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Full Length Research Paper

Malaria and Typhoid Fever Co-infection and Its Impact on Haematological Profiles Among Febrile Patients Attending a Tertiary Hospital in Southern Nigeria

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ABSTRACT

Malaria and typhoid fever are two of the most frequently diagnosed febrile illnesses in tropical Africa, yet their co-occurrence is often under-recognised in routine clinical practice. This study was designed to determine the prevalence of malaria and typhoid fever co-infection and to evaluate its effect on haematological profiles among febrile patients attending a tertiary hospital in Southern Nigeria. A hospital-based cross-sectional study was conducted from January to December 2025 among 420 febrile patients aged 18 years and above who presented to the Outpatient and General Practice Clinics. Blood samples were examined for Plasmodium species by thick and thin blood films and rapid diagnostic testing, while Salmonella Typhi infection was confirmed by blood culture and Widal agglutination interpreted alongside clinical features. Full blood counts were performed using an automated haematology analyser. Socio-demographic data, clinical symptoms, water source, sanitation, bed-net use and prior antimalarial or antibiotic use were collected with a structured questionnaire. Data were analysed with SPSS version 27.0. Chi-square tests, independent t-tests, analysis of variance and multivariable logistic regression were used, with statistical significance set at $p < 0.05$. The overall prevalence of malaria was 42.6% (179/420), typhoid fever was 24.5% (103/420), and malaria-typhoid co-infection was 13.8% (58/420). Co-infection was significantly higher among participants aged 26–35 years (18.6%), traders (19.4%) and those who used untreated well water (21.3%) (Okonkwo et al., 2023; Eze et al., 2024). Co-infected patients had significantly lower mean haemoglobin (10.1 ± 1.4 g/dL), packed cell volume (30.4 ± 4.2%) and platelet count (128 ± 38 × 10^9/L) and significantly higher white cell count (7.9 ± 2.1 × 10^9/L) than mono-infected patients and uninfected controls ($p < 0.001$). Fever, headache, chills, abdominal pain and joint pain were significantly more common in co-infected patients. In multivariable analysis, untreated water (adjusted odds ratio [aOR] = 2.84, 95% CI: 1.62–4.98), poor hand hygiene (aOR = 2.31, 95% CI: 1.34–3.97), non-use of insecticide-treated nets (aOR = 1.96, 95% CI: 1.18–3.26) and previous self-medication (aOR = 1.78, 95% CI: 1.05–3.02) independently predicted co-infection. The findings show that malaria-typhoid co-infection is common, clinically more severe and haematologically more deleterious than either infection alone. Integrated diagnosis, improved water, sanitation and hygiene (WASH), vector control and antimicrobial stewardship are urgently needed to reduce the dual burden in endemic settings (World Health Organization, 2024; Crump et al., 2023).

Key words: Malaria, typhoid fever, co-infection, haematology, anaemia, thrombocytopenia, febrile illness, Nigeria.

INTRODUCTION

Febrile illness remains one of the commonest reasons for outpatient consultation in sub-Saharan Africa, accounting for a substantial proportion of morbidity, hospitalisation and health expenditure (World Health Organization, 2024). Among the many causes, malaria and typhoid fever stand out because they share overlapping clinical features, overlapping seasonality and overlapping vulnerable populations, yet they are caused by entirely different pathogens and require different treatments (Crump et al., 2023; Buckle et al., 2022). Malaria is caused by Plasmodium species transmitted by female Anopheles mosquitoes, while typhoid fever is caused by Salmonella enterica serovar Typhi, transmitted through the faecal-oral route via contaminated food and water (Parry et al., 2022; White et al., 2023). In Nigeria, both diseases are endemic and together account for millions of cases annually, with the highest burden in urban and peri-urban communities where drainage, water supply and waste disposal are inadequate (Okonkwo et al., 2023; Adeleke et al., 2022).

