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Occurrence of *Salmonella* Enteric Serovar Typhi Antibodies among Blood Donors in Ghana

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Abstract

Background: Donated blood contaminated with *S.* Typhi can cause post-transfusion sepsis. This study aimed to determine the correlation between some risk factors of typhoid fever and seroprevalence of antibodies against *S.* Typhi among blood donors. **Methodology:** Following informed consent, socio-demographic and information on risk factors of typhoid infection was obtained using pre-structured questionnaires from 400 apparently healthy blood donors at the Tema General Hospital. Blood was also collected for serology and cultured for identification of pathogens by standard bacteriological method. **Results:** Blood culture did not reveal any *S.* Typhi isolate out of the tested 400 (348 males and 52 females) samples from apparently healthy blood donors. However, IgM and IgG antibody seroprevalence of 9.3% and 3.5% were detected. Age group of 17 - 24 years was the highest risk group, persons with a history of typhoid infection, and sources of drinking water were major risk factors for typhoid infection. It was also observed that prevalence of IgM was highest among new donors (62.2%), but lower in donors with a history of 1 to 3 blood donations (32.4%) and least among regular donors (>3 donations (5.4%)). In addition, typhoid prevention awareness and typhoid knowledge (knowledge about typhoid transmission) among the donors were poor (4.3% and 5.9% respectively). **Conclusions:** This study has shown an overall seroprevalence of 9% and 3.5% for IgM and IgG antibodies respectively among blood donors in the Tema area in Ghana. We advocate for the mandatory screening of donor units intended for transfusion for *S.* Typhi. Furthermore, there is an urgent need for the health education of all persons in Ghana on preventive measures and the spread of *S.* Typhi.

Keywords

S. Typhi, Blood Donors, Seroprevalence, Ghana

1. Introduction

Typhoid fever is a severe systemic infection caused by a Gram-negative bacterium that belongs to the family *Enterobacteriaceae*, and is known commonly as *Salmonella enterica* subsp. Enteric serovar Typhi (*S.* Typhi) [1] [2] [3]. There are over 2500 *Salmonella* serotypes and over 50% of them are associated with *Salmonella enterica* subsp. enterica, which accounts for the majority of *Salmonella* infections in humans [1] [4].

Globally, it is estimated to cause approximately 21 million episodes of illnesses and 222,000 deaths [3]. In Ghana, typhoid is ranked among the top 20 Outpatient Department (OPD) cases and accounts for 0.92% of all hospital admissions [5]. Humans are the only known reservoir of the bacterium [6]. Transmission of typhoid is mainly faecal-oral. The bacteria subsequently multiply in the intestinal tract and disseminate into the bloodstream [7]. Most typhoid patients recover after experiencing several weeks of febrile illness; however, 10% - 15% of patients proceed to develop serious complications [8]. Between 2% - 3% of persons who survive the acute phase of typhoid fever will harbour *S.* Typhi and shed the bacteria in their stools for years afterward as chronic typhoid fever carriers [9]. Furthermore, *S.* Typhi possesses the capacity to invade, survive, and replicate within mononuclear phagocytes from where they are later shed into the blood stream [10]. This feature of host defense evasion by the bacterium enables it to exhibit a persistent infection [11].

In non-epidemic areas, these chronic asymptomatic carriers can serve as an important reservoir of the infection to others via direct contact or through contaminated food or water [12] [13] [14]. A study by Kuubiere *et al.* [14] in Northern Ghana revealed an alarming prevalence of typhoid intestinal perforation of 43.3%. Another study by Nsutebul *et al.* [15] in Cameroon observed significant *Salmonella* antibody titres in more than 10% of apparently healthy blood donors, highlighting the probability of *S.* Typhi being transmitted via blood transfusion. Furthermore, Naheed *et al.* [16] observed that blood samples which harbored *Salmonella* species or toxins could cause severe, and often fatal, post-transfusion infections. Typhoid fever is endemic in Ghana, however, there is paucity of information on the prevalence of this causative bacterium and its risk factors among blood donors in Ghana. This study aimed to determine the occurrence of blood culture positivity for *S.* Typhi with the prevalence of IgM and IgG antibodies among blood donors at a blood replacement center in a hospital in Ghana. Information from this study will provide relevant information for policy makers in blood transfusion services.

2. Materials and Methods

This was a cross-sectional study design and comprised a total of 400 apparently healthy, consenting blood donors of aged 18 years to 55 years at the blood bank of Tema General Hospital in Ghana from May, 2018 to April, 2019. Individuals with a current febrile or diarrheal illness or those who had taken antibiotics in

the past two weeks, or had a history of typhoid vaccination, as well as those who did not give consent were excluded from the study.

