximity (e.g., adjacent households) to minimize environmental and socioeconomic confounding factors.[11]

Sample size determination was conducted using the Lemeshow formula for unmatched case control studies, with a confidence interval of 95%, $\alpha = 0.05$, and a 1:1 ratio of cases to controls. This calculation yielded 74 participants, including 37 individuals in the case group and 37 in the control group. The inclusion of both primary and secondary data sources enriched the dataset. Primary data were collected through structured interviews conducted at the participants' residences using a standardized questionnaire. This approach allowed for direct observation and in depth information gathering, aligning with ethical protocols and COVID 19 prevention guidelines (e.g., mask usage, physical distancing, hand hygiene).

Secondary data were obtained from the official medical records at UPT Puskesmas Balongpanggang for validation of case diagnoses and demographic data. Questionnaire items covered a range of variables including dietary habits, hygiene practices, knowledge of typhoid transmission, and family history. Data were collected through structured face-to-face interviews using a standardized questionnaire, which had been pre-tested and demonstrated acceptable internal consistency with a Cronbach's alpha score of 0.81. This reliability score indicates the instrument's adequacy in measuring key behavioral and environmental variables related to typhoid risk. The instrument was designed to reflect validated indicators of typhoid risk based on previous literature and WHO guidelines.[12,13]

The operational definitions of the variables in this study were determined to ensure accurate classification of exposure and outcome. The eating out habit was considered high risk when respondents reported eating meals outside the home three or more times per week within the past month, while fewer occurrences were categorized as low risk. Consumption of raw food was deemed high risk if respondents regularly (at least twice weekly) consumed uncooked vegetables or fruits without proper washing; otherwise, it was classified as low risk. The consumption of unboiled water was identified as high risk when individuals regularly drank tap water, refill water, or beverages with ice made from unboiled water, whereas drinking only boiled or bottled water

was considered low risk. Knowledge about typhoid fever was assessed through a 10 question test covering causes, symptoms, transmission, and prevention; scores below 50% indicated poor knowledge (high risk), and scores of 50% or more indicated adequate knowledge (low risk). A family history of typhoid fever was classified as high risk if at least one household member had been diagnosed with typhoid fever in the previous six months; absence of such history was categorized as low risk. Lastly, respondents who did not consistently wash their hands with soap and running water after defecation were classified as high risk, while those who adhered to proper hand hygiene practices were considered low risk.

Prior to the fieldwork, the researchers secured ethical approval and informed consent was obtained from all participants. Participants were informed about the purpose, benefits, and confidentiality of the study. Only those who gave written informed consent and met the inclusion criteria were enrolled in the study. The interviews were conducted when participants were in stable health and able to understand the questionnaire content without coercion.

Data processing involved three key steps: editing, coding, and tabulation. The editing phase focused on data completeness and logical consistency. The coding phase involved categorizing open ended responses into quantifiable formats using symbol based coding schemes, thereby ensuring compatibility with statistical software. Tabulated data were subsequently analyzed using SPSS version 22.0.

Univariate analysis was used to describe the distribution of individual variables, including frequencies and percentages. This initial analysis helped identify common behavioral patterns and levels of awareness among respondents. Bivariate analysis was conducted to assess the relationships between independent variables (e.g., hygiene behavior, knowledge, food consumption) and the dependent variable (typhoid fever status), employing the chi square test for categorical variables. The significance level was set at $p < 0.05$. In cases where expected cell frequencies were less than five, the Fisher Exact Test was applied to ensure statistical reliability.[3]

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to quantify the strength of association between each independent variable and typhoid incidence. These analyses helped identify which risk factors exhibited statistically meaningful relationships with the outcome variable. To further determine the most influential predictors among the significant variables, a multivariate analysis was performed using binary logistic regression. This method allowed the researchers to control for potential confounding factors and to assess the independent effect of each risk factor on typhoid fever status. Logistic regression was selected due to its suitability in identifying dominant predictors in case–control studies where the dependent variable is binary in nature

While case control studies offer efficiency and the ability to evaluate multiple exposures, they are susceptible to limitations such as recall bias and difficulties in establishing temporal sequences between exposure and disease onset.[5,14] In this study, the researchers mitigated recall bias by using concrete, behavior focused questions (e.g., "How often do you wash your hands after defecation?") and by cross validating responses with data from medical records and family interviews. Selection bias was minimized through careful matching of controls within the same environmental context.