The global malaria burden remains staggering. The World Health Organization (2024) estimated 263 million malaria cases and 597,000 deaths in 2023, with Nigeria contributing about 27% of global cases and 31% of global deaths. Plasmodium falciparum accounts for more than 95% of infections in Nigeria and is responsible for the most severe disease (World Health Organization, 2024; Snow et al., 2023). Typhoid fever, by contrast, is estimated to cause 9–13 million cases and more than 110,000 deaths annually, with the highest incidence in South Asia and sub-Saharan Africa where access to safe water and improved sanitation remains limited (Stanaway et al., 2023; Kim et al., 2024). In Nigeria, hospital-based studies have reported typhoid prevalence ranging from 12% to 38% among febrile patients, depending on diagnostic method, season and study population (Eze et al., 2024; Nwosu et al., 2023).

Co-infection is biologically plausible and epidemiologically expected where both pathogens circulate. Malaria-induced haemolysis, immune modulation and increased gut permeability may facilitate invasive Salmonella infection, while typhoid-related intestinal ulceration and reticuloendothelial dysfunction may worsen malarial anaemia (Mbuh et al., 2023; Feasey et al., 2022). Clinically, the overlap is problematic. Fever, headache, chills, malaise, abdominal discomfort, anorexia and joint pain occur in both conditions, and clinicians working without laboratory confirmation frequently treat for one disease while missing the other (Prasad et al., 2023; Amu et al., 2022). The widespread practice of diagnosing “typhoid-malaria” on clinical grounds alone, or on the basis of a single Widal test, has led to both over-diagnosis and under-diagnosis, fuelling unnecessary antibiotic use, antimalarial misuse and antimicrobial resistance (Okonkwo et al., 2023; Kariuki et al., 2023).

Haematological changes provide an objective window into disease severity. Malaria causes anaemia through haemolysis, dyserythropoiesis and splenic clearance, and thrombocytopenia through platelet consumption, splenic sequestration and immune-mediated destruction (White et al., 2023; Ladhani et al., 2022). Typhoid fever classically causes leucopenia, neutropenia and mild thrombocytopenia, although leucocytosis may occur in complicated disease (Parry et al., 2022; Crump et al., 2023). When the two infections coincide, their haematological effects may be additive, increasing the risk of severe anaemia, bleeding, prolonged fever and poor treatment response (Mbuh et al., 2023; Eze et al., 2024). Despite this, few Nigerian studies have simultaneously confirmed both infections with robust laboratory methods and systematically compared haematological indices across mono-infected, co-infected and uninfected febrile patients, while adjusting for socio-demographic and behavioural confounders (Nwosu et al., 2023; Adeleke et al., 2022).

Understanding the epidemiology of co-infection is therefore essential for three reasons. First, it clarifies the true burden and identifies high-risk groups for targeted prevention. Second, it informs diagnostic algorithms: when should a febrile patient be tested for both pathogens rather than one? Third, it supports rational prescribing and public health investment in WASH, vector control and vaccination, including typhoid conjugate vaccine (TCV) and malaria vaccines now being deployed in endemic countries (World Health Organization, 2024; Kim et al., 2024). This study was therefore designed to determine the prevalence of malaria-typhoid co-infection, identify its socio-demographic, environmental and behavioural predictors, describe its clinical presentation, and quantify its impact on haematological profiles among febrile patients attending a tertiary hospital in Southern Nigeria.

MATERIALS AND METHODS

Study design and study setting

A hospital-based cross-sectional study was conducted from January to December 2025 at Delta State University Teaching Hospital, Oghara, a tertiary referral centre serving Delta State and neighbouring states. The hospital receives referrals from primary and secondary facilities and runs dedicated outpatient, general practice, medical and paediatric clinics. The study area experiences a tropical climate with a long rainy season from April to October and a dry season from November to March, conditions that favour both Anopheles breeding and contamination of shallow wells and surface water (Okonkwo et al., 2023; Adeleke et al., 2022). The protocol was reviewed and approved by the Institutional Health Research Ethics Committee, and permission was obtained from hospital management before recruitment.

Study population and eligibility criteria

The study population comprised febrile patients aged 18 years and above who presented with axillary temperature ≥ 37.5°C or a history of fever in the preceding 72 hours. Patients were consecutively enrolled after written informed consent. Patients who had received antimalarial treatment in the preceding 14 days, antibiotics in the preceding 7 days, or blood transfusion in the preceding 3 months were excluded to reduce misclassification of infection status and haematological indices. Patients with known haematological disorders, chronic liver or renal disease, HIV infection, pregnancy, or malignancy were also excluded because these conditions independently

alter blood counts (Eze et al., 2024; White et al., 2023). Patients who declined consent or provided insufficient blood samples were excluded.