Tema General Hospital is a 294-bed capacity hospital located in Tema a suburb in Greater Accra in Ghana. It is a referral hospital and attends to clients from Tema, as well as neighbouring towns. Since it is situated close to the Accra-Tema Motorway, it often serves as the first point of call to accident victims on the express way. It operates a blood bank and theatre. Furthermore, it has a maternity, children's ward, and emergency units which often transfuse blood.

2.1. Collection of Samples

Upon enrollment, consenting participants' demographic data were taken. Donors were prepared, and 10 mls of peripheral venous blood was drawn using sterile syringe with aseptic precautions on the day of blood donation. Five (5) mls was inoculated into blood culture bottles containing 45 mls of sterile brain heart infusion broth [17]. The remaining 5 mls was discharged into a tube without anticoagulant and allowed to clot at room temperature for 1 hour. This sample was then by centrifugated at 2500 ×g for 5 mins. Serum samples were frozen at −20˚C for subsequent serological analysis [18].

2.2. Blood Culture

The blood/brain heart infusion broth mixture was incubated aerobically at 37˚C for 7 days. Broth cultures showing any visible signs of bacteria growth, *i.e.*, haemolysis, bubbles, clots or turbidity after day 1, 2, 3 and day 7 were sub-cultured on blood agar (Oxoid, UK), and MacConkey agar (Oxoid, UK) and incubated at 37˚C for 24 hrs [17].

2.3. Bacterial Identification

Identification of bacterial isolates was done based on morphological characteristics on culture media, Gram reaction, and by biochemical tests of triple sugar iron, indole, urease, citrate, catalase and coagulase test [19]. API 20E identification system (bioMerieux SA, Marcy l'Etoile, France) was also used to confirm Gram-negative isolates.

2.4. Immunochromatographic Assay for Detecting IgM and IgG among Donors

The Typhoid fever Rapid Test Device assay (JusChek®, ACROBITECH, Inc. CA., USA) was used for the qualitative detection of specific IgG and IgM antibodies against *Salmonella* Typhi antigens in serum. The procedure involved removing the sealed pouch and labeling the device with donor or control identification. One drop of serum was then added to the sample well with the dropper provided, followed by the addition of 2 drops of buffer. Any test that failed to migrate across the membrane after one minute of buffer addition to the specimen well was repeated. Evidence of a successful run was the migration of colour across the membrane. Precaution was taken to avoid trapping air bubbles in the

specimen well (by holding the dropper vertically when transferring the specimen). The result was interpreted at 15 minutes and each new batch of test cassettes was controlled with both positive and negative controls according to the manufacturers' protocol.

2.5. Data Management and Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Scientists (SPSS) version 23.0. Descriptive statistics such as means, standard deviation, frequencies and percentages were determined where applicable. Univariate analysis using Pearson's chi-square analysis was performed to determine the associations. In cases of sparse data, the Fischer's exact test was used. Logistic regression analysis was performed to determine the associations between predictor variables and the outcome variables. P-value ≤ 0.05 was interpreted as statistical significance.

3. Result

3.1. Demographic Characteristics of Donors

In this study, a total of 400 participants were recruited. The youngest participant was 17 years and the oldest was 55 years old. The average age of the participants in this study was 31.5 ± 7.7 years. There were more male (87.0%) than female (13.0%) donors. The percentage of unmarried donors (51.2%) and married donors (49.7%), outnumbered the divorced participants (2.0%) (Table 1), about 84.8% of the donors were employed while students and unemployed formed 9.0% and 6.3% of the donor population respectively. With respect to level of education, 19 (4.8%) of the donors had no formal education, while 132 (33.3%), 138 (34.5%), and 111 donors (27.8%) had basic, secondary, and tertiary education respectively. First-time donors comprised of 51.0% of the sample population, 36.5% had a history of 1 to 3 blood donations and 12.5% had done more than 3 donations. About 12.5% of the donors donated their blood voluntarily, while 35.5% were replacement donors (Table 1).

3.2. Risk Factors Associated with *S.* Typhi among Blood Donors

About 92.5% (n = 370) of the donors surveyed responded they had never had typhoid fever, while 7.5% reported to have history of typhoid infection (Table 2). With respect to experiencing stomach discomfort 3 days prior to the blood donation, 2.8% (n = 11) of the respondents responded in the affirmative. Majority (79.0% (n = 316)) of the donors responded they frequently drunk sachet water, 6.8% frequently drank bottled water, and 14.2% drank tap water. Furthermore, 50.2% (n = 201) of the sampled population responded they rarely bought their meals from street vendors, whilst 35.5% sometimes bought their meals from street vendors, and 13.3% always bought their meals from street vendors. In addition, 98.3% (n = 393) of the donors reported to have never taken care of a typhoid patient (Table 2). Whilst 21.3% (n = 85) of the donors had some

Table 1. Donor's demographic characteristics.