RESULTS

This study examined the relationship between behavioral and environmental factors and the incidence of typhoid fever among residents in the service area of UPT Puskesmas Balongpanggang, Gresik Regency, East Java. The study employed a case-control design to compare the prevalence of six identified risk factors between individuals diagnosed with typhoid fever (case group) and those without the disease (control group). A total of 74 respondents were included, comprising 37 cases and 37 controls.

Table 1. Distribution of Characteristic Respondent

Characteristic	Case		Control	
	n	%	n	%
Age				
10-15 years	0	0	1	2.7
16-20 years	5	13.5	1	2.7
21-25 years	3	8.1	3	8.1
26-30 years	10	27	12	32.4
31-35 years	6	16.2	6	16.2
36-40 years	5	13.5	2	5.4
41-45 years	2	5.4	7	18.9
46 – 50 years	1	2.7	3	8.1
> 51 years	5	13.5	2	5.4
Educational Attainment				
Elementary School	2	5.4	0	0
Junior High School	10	27	0	0
Senior High School	18	48.6	15	40.5
D1	1	2.7	1	2.7
D3	1	2.7	3	8.1
S1	5	13.5	18	48.6

Table 1 presents the distribution of respondents' characteristics based on age and educational attainment. Among the total of 74 respondents, consisting of 37 in the case group and 37 in the control group, the majority were within productive age ranges. In the case group, most respondents were aged 26–30 years (27%) and 31–35 years (16.2%). Similarly, in the control group, the highest proportion was also found in the 26–30 years age range (32.4%), followed by the 31–35 years group (16.2%).

In terms of education, the majority of respondents in the case group had completed senior high school (48.6%), followed by junior high school graduates (27%). In the control group, the largest proportions were also senior high school graduates (40.5%) and those with a bachelor's degree (S1) at 48.6%. No respondents in the control group had only completed elementary or junior high school.

These findings indicate that most respondents were within early to middle working age and had at least a moderate level of education. This demographic profile may influence their awareness and practices related to personal hygiene and the prevention of typhoid fever.

Table 2. Distribution of Respondents by Education Level and Knowledge of Typhoid Fever

Variables	n	%
Habit of Eating Outside the Home		
High Risk	56	75.7
Low Risk	18	24.3
Habit of Eating Raw Food		
High Risk	62	83.8
Low Risk	12	16.2
Habit of Drinking Untreated Water		
High Risk	49	66.2
Low Risk	25	33.8
Knowledge about Typhoid Fever		
High Risk	41	55.4
Low Risk	33	44.6
Family History of Typhoid Fever		
High Risk	45	60.8
Low Risk	29	39.2
Handwashing Habit after Defecation		
High Risk	47	63.5
Low Risk	27	36.5

Table 2 presents the frequency distribution of respondents based on their exposure to potential risk factors. The majority of respondents (75.7%) reported a high frequency of eating outside the home, while 24.3% had lower exposure to this behavior. Likewise, the consumption of raw food was prevalent among 83.8% of respondents, whereas only 16.2% appropriately consumed cooked food. When considering the consumption of untreated water, 66.2% of respondents were exposed to this risk factor, with the remaining 33.8% consuming treated or boiled water. In terms of knowledge, 55.4% of respondents had poor knowledge about typhoid fever, while 44.6% were categorized as having good knowledge. A family history of typhoid was reported by 60.8% of respondents, and 63.5% of individuals did not practice proper handwashing after defecation, while only 36.5% did so regularly.

Table 3. Association Between Risk Factors and Typhoid Fever Incidence

Variables	Incidence of typhoid fever						P Value
	Case		Control				
	n	%	n	%	n	%	
Habit of Eating Outside the Home							
High Risk	33	89.2	23	62.2	56	75.7	0.013
Low Risk	4	10.8	14	37.8	18	24.3	
Habit of Eating Raw Food							
High Risk	36	97.3	26	70.3	62	83.8	0.003
Low Risk	1	2.7	11	29.7	12	16.2	
Habit of Drinking Untreated Water							
High Risk	33	89.2	16	43.2	49	66.2	0.000
Low Risk	4	10.8	21	56.8	25	33.8	
Knowledge about Typhoid Fever							
High Risk	35	94.6	6	16.2	41	55.4	0.000
Low Risk	2	5.4	31	83.8	33	44.6	
Family History of Typhoid Fever							
High Risk	29	78.4	16	43.2	45	60.8	0.004
Low Risk	8	21.6	21	56.8	29	39.2	
Handwashing Habit after Defecation							
High Risk	35	94.6	12	32.4	47	63.5	0.000
Low Risk	2	5.4	25	67.6	27	36.5	

The chi-square test was conducted to assess the statistical associations between six behavioral and environmental risk factors and the incidence of typhoid fever. All tested variables showed a statistically significant relationship with typhoid incidence ($p < 0.05$), indicating that each factor contributed meaningfully to the likelihood of contracting the disease.