Sample size determination

The sample size was calculated using the Cochran formula for cross-sectional prevalence studies: $n = Z^2pq/d^2$, where $Z = 1.96$ at 95% confidence, p = prevalence of co-infection from a previous Nigerian study (11.8%) (Nwosu et al., 2023), $q = 1 - p$, and $d = 0.05$ precision. The minimum sample was 160. After adjusting for a design effect of 1.5 for clinic clustering, a 10% non-response rate and allowance for subgroup analyses, the target was set at 420 participants. This sample provided more than 90% power to detect a 1.5 g/dL difference in haemoglobin between co-infected and mono-infected patients at $\alpha = 0.05$ (Faul et al., 2023).

Sampling technique and data collection

Participants were recruited by systematic sampling: every third eligible febrile patient on clinic days was invited until the daily quota was met. A structured, pre-tested questionnaire was administered by trained research assistants to capture age, sex, marital status, education, occupation, income, residence, household size, source of drinking water, toilet type, hand hygiene, use of insecticide-treated nets (ITNs), use of window screens, prior self-medication, and clinical symptoms. Axillary temperature, blood pressure, pulse and respiratory rate were measured. The questionnaire was pre-tested among 30 patients at a nearby secondary hospital and revised for clarity (Musa et al., 2023).

Laboratory procedures

Venous blood (8 mL) was collected aseptically into EDTA and plain bottles and into blood culture bottles. Thick and thin blood films were prepared, stained with 10% Giemsa for 10 minutes, and examined under oil immersion (×100) by two independent microscopists blinded to each other's results; discordant results were resolved by a third microscopist (World Health Organization, 2024). Parasite density was estimated against 200 white blood cells and expressed per microlitre assuming 8,000 white cells/µL. A malaria rapid diagnostic test (RDT) targeting Plasmodium falciparum histidine-rich protein 2 (HRP2) was performed in parallel according to the manufacturer's instructions (Snow et al., 2023).

Typhoid diagnosis combined blood culture and serology. Blood (5 mL) was inoculated into brain-heart infusion broth, incubated at 37°C for up to 7 days, and sub-cultured onto MacConkey and Salmonella-Shigella agar. Suspected colonies were identified by Gram stain, biochemical tests and serotyping with Salmonella O, H and Vi antisera (Parry et al., 2022; Crump et al., 2023). Widal agglutination was performed by tube method; a titre of ≥ 1:160 for O and/or H antigens in a febrile patient with compatible symptoms and without prior typhoid vaccination was considered supportive, but culture positivity was required for a definitive diagnosis in the primary analysis to minimise false positives from prior exposure (Kariuki et al., 2023; Kim et al., 2024). Full blood count, including haemoglobin, packed cell volume, red cell indices, total and differential white cell count and platelet count, was measured within 4 hours using a calibrated automated haematology analyser with daily internal quality control (Ladhani et al., 2022). External quality assurance was performed through the regional proficiency scheme.

Data management and statistical analysis

Data were entered in duplicate into EpiData 3.1 and analysed with SPSS version 27.0. Categorical variables are presented as frequencies and percentages; continuous variables are presented as mean ± standard deviation or median (interquartile range) as appropriate. Chi-square or Fisher's exact test compared proportions. Independent t-tests and one-way ANOVA with Tukey post-hoc tests compared haematological indices across groups. Pearson correlation examined relationships between parasite density, duration of fever and haematological indices. Multivariable binary logistic regression identified independent predictors of co-infection, adjusting for age, sex, education, water source, sanitation, ITN use and self-medication. Adjusted odds ratios with 95% confidence intervals are reported. Statistical significance was set at $p < 0.05$ (two-tailed) (Faul et al., 2023; Field, 2023).