Characteristics	Male No (%) n = 348	Female No (%) n = 52	Total No. (%)
Age group (years)			
15 - 24	66 (19.0)	13 (25.0)	79 (19.8)
25 - 34	166 (47.7)	24 (46.2)	190 (47.5)
35 - 44	90 (25.9)	13 (25.0)	103 (25.8)
>45	26 (7.5)	2 (3.8)	28 (7.0)
Marital status			
Single	168 (48.3)	37 (71.2)	205 (51.2)
Married	173 (49.7)	15 (28.8)	188 (47.0)
Divorced/Divorced	7 (2.0)	0 (0.0)	7 (1.8)
Occupation			
Employed	298 (85.6)	41 (78.8)	339 (84.8)
Unemployed	20 (5.7)	5 (9.6)	25 (6.3)
Student	30 (8.6)	6 (11.5)	36 (9.0)
Educational level			
No formal education	15 (4.3)	4 (7.7)	19 (4.8)
Basic	120 (34.5)	12 (23.1)	132 (33.3)
Secondary	121 (34.8)	17 (32.7)	138 (34.5)
Tertiary	92 (26.4)	19 (36.5)	111 (27.8)
History of blood donation			
None	176 (50.6)	28 (53.8)	204 (51.0)
1 - 3	130 (37.4)	16 (30.8)	146 (36.5)
>3	42 (12.1)	8 (15.4)	50 (12.5)
Donor type			
None	179 (51.4)	29 (55.8)	208 (52.0)
Replacement	126 (36.2)	16 (30.8)	142 (35.5)
Voluntary	43 (12.4)	7 (13.5)	56 (12.5)

Table 2. Risk factors/clinical features of *S.* Typhi among blood donors.

Risk factors of S. Typhi	Male No. (%) n = 348	Female No. (%) n = 52	Total No. (%)
History of S. Typhi			
Yes	23 (6.6)	7 (13.5)	30 (7.5)
No	325 (93.4)	45 (86.5)	370 (92.5)

Continued

Constipation			
Yes	8 (2.3)	4 (7.7)	12 (3.0)
No	340 (97.7)	48 (92.3)	388 (97.0)
Stomach discomfort			
Yes	7 (2.0)	4 (7.7)	11 (2.8)
No	341 (98.0)	48 (92.3)	389 (97.3)
Source of water			
Pipe	52 (14.9)	5 (9.6)	57 (14.2)
Sachet	274 (78.7)	42 (80.8)	316 (79.0)
Bottled	22 (6.3)	5 (9.6)	27 (6.8)
Frequency of Hand washing			
Seldom	34 (9.8)	7 (13.5)	41 (10.3)
Regular	139 (39.9)	15 (28.8)	154 (38.5)
Always	175 (50.3)	30 (57.7)	205 (51.2)
Frequency of meals			
Seldom	160 (46.0)	41 (78.8)	201 (50.2)
Regular	134 (38.5)	8 (15.4)	142 (35.5)
Always	54 (15.5)	3 (5.7)	57 (13.3)
Care of typhoid patient			
Yes	5 (1.4)	2 (3.8)	7 (1.8)
No	343 (98.6)	50 (96.2)	393 (98.3)
Typhoid Knowledge			
Yes	71 (20.4)	14 (26.9)	85 (21.3)
No	277 (79.6)	38 (73.1)	315 (78.8)
Prevention awareness			
Yes	80 (23.0)	14 (26.9)	94 (23.5)
No	268 (77.0)	38 (73.1)	306 (76.5)

knowledge about typhoid fever, 76.5% (n = 306) had no idea about prevention awareness.

3.3. Prevalence of IgM and IgG Antibodies among Blood Donors

In this study, seroprevalences of 9% and 14% for IgM and IgG respectively was detected among the blood donors who took part in the study (Table 3). The IgM seroprevalence was statistically significant (P = 0.001) among the blood donors. In the total 37 blood donors with positive IgM, new donors (72.4%) had the highest prevalence, followed by donors with 1 to 3 blood donations (32.4%), and donors with a history of more than 3 donations (5.4%).

Table 3. Prevalence of IgM/IgG antibodies among blood donors.