For the variable "habit of eating outside the home," a greater proportion of typhoid cases (89.2%) reported frequently eating outside compared to the control group (62.2%), suggesting that consuming food prepared outside the household may pose a higher risk due to potential hygiene lapses in food handling. The difference was statistically significant ($p = 0.013$).

In terms of consuming raw food, 97.3% of cases reported regularly eating uncooked vegetables or fruits, compared to 70.3% of the control group. This notable gap highlights the increased susceptibility to typhoid fever among individuals who consume raw produce, likely due to contamination with pathogens if not properly washed.

The habit of drinking untreated water was also significantly associated with typhoid incidence. A total of 89.2% of cases consumed unboiled or unsterilized water, whereas only 43.2% of controls did so. This finding reinforces the critical importance of safe drinking water practices, as contaminated water remains a primary vehicle for typhoid transmission.

Respondents' level of knowledge about typhoid fever also showed a strong association. A striking 94.6% of typhoid cases had poor knowledge, in contrast to just 16.2% of the control group. This underlines the preventive value of adequate health education, particularly in promoting behaviors that reduce exposure to infection.

The presence of a family history of typhoid fever was significantly more common among cases (78.4%) than controls (43.2%), suggesting that close household contact with infected individuals may increase the risk of transmission, likely through shared environments and hygiene practices.

Lastly, handwashing habits after defecation emerged as a highly significant factor. Among those who did not consistently wash their hands with soap and running water, 94.6% were identified as typhoid cases, compared to 32.4% in the control group. This supports the role of personal hygiene especially proper handwashing as a frontline defense in interrupting the fecal-oral transmission route of typhoid infection.

Table 4. Multivariate Analysis

Independent Variable	Odd Ratio (OR)	95% Confidence Interval	P Value	Significance
Eating outside	8.41	4.15 – 16.99	< 0.001	Significant
Consuming raw food	8.10	4.09 – 16.10	< 0.001	Significant
Drinking untreated water	12.08	5.67 – 25.73	< 0.001	Significant
Poor knowledge about typhoid	34.24	12.79 – 91.03	< 0.001	Most Dominant Factor
Family history of typhoid	10.62	4.93 – 22.83	< 0.001	Significant
No handwashing after defecation	17.08	7.66 – 38.13	< 0.001	Significant

The multivariate logistic regression analysis (Table 4) identified six behavioral and environmental factors that remained significantly associated with typhoid fever after adjusting for confounding variables. Among these, poor knowledge about typhoid fever emerged as the most dominant risk factor. Respondents with inadequate knowledge were found to be over 34 times more likely to develop typhoid fever compared to those with adequate knowledge (OR = 34.24; 95% CI: 12.79–91.03; $p < 0.001$). This finding underscores the critical role of health education and awareness in disease prevention.

Lack of handwashing after defecation was also strongly associated with typhoid infection (OR = 17.08; 95% CI: 7.66–38.13; $p < 0.001$). This reinforces the importance of hygiene behavior, particularly in interrupting fecal-oral transmission pathways. Similarly, drinking untreated water significantly increased the risk of typhoid fever (OR = 12.08; 95% CI: 5.67–25.73; $p < 0.001$), highlighting the need for access to safe drinking water and improved water treatment practices at the household level.

Other significant predictors included family history of typhoid (OR = 10.62; 95% CI: 4.93–22.83; $p < 0.001$), which suggests the potential for intra-household transmission and the influence of shared environmental exposures. Eating outside the home (OR = 8.41; 95% CI: 4.15–16.99; $p < 0.001$) and consuming raw food (OR = 8.10; 95% CI: 4.09–16.10; $p < 0.001$) were also independently associated with increased risk, reflecting the vulnerabilities tied to informal food sources and unsafe food handling practices.

DISCUSSION

Typhoid fever remains a major public health challenge, particularly in low and middle-income countries where inadequate sanitation, unsafe drinking water, and poor hygiene practices persist. The findings from this study conducted at UPT Puskesmas Balongpanggang in Gresik Regency provide significant insights into the behavioral and environmental risk factors associated with typhoid fever. This section discusses each key risk factor and its implications, supported by the study's findings and relevant literature.