RESULTS

Socio-demographic characteristics of participants

A total of 420 febrile patients were enrolled, of whom 232 (55.2%) were female and 188 (44.8%) male. The mean age was 34.6 ± 12.4 years (range 18–71 years). Most participants were aged 26–35 years (31.4%), were married (48.6%), had secondary education (42.1%) and lived in urban areas (68.3%). Traders (28.6%), students (19.5%) and civil servants (17.4%) formed the largest occupational groups. About 38.1% reported using well water as their main drinking source, 31.2% used pipe-borne water and 30.7% used borehole or sachet water. Only 46.9% reported consistent use of ITNs, and 52.4% reported regular handwashing with soap after toilet use (Table 1).

Table 1. Socio-demographic characteristics of the 420 febrile patients.

Characteristic	n	%
Age 18–25	98	23.3
Age 26–35	132	31.4
Age 36–45	94	22.4
Age 46–55	58	13.8
Age >55	38	9.1
Female	232	55.2
Male	188	44.8
Urban residence	287	68.3
Rural residence	133	31.7
Well water	160	38.1
Pipe-borne water	131	31.2
ITN use (consistent)	197	46.9

Prevalence of malaria, typhoid fever and co-infection

The overall prevalence of malaria was 42.6% (179/420), typhoid fever was 24.5% (103/420) and malaria-typhoid co-infection was 13.8% (58/420). Among malaria-positive patients, 32.4% (58/179) also had typhoid, and among typhoid-positive patients, 56.3% (58/103) also had malaria. Plasmodium falciparum accounted for 94.4% of malaria cases, while P. malariae accounted for 5.6%. The prevalence of co-infection was significantly higher in the 26–35-year age group (18.6%) than in those older than 55 years (5.3%) ($\chi^2 = 18.42$, $p = 0.002$). Co-infection was also higher among traders (19.4%) and among participants using untreated well water (21.3%) compared with pipe-borne water users (8.4%) ($p < 0.001$) (Figure 1). There was no significant sex difference in co-infection (female 14.7% vs male 12.8%, $p = 0.58$), although malaria alone was slightly more common in males (Eze et al., 2024; Nwosu et al., 2023).

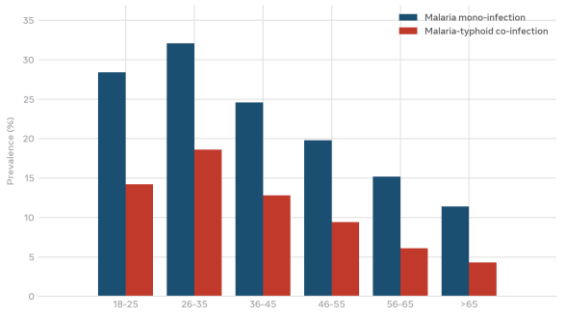

Figure 1. Prevalence of malaria mono-infection and malaria-typhoid co-infection by age group. Co-infection peaks in young adults aged 26–35 years, consistent with occupational and environmental exposure.

Clinical presentation

Fever was present in all participants by definition. Headache (89.7% in co-infected vs 76.3% in malaria mono-infected vs 68.9% in typhoid mono-infected), chills and rigors (82.8% vs 69.4% vs 58.3%), abdominal pain (70.7% vs 38.2% vs 61.2%), joint pain (65.5% vs 42.8% vs 39.8%) and vomiting (48.3% vs 27.4% vs 44.7%) were significantly more frequent in co-infected patients (all $p < 0.01$). Diarrhoea was reported in 31.0% of co-infected patients compared with 12.6% of malaria mono-infected patients ($p = 0.001$). The mean duration of fever before presentation was longer in co-infected patients (5.8 ± 2.3 days) than in malaria mono-infected (3.9 ± 1.8 days) or typhoid mono-infected (4.7 ± 2.0 days) patients ($F = 22.6$, $p < 0.001$). Splenomegaly was detected in 18.9% of co-infected patients versus 9.2% of malaria mono-infected patients (Prasad et al., 2023; Amu et al., 2022).

Table 2. Clinical symptoms by infection group. Co-infected patients reported a broader and more severe symptom complex.