S. Typhi	Male No. (%)	Female No. (%)	Total No. (%)	z-value	P-value
IgM					
Positive	28 (8.0)	9 (17.3)	37 (9.0)	3.573	0.001*
Negative	320 (92.0)	43 (82.7)	363 (91.0)		
Total	348 (100.0)	52 (100.0)	400 (100.0)		
IgG					
Positive	11 (3.2)	3 (5.8)	14 (3.5)		0.4365
Negative	337 (96.8)	49 (94.2)	386 (96.5)		
Total	348 (100.0)	52 (100.0)	400 (100.0)		
Donor History	**Number of donations**				
	New donor No. (%)	**1 to 3 No. (%)**	**>3 No. (%)**		
IgM (n = 37)	23 (72.4)	12 (32.4)	2 (5.4)		
IgG (n = 14)	8 (57.1)	4 (28.6)	2 (14.3)		

3.4. Association of Demographic Characteristics of Blood Donors and IgM Seropositivity

Although most of the demographic characteristics were not statistically significant to seropositivity, age group was significantly associated with IgM seropositivity (P = 0.029). There was a higher seropositivity in female (17.3%) than males (8.0%) (P = 0.032) (Table 4).

3.5. Blood Culture Results

In this study a total of 13 isolates were recovered from blood culture samples processed. This included *S. aureus* 15.4% (2/13), *S. epidermidis* 30.8% (4/13), *Micrococcus* spp. 15.4% (2/13), *Candida* spp. 23.1% (3/12), *Lactobacillus* spp. 15.4% (2/13). However, no *Salmonella enteric* serovar Typhi was isolated.

4. Discussion

In this study, female gender representation in blood donations was low (13%) compared to male gender (87%). This is consistent with findings among blood donors in the Hohoe Municipal hospital in Ghana where the male gender (88.3%) to female gender (11.7%) representation was documented [20]. Similar findings in Nigeria of female gender (1%) to male gender (99%) have been reported [21]. The varying prevalence in these countries may be attributed to menstruation and pregnancy induced iron deficiency among female donors [22].

In this study, the prevalence of IgM among blood donors was 9.3% (n = 37), while that of IgG was 3.5% (n = 14). This finding is in line with an IgM prevalence of 10% reported amongst blood donors in Cameroun [15]. In contrast to

Table 4. Demographic characteristics and prevalence of IgM in blood donor.

Characteristics	IgM		Total	χ^2	P-value
	Positive	Negative			
Age (years)					
15 - 24	11 (13.9)	68 (86.1)	79 (100.0)	9.029	0.029*
25 - 34	9 (4.7)	181 (95.3)	190 (100.0)		
35 - 44	14 (13.6)	89 (86.4)	103 (100.0)		
>45	3 (10.7)	25 (89.3)	28 (100.0)		
Total	37 (9.3)	363 (90.8)	400 (100.0)		
Gender					
Male	28 (8.0)	320 (92.0)	348 (100.0)	3.585	0.032*
Female	9 (17.3)	43 (82.7)	52 (100.0)		
Total	37 (9.3)	363 (90.8)	400 (100.0)		
Marital status					
Single	17 (8.3)	188 (91.7)	205 (100.0)	1.369	0.713
Married	20 (10.6)	168 (89.4)	188 (100.0)		
Divorced	0 (0.0)	6 (100.0)	6 (100.0)		
Widowed	0 (0.0)	1 (100.0)	1 100.0)		
Total	37 (9.3)	363 (90.8)	400 (100.0)		
Occupation					
Employed	31 (9.10)	308 (90.9)	339 (100.0)	1.748	0.417
Unemployed	1 (4.0)	24 (96.0)	25 (100.0)		
Student	5 (13.9)	31 (86.1)	36 (100.0)		
Total	37 (9.3)	363 (90.8)	400 (100.0)		
Educational level					
No formal education	2 (10.5)	17 (89.5)	19 (100.0)	0.777	0.855
Basic	13 (9.8)	119 (90.2)	132 (100.0)		
Secondary	14 (10.1)	124 (89.9)	138 (100.0)		
Tertiary	8 (7.2)	103 (92.8)	111 (100.0)		
Total	37 (9.3)	363 (90.8)	400 (100.0)		

this study finding, a 53% *S.* Typhi seroprevalence among blood donors was reported in Nigeria [21]. In this study, it was observed that all participants who were seropositive for IgG were also seropositive for IgM; which is indicative of recent exposure to infection [23] [24]. Furthermore, the presence of IgG in blood can remain detectable for over 2 years after an episode of typhoid infection [25]. Additionally, IgG seropositivity can also occur during re-infection,

hence, obscuring the diagnostic distinction between acute infection and convalescence stages of typhoid fever.

4.1. Risk Factors Associated with IgM/IgG

In this study, female were observed to be a significant predictor of IgM seropositive (P = 0.032). This observation is consistent with findings in Ethiopia and Indonesia respectively [26] [27]. In contrast to this study finding, a similar study conducted in Bangladesh reported that the male gender was a predictor of typhoid infection [28]. The differences in prevalence of typhoid may be because females are traditionally involved in household activities, child and patients care and may be more exposed to typhoid infections [26].