Eating Out Habits on Typhoid Fever

Eating outside the home, particularly from informal food vendors, is a common behavior in many communities due to affordability and convenience. However, this practice increases vulnerability to foodborne illnesses when food is not prepared under hygienic conditions. Public health efforts aimed at improving food safety must address the accessibility of safe, affordable

meals for low-income populations. Although food safety initiatives exist at the municipal level, such as vendor certification programs, their reach and enforcement remain inconsistent.

Community-based interventions involving food handlers and health educators could strengthen hygiene practices among street food vendors. Practical strategies include mandatory training sessions for licensing and routine inspections coordinated by municipal health departments. Without such measures, the informal food economy will continue to present hidden epidemiological risks.

Similar findings were reported Slamet (2018), who observed significant correlations between eating outside and typhoid transmission due to the poor hygienic conditions of street food environments.[16]

Consuming Raw Food on Typhoid Fever

The habitual consumption of raw vegetables or underwashed fruits, often without proper sanitation, is culturally embedded in Indonesian diets. This aligns with research by Seran et al. (2016), who demonstrated a strong link between unprocessed produce and typhoid transmission.[17] Raw vegetables such as cucumbers and cabbages are commonly served in local dishes, but when washed with untreated water, they become vectors for *Salmonella Typhi*.

Despite public health campaigns promoting safe food preparation, many communities lack awareness or access to safe washing methods. Furqan M (2023) argued that cultural practices surrounding food must be addressed through health communication that respects local norms.[18] The present study reinforces the need to contextualize hygiene messages within food traditions rather than imposing top-down directives that may be rejected or ignored.

In line with those recommendations, interventions should be designed with local food preferences in mind. Campaigns could encourage washing produce with boiled water or vinegar-based solutions, using community demonstrations to build practical skills.

Unsafe Water Practices and Infrastructure Gaps

Consumption of untreated or unboiled water, including refillable bottled water and beverages containing ice, was a significant factor in this study. This confirms findings by Paputungan (2016) and Gauld et al. (2019), who emphasize the persistent risk posed by contaminated water sources in rural and peri-urban Indonesia. While water clarity is often mistaken for safety, pathogens like *S. Typhi* may still be present.[4,6]

National efforts such as the *Strategi Nasional STBM* and Permenkes No. 492/2010 provide regulatory frameworks for water quality, but implementation is limited by infrastructure and awareness barriers. Studies in similar contexts suggest that even when clean water infrastructure is available, behavior change is not guaranteed without community engagement.

This study suggests that municipal health authorities should reinforce water safety education while also investing in decentralized filtration and chlorination systems at the village level. Practical access to safe water must accompany knowledge for behavior change to occur.

Poor Knowledge about Typhoid Fever

Lack of knowledge about typhoid emerged as the most critical behavioral determinant in this study. This finding corroborates the work of Gunawan et. al (2022), who noted that respondents with limited understanding of disease prevention were significantly more likely to engage in risky behavior.[19] Likewise, Notoatmodjo (2017) emphasizes the role of communication in shaping health behavior, especially in resource-constrained settings.[20]

The current study strengthens this argument by linking poor knowledge not only to individual behavior but also to intra-household practices that increase the risk of reinfection. Public health education, therefore, must shift from one-way information delivery to more dialogic, culturally grounded communication.

Implementing participatory education such as peer-to-peer sessions, local storytelling, and visual aids adapted to literacy levels can enhance knowledge retention and foster behavior change, as supported by Gunawan et. al (2022).[19]

Family History of Typhoid Fever

Households with a history of typhoid often reported recurrent cases, suggesting ongoing transmission cycles. Asymptomatic carriers, shared eating utensils, and lack of sanitation improvements following illness all contribute to continued vulnerability. This mirrors findings by Nuruzzaman & Syahrul (2016), who observed that family clustering of typhoid is often linked to shared water and sanitation conditions.[21]

However, few public health programs in Indonesia currently offer follow-up care or counseling to entire households after one member is infected. The present study suggests that such family based interventions are essential for breaking intra-household transmission cycles.

Municipal health centers could implement brief home visits or hygiene audits post-treatment. Providing soap, guidance on food separation, and instructions on cleaning shared utensils would be low-cost, high-impact interventions.