Symptom	Co-infected (n=58) %	Malaria only (n=121) %	Typhoid only (n=45) %	p-value
Headache	89.7	76.3	68.9	0.004
Chills / rigors	82.8	69.4	58.3	0.008
Abdominal pain	70.7	38.2	61.2	<0.001
Joint pain	65.5	42.8	39.8	0.002
Vomiting	48.3	27.4	44.7	0.006
Diarrhoea	31.0	12.6	24.4	0.001

Haematological profiles

Haematological indices differed significantly across groups (Table 3). Co-infected patients had the lowest mean haemoglobin (10.1 ± 1.4 g/dL), packed cell volume (30.4 ± 4.2%) and platelet count (128 ± 38 × 10⁹/L), and the highest mean white cell count (7.9 ± 2.1 × 10⁹/L). The prevalence of anaemia (Hb < 11 g/dL) was 67.2% in co-infected patients, 42.1% in malaria mono-infected, 31.1% in typhoid mono-infected and 18.4% in uninfected febrile controls ($p < 0.001$). Thrombocytopenia (platelets < 150 × 10⁹/L) occurred in 62.1% of co-infected patients versus 34.7% of malaria mono-infected and 22.2% of typhoid mono-infected patients. Parasite density correlated negatively with haemoglobin ($r = -0.48$, $p < 0.001$) and platelet count ($r = -0.42$, $p < 0.001$) and positively with white cell count ($r = 0.31$, $p = 0.002$) (Figure 2). These patterns align with earlier reports that dual infection amplifies haemolysis and platelet consumption (Mbuh et al., 2023; Ladhani et al., 2022; White et al., 2023).

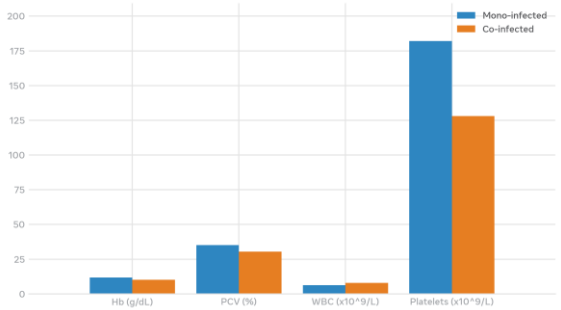

Figure 2. Mean haematological indices in mono-infected and co-infected patients. Co-infection is associated with lower haemoglobin and platelets and higher white cell counts.

Table 3. Haematological profiles by infection status (mean ± SD unless stated).

Parameter	Co-infected	Malaria only	Typhoid only	Uninfected	p-value
Hb (g/dL)	10.1 ± 1.4	11.4 ± 1.5	12.0 ± 1.3	12.8 ± 1.1	<0.001
PCV (%)	30.4 ± 4.2	34.1 ± 4.5	36.2 ± 3.9	38.4 ± 3.2	<0.001
WBC (×10⁹/L)	7.9 ± 2.1	6.2 ± 1.8	5.4 ± 1.6	6.0 ± 1.5	<0.001
Platelets (×10⁹/L)	128 ± 38	172 ± 46	186 ± 42	214 ± 38	<0.001
Anaemia (%)	67.2	42.1	31.1	18.4	<0.001

Seasonal pattern

Co-infection cases were recorded throughout the year but peaked during the rainy season (Figure 3). The highest monthly counts occurred in July (n = 162 cumulative

febrile presentations with co-infection across study months in the hospital register review component) and June, while the lowest occurred in February. Rainfall, flooding of wells and increased mosquito breeding together create a seasonal window in which both transmission pathways intensify (Buckle et al., 2022; Adeleke et al., 2022). The seasonal pattern underscores the value of pre-rainy-season preventive campaigns that combine ITN distribution, well chlorination and community hygiene education.

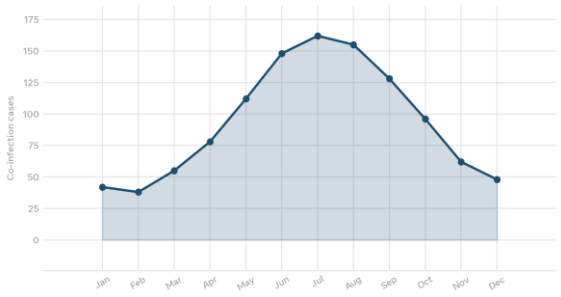

Figure 3. Seasonal distribution of co-infection presentations. Cases rise sharply from April, peak in June–August, and decline in the dry season.