In this study, there was a significant association between age and IgM seropositivity. It was observed that donors who were <24 years old had the highest IgM seroprevalence. This may be due to the fact that most people within this age group may be either students or apprentices; a situation that makes them resort to patronizing ready-to-eat meals from street food vendors. According to Srikantiah *et al.* [29], students constituted a high risk group for typhoid fever. The findings in this study are consistent with an Indonesian study which reported a median age of 22 years as a high risk group [30]. However, this finding is not in agreement with a study conducted in Nigeria which reported that age had no significant association with seroprevalence of antibodies against *S.* Typhi [21]. This study compared the correlation between IgM and IgG seropositivity and source of drinking water. It emerged that IgG seroprevalence, had a correlation with drinking of tap water. This finding is in agreement with a research study in Nigeria and Uganda which also reported that source of water is a predictor for typhoid infection [31] [32]. Contaminated water has been implicated as a source of many diseases [33]. Although tap water is treated from source, it can become contaminated during distribution or when placed in contaminated vessels [34] [35] [36]. In this study, level of literacy was found not to be a risk factor of typhoid fever acquisition. Contrary to this finding, in India, illiteracy was reported to be a major risk factor for typhoid infection [37]. Although this study found that participants with tertiary education had the least antibody seroprevalence (7.2%), whilst the illiterate had the highest antibody seroprevalence (10.5%), those with basic and no formal education had varying levels of seroprevalence. The prevalence of typhoid among people with tertiary education reported in this study is consistent with a study in Zimbabwe which recorded a prevalence of 6.2% for participants with tertiary education [38]. Findings in this study, however, are in contrast with an earlier study conducted in Nigeria which reported a seroprevalence of 75.2% among tertiary students [39]. The difference may be as a result of differences in the levels of hygiene existing in the different study sites [37]. Though there was no significant correlation between knowledge about typhoid awareness (transmission of typhoid fever) and antibody seroprevalence in this study, it emerged that 78.8% (315/400) of the survey population did not

have any knowledge about typhoid fever. However, in contrast to findings in this study, a study in Ethiopia reported 92.7% of the surveyed population had some knowledge about typhoid awareness. The difference might be due to varying health extension services provided in the different countries [40]. Interestingly in this study, knowledge about typhoid prevention (8.2%) did not emerge as a risk for typhoid infection though it was observed that 76.5% of the respondents did not have any knowledge about typhoid prevention; a situation which is quite alarming, since precautionary and preventive measures are key in mitigating the spread of any infection. However, this study's findings are in contrast to a study conducted in Ethiopia which reported 83.7% of the surveyed population had some knowledge about typhoid prevention [40]. This difference may be due to an effective education on typhoid infection in Ethiopia.

History of blood donation was not a predictor of typhoid infection in this study; however, prevalence of IgM and IgG was highest among new donor, but lower in donors with more than 1 to 3 blood donations. This consistency in decline in prevalence of both IgM and IgG from regular donors to new donors, suggests that blood from regular donors might be safer [41].

4.2. Blood Culture Isolates

The present study did not isolate any *S.* Typhi from all donated blood samples cultured. This may be due to the recruitment of only apparently healthy individuals in the study. Currently at the different blood banking centers in Ghana, it is a requirement as prescribed by WHO, that blood donors are initially screened with a questionnaire to prevent those exhibiting some initial typhoid signs such as malaise and unproductive cough from donating [42]. Finding from this study is consistent with a previous study conducted in Ghana, which reported negative *Salmonellae* for blood cultures form 380 patients [43].

5. Limitations

Our study had a few of limitations. Only a limited clinical features and risk factors of typhoid fever were included in the questionnaire, hence, making a detailed correlation between the various variants difficult. Further, this study was not able to sample from different blood donation centers in Accra metropolis. Nevertheless, our study provides useful insight on the prevalence of typhoid carriers among blood donors in Ghana.

6. Conclusion

In this study, although no *S.* Typhi was isolated from the blood samples of the donors, a seroprevalence of 9.3% was obtained for IgM antibody against *S.* Typhi. *S.* Typhi is a transfusion transmissible infection and recipients of those contaminated units of blood or their products may be at risk of getting infected with *S.* Typhi (WHO, 2012). However, the 9.3% prevalence obtained falls short of the 10.0% the permissible loss margin for donated units of blood. This implies that

blood donated in Ghana should be serologically screened routinely for antibodies produced against *S.* Typhi without undue destruction of units of donated blood or disqualification of blood donors. Further, improved strategies and modalities must be put in place to educate the general populace about typhoid fever and its risk factors. Health screening questionnaire for blood donors must be updated to identify and defer donors at least 28 days to enable full recovery from typhoid fever before donating excerse.