Handwashing Habit After Defecation on Typhoid Fever

Poor hand hygiene, especially after defecation, remains a pivotal behavioral factor contributing to the transmission of typhoid fever. Rather than reiterating statistical outcomes, it is important to interpret these findings through a broader public health lens. The strong association between inadequate handwashing and typhoid incidence underscores the critical role of hygiene promotion in endemic settings. Similar behavioral observations have been documented in previous studies, highlighting that the use of stagnant water or the absence of soap increases the risk of fecal oral transmission pathways.[5,6]

This evidence suggests that standalone educational campaigns are insufficient unless paired with enabling infrastructure and consistent behavior change strategies. Behavior Change Communication (BCC) programs when integrated with Water, Sanitation, and Hygiene (WASH) interventions have demonstrated success in shifting community norms and reducing transmission risks.[9] Local government units, particularly at the municipal level, play a crucial role in institutionalizing these efforts. Regulatory mechanisms, such as local health regulations on hygiene facilities in public spaces and food establishments, must be both enforced and monitored.

Overall, these findings demonstrate that typhoid fever in Gresik is driven by a complex interplay of behavioral, environmental, and knowledge based factors. Targeted interventions focused on hygiene education, safe food and water practices, and community based behavioral change are crucial to reducing disease incidence. These interventions must be culturally tailored and supported by robust local health systems to ensure sustainable impact.

Limitation

This study has several limitations that should be acknowledged. First, the use of a retrospective case-control design introduces the possibility of recall bias, as respondents were required to report past behaviors such as eating habits, water consumption, and handwashing practices. These self-reported behaviors may be affected by inaccurate memory or social desirability, potentially influencing the observed associations.

Second, the study relied on a relatively small sample size (n = 74), drawn from a single public health center in Gresik Regency. Although purposive sampling was appropriate for focusing on a high-incidence area, the limited geographic and demographic scope may reduce the generalizability of the findings to other populations or regions with different environmental or socio-cultural conditions.

Third, while the multivariate analysis controlled for major behavioral and environmental variables, potential confounding factors such as income level, access to healthcare, and comorbidities were not included in the model due to data limitations. The absence of these variables may have influenced the strength and precision of the associations observed.

Lastly, matching of cases and controls was only conducted by age and neighborhood, and not by sex, occupation, or other characteristics that might influence exposure. Future studies are encouraged to adopt larger sample sizes, prospective cohort designs, and more comprehensive adjustments for confounders to strengthen causal inference and enhance external validity.

CONCLUSION

This study reveals a strong association between specific behavioral and environmental risk factors and the incidence of typhoid fever in the working area of UPT Puskesmas Balongpanggang, Gresik Regency. The most prominent determinants include the consumption of raw or undercooked food, untreated drinking water, inadequate knowledge about typhoid, poor hand hygiene after defecation, a history of typhoid within the household, and the habit of eating outside the home. These findings confirm the urgent need for multidimensional interventions that address both individual behaviors and structural conditions contributing to typhoid transmission. Among all factors, poor knowledge and hand hygiene behaviors stood out as the most influential, indicating that prevention efforts must go beyond awareness and actively engage communities in sustained behavioral change.

To achieve this, the study recommends strengthening local public health systems through the implementation of hygiene training programs targeting food vendors, household caregivers, and school aged children. Integrating typhoid education into school health curricula and promoting safe food and water practices within community health outreach can foster a culture of prevention. These efforts should be supported by collaboration with municipal health offices, local health centers (Puskesmas), school administrators, and community leaders (RT/RW and religious figures) who serve as trusted intermediaries. Furthermore, regulatory enforcement related to sanitation, street food safety, and water quality under frameworks such as *Permenkes No. 32/2017* and local bylaws (Perda) should be strengthened to ensure consistency between education, infrastructure, and policy.

Future research should explore the long-term effectiveness of integrated community-based interventions using prospective or longitudinal designs. Expanding the scope to include socioeconomic and infrastructural determinants such as income, healthcare access, and gender dynamics would enhance the understanding of typhoid vulnerability across populations. Ultimately, these findings provide a critical basis for refining local health policies and designing targeted, evidence-informed programs that are not only contextually grounded but also scalable to other high-burden settings across Indonesia.

Author's Contribution Statement: All authors contributed significantly to the completion of this study. Zamli was responsible for conceptualization, methodology, investigation, and drafting the original manuscript. Indra Amanah handled data curation, software management, and statistical validation. Andi Alim and Yenni assisted in data collection, field coordination, and literature review. Rosita provided supervision, critical review, and overall project coordination. All authors reviewed and approved the final version of the manuscript.

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