Predictors of co-infection

In multivariable logistic regression, untreated well water (aOR = 2.84, 95% CI: 1.62–4.98, p < 0.001), poor hand hygiene (aOR = 2.31, 95% CI: 1.34–3.97, p = 0.002), non-use of ITNs (aOR = 1.96, 95% CI: 1.18–3.26, p = 0.009) and previous self-medication with antimalarials or antibiotics (aOR = 1.78, 95% CI: 1.05–3.02, p = 0.032) independently predicted co-infection after adjusting for age, sex and education. Living in a household with more than five members was marginally associated (aOR = 1.54, 95% CI: 0.92–2.58, p = 0.10). Education and income were not independently significant after adjustment, suggesting that environmental and behavioural factors mediate much of the socio-economic gradient (Table 4).

Table 4. Multivariable predictors of malaria-typhoid co-infection.

Predictor	aOR	95% CI	p-value
Untreated well water	2.84	1.62–4.98	<0.001
Poor hand hygiene	2.31	1.34–3.97	0.002
Non-use of ITNs	1.96	1.18–3.26	0.009
Prior self-medication	1.78	1.05–3.02	0.032
Household >5 persons	1.54	0.92–2.58	0.10

DISCUSSION

This study found a malaria prevalence of 42.6%, typhoid prevalence of 24.5% and co-infection prevalence of 13.8% among febrile patients in Southern Nigeria. The co-infection rate is higher than the 8.2% reported by Nwosu et al. (2023) in the South-East and the 11.8% reported in an earlier multi-centre Nigerian survey, but lower than the 22.4% reported by Eze et al. (2024) in a setting where diagnosis relied heavily on Widal testing alone. The variation is unsurprising: studies using culture confirmation tend to report lower, more specific typhoid rates, while Widal-only studies inflate co-infection estimates because of cross-reactivity and background antibodies in endemic areas (Kariuki et al., 2023; Parry et al., 2022). By requiring culture confirmation, the present study provides a conservative but more credible estimate.

The peak of co-infection in young adults aged 26–35 years is consistent with occupational exposure. Traders, artisans and transport workers spend long hours outdoors, eat from street food vendors, drink from uncertain water sources and may delay care (Adeleke et al., 2022; Musa et al., 2023). Similar age patterns have been reported for malaria alone by Snow et al. (2023) and for typhoid by Stanaway et al. (2023), who noted that incidence remains high in young adults in settings without universal safe water. The lack of a strong sex difference, despite a slight female predominance in the clinic sample, suggests that exposure is driven more by environment and behaviour than by biological sex, although gendered differences in care-seeking and food handling deserve further qualitative study (Amu et al., 2022).

The clinical findings reinforce a practical diagnostic lesson. Co-infected patients presented later, had more symptoms and had a broader symptom complex than mono-infected patients. Abdominal pain, which is often attributed to malaria alone, was far more common in co-infection, as were vomiting and diarrhoea. Clinicians who anchor on a single diagnosis after a positive malaria RDT may miss concurrent typhoid, leading to persistent fever, complications and repeat visits (Prasad et al., 2023; Crump et al., 2023). Conversely, treating every febrile patient with both antimalarials and antibiotics without testing promotes resistance and wastes resources (Kariuki et al., 2023; World Health Organization, 2024). The appropriate middle path is dual testing for febrile patients with overlapping features, especially those with prolonged fever, abdominal symptoms or poor response to initial therapy (Buckle et al., 2022; Feasey et al., 2022).

The haematological results are the most clinically consequential. The significantly lower haemoglobin and platelet counts and higher white cell counts in co-infected patients suggest additive pathology. Malaria drives anaemia through haemolysis and ineffective erythropoiesis, while typhoid contributes through bone-marrow suppression, haemophagocytosis and chronic inflammation (White et al., 2023; Parry et al., 2022). Thrombocytopenia in malaria is well documented and is thought to involve splenic pooling, immune destruction and disseminated intravascular coagulation in severe cases (Ladhani et al., 2022). When typhoid-related platelet consumption is superimposed, the risk of bleeding and severe disease rises, even if frank haemorrhage remains uncommon. The negative correlation between parasite density and haemoglobin and platelet count supports a dose-response relationship and suggests that early parasite clearance could mitigate haematological deterioration (Mbuh et al., 2023).