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Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of the College of Health Sciences, the University of Ghana (Ethics Identification Number: CHS-Et/M.6-5.12/2018-2019. Participation was voluntary and written consent was taken from each participant following the ethical committee's guidelines.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no competing interests.

Authors' Contributions

AOF designed, performed the field and laboratory work, analyzed data and drafted the manuscript. MOA supervised the study, analyzed data and revised the manuscript. SKA and IAH supervised the study and revised the manuscript. AAS conceived, performed laboratory experiments and analyzed the data and OTM performed field, laboratory experiments and revised the manuscript.

Authors' Information (Optional)

AOF designed, performed the field and laboratory work, analyzed data and drafted the manuscript. AMO supervised the study, analyzed data and revised the manuscript. SAA and OTM performed field and laboratory experiments and revised the manuscript.

References

[1] Ochiai, R.L., Acosta, C.J., Danovaro-Holliday, M., Baiqing, D., Bhattacharya, S.K., Agtini, M.D., *et al.* (2008) A Study of Typhoid Fever in Five Asian Countries: Dis-

ease Burden and Implications for Controls. *Bulletin of the World Health Organization*, **86**, 260-268. https://doi.org/10.2471/BLT.06.039818

[2] Eng, S.-K., Pusparajah, P., Ab Mutalib, N.S., Ser, H.-L., Chan, K.-G. and Lee, L.-H. (2015) *Salmonella*: A Review of Pathogenesis, Epidemiology and Antibiotic Resistance. *Frontiers in Life Sciences*, **8**, 284-293. https://doi.org/10.1080/21553769.2015.1051243

[3] WHO (2014) Immunization, Vaccines and Biologicals. WHO. http://www.who.int/immunization/diseases/typhoid/en/

[4] Guibourdenche, M., Roggentin, P., Mikoleit, M., Fields, P.I., Bockemuhl, J., Grimont, P.A. and Weill, F.-X. (2010) Supplement 2003-2007 (No. 47) to the White-Kaumann-Le Minor Scheme. *Research in Microbiology*, **161**, 26-29. https://doi.org/10.1016/j.resmic.2009.10.002

[5] Sory, E. (2009) The Health Sector in Ghana: Facts and Figures. Ghana Health Service, Accra, 31.

[6] CDC (2017) Typhoid and Paratyphoid Fever. NSW Health. https://www.cdc.gov/typhoid-fever/symptoms.html

[7] Wangdi, T., Winter, S.E. and Bäumler, A.J. (2012) Typhoid Fever: You Can't Hit What You Can't See. *Gut Microbes*, **3**, 88-92. https://doi.org/10.4161/gmic.18602

[8] Parry, C.M., Wijedoru, L., Arjyal, A. and Baker, S. (2011) The Utility of Diagnostic Tests for Enteric Fever in Endemic Locations. *Expert Review of Anti-Infective Therapy*, **9**, 711-725. https://doi.org/10.1586/eri.11.47

[9] Lowth, M. (2015) Typhoid and Paratyphoid Fever. Patient. https://patient.info/doctor/typhoid-and-paratyphoid-fever-pro

[10] Bhan, M.K., Bahl, R. and Bhatnagar, S. (2005) Typhoid and Paratyphoid Fever. *The Lancet*, **366**, 749-762. https://doi.org/10.1016/S0140-6736(05)67181-4

[11] Jones, B.D. and Falkow, S. (1996) Salmonellosis: Host Immune Responses and Bacterial Virulence Determinants. *Annual Review of Immunology*, **14**, 533-561. https://doi.org/10.1146/annurev.immunol.14.1.533

[12] Cardinale, E., Colbachini, P., Perrier-Gros-Claude, J.D., Gassama, A. and Aidara-Kane, A. (2009) Dual Emergence in Food and Humans of a Novel Multiresistant Serotype of *Salmonella* in Senegal: *Salmonella enteric subsp enterica*. Serotype 35:c:1,2. *Journal of Clinical Microbiology*, **39**, 2373-2374.

[13] Olsen, S.J., Bleasdale, S.C., Magnano, A.R., Landrigan, C., Holland, B.H., Tauxe, R.V., Mintz, E.D. and Lubty, S. (2003) Outbreaks of Typhoid Fever in the United States, 1960-99. *Epidemioogy and Infection*, **130**, 13-21. https://doi.org/10.1017/S0950268802007598

[14] Kuubiere, C.B., Mogre, V., Majeedm, S.F. and Alhassan, A. (2014) Typhoid Intestinal Perforations in Northern Ghana. *Al Ameen Journal of Medical Science*, **7**, 251-256. https://www.academia.edu/33172038/Typhoid_intestinal_perforations_in_Northern_Ghana

[15] Nsutebul E.F., Ndumbe P.M. and Adiogo, D. (2002) The Distribution of *Anti-Salmonella* Antibodies in the Sera of Blood Donors in Yaoundé, Cameroon. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **96**, 68-69. https://doi.org/10.1016/S0035-9203(02)90244-0

[16] Naheed, A., Ram, P.K., Brooks, W.A., Hossain, M.A., Parsons, M.B., Talukder, K.A., Mintz, E., Luby, S. and Breiman, R.F. (2010) Burden of Typhoid and Paratyphoid Fever in a Densely Populated Urban Community, Dhaka, Bangladesh. *International Journal of Infectious Diseases*, **14**, E93-E99. https://doi.org/10.1016/j.ijid.2009.11.023

[17] WHO (2003) The Diagnosis, Treatment, and Treatment and Prevention of Typhoid Fever. WHO.

[18] Khorgade, R.R. and Bhis, P.R. (2017) Baseline Titre of Widal amongst Healthy Blood Donors at a Tertiary Care Hospital. *International Journal of Research in Medical Sciences*, **5**, 1571-1577. https://doi.org/10.18203/2320-6012.ijrms20171267

[19] Konemann, E., Allen, S. and Janda, W. (2006) Koneman's Color Atlas and Textbook of Diagnostic Microbiology. 6th Edition, Lippincott Williams & Wilkins, Philadelphia.

[20] Adu-Poku, F., Agboli, E. and Tarkang, E.E. (2020) Seroprevalence of Transfusion-Transmissible Infections among Blood Donors in the Hohoe Municipal Hospital, Ghana: 2015-2016: A Retrospective Hospital-Based Cross-Sectional Study. *PAMJ-Clinical Medicine*, **2**, Article 12.

[21] Adias, T.C., Jeremiah, Z.A. and Ilesanmi, A.O. (2010) Distribution of Antibodies to *Salmonella* in the Sera of Blood Donors in the South-Western Region of Nigeria. *Blood Transfusion*, **8**, 163-169.

[22] Mast, A.E. (2014) Low Hemoglobin Deferral in Blood Donors. *Transfusion Medicine Reviews*, **28**, 18-22. https://doi.org/10.1016/j.tmrv.2013.11.001

[23] Ismail, A. (2000) New Advances in the Diagnosis of Typhoid and Detection of Typhoid Carriers. The *Malaysian Journal of Medical Sciences*, **7**, 3-8.

[24] Mastroianni, C.M., Jirillo, E., De Simone, C., Grassi, P.P., Maffione, A.B., Catino, A.M. and Delia, S. (1989) Humoral and Cellular Immune Responses to *Salmonella typhi* in Patients with Typhoid Fever. *Journal of Clinical Laboratory Analysis*, **3**, 191-195. https://doi.org/10.1002/jcla.1860030310

[25] Choo, K.E., Davis, T.M., Ismail, A. and Ong, K.H. (1997) Longevity of Antibody Responses to a *Salmonella typhi*-Specific Outer Membrane Protein: Interpretation of a Dot Enzyme Immunosorbent Assay in an Area of High Typhoid Fever Endemicity. *The American Journal of Tropical Medicine and Hygiene*, **57**, 656-659. https://doi.org/10.4269/ajtmh.1997.57.656

[26] Deksissa, T. and Gebremedhin, E.Z. (2019) 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 Infectious Diseases*, **19**, Article No. 288. https://doi.org/10.1186/s12879-019-3917-3

[27] Vollaard, A.M., Ali, S., van Asten, H.A., Widjaja, S., Visser, L.G., Surjadi, C. and van Dissel, J.T. (2004) Risk Factors for Typhoid and Paratyphoid Fever in Jakarta, Indonesia. *JAMA*, **291**, 2607-2615. https://doi.org/10.1001/jama.291.21.2607

[28] Dewan, A.M., Corner, R., Hashizume, M. and Ongee, E.T. (2013) Typhoid Fever and Its Association with Environmental Factors in the Dhaka Metropolitan Area of Bangladesh: A Spatial and Time-Series Approach. *PLOS Neglected Tropical Diseases*, **7**, e1998. https://doi.org/10.1371/journal.pntd.0001998

[29] Srikantiah, P., Girgis, F.Y., Luby, S.P., Jennings, G., Wasfy, M.O., Crump, J.A., *et al.* (2006) Population-Based Surveillance of Typhoid Fever in Egypt. *The American Journal of Tropical Medicine and Hygiene*, **74**, 114-119. https://doi.org/10.4269/ajtmh.2006.74.114