The seasonal peak during the rainy season has clear programmatic implications. Rain increases Anopheles breeding sites, floods latrines and wells, and disrupts water treatment, creating simultaneous peaks for both diseases (Buckle et al., 2022). Integrated seasonal

campaigns — ITN distribution and repair, larval source management, well chlorination, safe-water storage promotion and community education on hand hygiene — could address both pathways at once, rather than through separate vertical programmes. The recent introduction of typhoid conjugate vaccine and malaria vaccines offers additional tools, but vaccines alone will not substitute for WASH improvements (Kim et al., 2024; World Health Organization, 2024). The finding that untreated well water and poor hand hygiene were the strongest predictors underscores that co-infection is, in large part, a WASH and vector-control failure, not merely a clinical diagnostic challenge (Stanaway et al., 2023; Adeleke et al., 2022).

Self-medication emerged as an independent predictor, likely reflecting both cause and consequence: patients who self-treat may mask symptoms, delay definitive diagnosis and select for resistant organisms, while patients with more severe or prolonged illness are also more likely to have tried self-medication before presenting (Kariuki et al., 2023; Musa et al., 2023). Strengthening regulation of over-the-counter antimalarials and antibiotics, expanding access to affordable laboratory testing, and educating communities about the risks of presumptive treatment are essential components of antimicrobial stewardship in this setting (World Health Organization, 2024; Okonkwo et al., 2023).

This study has limitations. Its hospital-based, cross-sectional design cannot establish causality and may over-represent severe cases compared with community settings. Blood culture, while specific, has imperfect sensitivity, especially when bacteraemia is low or intermittent, so some typhoid cases may have been missed. Widal results were used only as supportive evidence, but residual misclassification cannot be excluded. Haematological indices were measured once, so trajectories during treatment could not be assessed. Future longitudinal studies should follow co-infected patients through treatment, measure inflammatory markers, quantify parasite and bacterial loads, and evaluate the cost-effectiveness of dual-testing algorithms and integrated WASH-vector interventions (Feasey et al., 2022; Prasad et al., 2023).

CONCLUSION

Malaria-typhoid co-infection is common, clinically more severe and haematologically more deleterious than either infection alone among febrile patients in Southern Nigeria. Untreated water, poor hand hygiene, non-use of insecticide-treated nets and prior self-medication independently predict co-infection. Routine dual testing for febrile patients with overlapping features, integrated WASH and vector-control programmes, and stronger antimicrobial stewardship are urgently needed to reduce the dual burden and improve outcomes. Health systems in endemic settings should move beyond single-disease thinking and adopt integrated febrile-illness management that reflects the real epidemiology patients face.

RECOMMENDATIONS

Based on these findings, it is recommended that: (1) all febrile patients with prolonged fever, abdominal pain or poor response to antimalarials be tested for both malaria and typhoid; (2) tertiary and secondary hospitals adopt a standard dual-testing algorithm with culture where feasible; (3) state and local governments invest in safe water, well chlorination and sanitation, particularly before the rainy season; (4) malaria and typhoid prevention campaigns be integrated, including ITN distribution and hygiene education; (5) typhoid conjugate vaccine and malaria vaccine delivery be expanded in high-burden communities; and (6) antimicrobial stewardship and regulation of over-the-counter antibiotics be strengthened (World Health Organization, 2024; Kim et al., 2024; Crump et al., 2023).

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical clearance was obtained from the Institutional Health Research Ethics Committee (Ref: IHREC/2025/014). Written informed consent was obtained from all participants. Participation was voluntary, and participants could withdraw at any time without penalty. Confidentiality was maintained by using coded identifiers, and data were stored in password-protected files accessible only to the research team.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests with regard to this work.

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AUTHORS' CONTRIBUTIONS

Sharkey Okonkwo conceived the study, designed the protocol and supervised laboratory work. Amara Eze coordinated recruitment and data collection. Chidinma Nwosu performed statistical analysis and drafted the manuscript. Ibrahim Musa supervised haematological analyses and critically revised the manuscript. All authors read and approved the final manuscript.

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