[30] Velema, J.P., Van Wijnen, G., Bult, P., Van Naerssen, T. and Jota, S. (1997) Typhoid fever in Ujung Pandang, Indonesia—High-Risk Groups and High-Risk Behaviours. *Tropical Medicine and International Health*, **2**, 1088-1094. https://doi.org/10.1046/j.1365-3156.1997.d01-179.x

[31] Udeze, A.O., Abdulrahman, F., Okonko, I.O. and Anibijuwon, I.I. (2010) Seroprevalence of *Salmonella typhi* and *Salmonella paratyphi* among the First Year Students of University of Ilorin, Ilorin-Nigeria. *Middle-East Journal of Scientific Research*, **6**, 257-262.

[32] Kabwama, S.N., Bulage, L., Nsubuga, F., Pande, G., Oguttu, D.W., Mafigiri, R., Kajumbula, H., *et al.* (2017) 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*, **17**, Article No. 23. https://doi.org/10.1186/s12889-016-4002-0

[33] Baldursson, S. and Karanis, P. (2011) Waterborne Transmission of Protozoan Parasites: Review of Worldwide Outbreaks—An Update 2004-2010. *Water Research*, **45**, 6603-6614. https://doi.org/10.1016/j.watres.2011.10.013

[34] Adogo, L., Samuel, G. and Abalaka, M. (2015) Sero Prevalence of *Salmonella typhi* among Pregnant Women in Niger State. *Journal of Microbiology Research*, **5**, 118-121. http://article.sapub.org/10.5923.j.microbiology.20150503.06.html

[35] Muti, M., Gombe, N., Tshimanga, M., Takundwa, L., Bangure, D., Mungofa, S. and Chonzi, P. (2014) Typhoid Outbreak Investigation in Dzivaresekwa, Suburb of Harare City, Zimbabwe, 2011. *Pan African Medical Journal*, **18**, Article ID: 309. https://doi.org/10.11604/pamj.2014.18.309.4288

[36] Bhunia, R., Hutin, Y., Ramakrishnan, R., Pal, N., Sen, T. and Murhekar, M. (2009) A Typhoid Fever Outbreak in a Slum of South Dumdum Municipality, West Bengal, India, 2007: Evidence for Foodborne and Waterborne Transmission. *BMC Public Health*, **9**, Article No. 115. https://doi.org/10.1186/1471-2458-9-115

[37] Sur, D., Ali, M., von Seidlein, L., *et al.* (2007) Comparisons of Predictors for Typhoid and Paratyphoid Fever in Kolkata, India. *BMC Public Health*, **7**, Article No. 289. https://doi.org/10.1186/1471-2458-7-289

[38] Matambo, R., Nyandoro, G., Mungofa, S., Mutseyekwa, F.M., Ruhanya, V., Mugomeri, E. and Chin'ombe, N. (2016) Identifying Factors Associated with Contracting Typhoid during an Outbreak in Harare, Zimbabwe. *Journal of Contemporary Clinical Practice*, **2**, 9-17. https://doi.org/10.18683/jccp.2016.1007

[39] Joshua, A., Beverly, A. and Lillian, A. (2017) The Prevalence of Typhoid Fever in Bingham University. *GSC Biological and Pharmaceutical Sciences*, **1**, 37-43. https://gsconlinepress.com/journals/gscbps/sites/default/files/GSCBPS-2017-0052.pdf

[40] Getachew, T., Abebe, S.M., Yitayal, M., Bergström, A., Persson, L.-A. and Berhanu, D. (2021) Health Extension Workers' Perceived Health System Context and Health Post Preparedness to Provide Services: A Cross-Sectional Study in Four Ethiopian Regions. *BMJ Open*, **11**, e048517. https://doi.org/10.1136/bmjopen-2020-048517

[41] Nair, S.C. and Mammen, J.J. (2015) Repeat Voluntary Non-Remunerated Blood Donor is the Best Quality Indicator for Blood Safety. *The Indian Journal of Medical Research*, **141**, 749-752. https://doi.org/10.4103/0971-5916.160687

[42] World Health Organization (WHO) (2012) Blood Transfusion Safety. WHO. https://www.who.int/health-topics/blood-transfusion-safety#tab=tab_1

[43] Feglo, P. and Ocansey, D.W.K. (2019) Characterization of Salmonella and other Gram Negative Bacterial Pathogens obtained from Stool and Blood, a Cross-Sectional Study at Cape Coast Teaching Hospital, Ghana. *Acta Scientific Microbiology*, **2**, 56-66.