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Evaluation of Tetanus Toxoid Vaccine Potency and Antibody Response to Routine Vaccination among a Population of Rivers State, Nigeria

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ABSTRACT: The study evaluates vaccine potency and investigates the prevalence of IgG antibodies for tetanus toxoid (TT) in routine vaccination among a population of Rivers State, Nigeria, with socio-demographic factors. Using ELISA kits, the study analysed blood samples from 282 participants, aiming to evaluate immunity levels against tetanus. The overall antibody response prevalence was 90.3%. Participants aged 21-30 years were again the majority (55.6%), and females constituted 93.2%. Married individuals accounted for 79.4% of the group, with 54% holding a tertiary education. Most were involved in business (45%) or civil service (39%). The clinical presentations predominantly showed pregnant women (76.2%) and an even distribution across gestational periods. The study revealed a significant prevalence of Tetanus Toxoid IgG antibodies, particularly among females (93.2%) and urban residents (91.3%). This highlights the effectiveness of vaccination programs in these groups and the need to sustain high immunity levels to prevent tetanus outbreaks, especially among women of reproductive age. The study highlighted lower tetanus immunity levels in rural populations (8.7%) and males (6.8%), underscoring the need to focus public health efforts on improving vaccine coverage in these underserved groups. The study found that 76.2% of the participants were pregnant women, emphasising the critical role of tetanus vaccination during pregnancy to prevent neonatal tetanus. This reinforces the importance of maternal health interventions in ensuring adequate tetanus protection. Education level, marital status, and occupation were found to influence tetanus immunity. Higher levels of immunity were associated with tertiary education (54%) and certain occupations like business/traders (45%) and civil servants (39%). These findings contribute to understanding how socio-demographic factors impact vaccination uptake and immunity. The study emphasises the importance of monitoring tetanus toxoid immunity, particularly among pregnant women, as a significant proportion (65.8%) reported pregnancy. The major conclusion from the study is that young, urban-dwelling women of reproductive age, particularly those aged 21-30, exhibit high antibody prevalence for tetanus. This finding contributes to understanding vaccine efficacy and the need for targeted immunisation programs, particularly in maternal health contexts.

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1. INTRODUCTION

Bacteria *Clostridium tetani* cause tetanus, an illness characterised by the production of a powerful neurotoxin that causes stiffness of the muscles, spasms, and in extreme cases, paralysis of the respiratory system, which ultimately leads to death. Although most vaccine-preventable illnesses may be passed from person to person, tetanus is unique in that it develops from infected wounds rather than transmission (Roper et al., 2017). Neonatal tetanus continues to be a challenge in low maternal immunisation coverage areas.

Tetanus is a fatal illness resulting from the neurotoxin *Clostridium tetani*, which is present in soil and may enter through wounds. Tetanus is not spread like other vaccine-preventable diseases but arises from environmental exposure. Neonatal tetanus continues to cause death in the world in developing countries owing to maternal vaccination deficiency and unsafe sanitary

birth practices (Roper et al., 2017). Although global cases of tetanus have declined, Nigeria still reports cases, particularly in rural areas with inadequate immunisation (WHO, 2023).

Immunisation is one of the most successful and cost-efficient public health strategies for controlling infectious illnesses, reducing morbidity, and achieving lifelong immunity in targeted populations (Plotkin, 2014). Mass vaccination campaigns are a cornerstone for the sustenance of vaccine-preventable diseases, with significance being felt especially in lower- and middle-income nations such as Nigeria, which is constantly confronted by severe challenges in its bid to control outbreaks of vaccine-preventable diseases like measles, diphtheria, and polio (WHO, 2023). The effectiveness of vaccination campaigns relies on several variables, such as vaccine strength, integrity of cold chain management, and the immune response stimulated among immunized persons (World Health Organization [WHO], 2021). Measurement of these variables is critical to the success of vaccination campaigns as well as to preventing the return of disease.

Greenwood (2014) and Yamoah et al. (2019) both agree that vaccines are crucial in preventing infectious illnesses from spreading throughout the world. Different jurisdictions may have different policies on the use of certain vaccines, such as those targeting children, adolescents, pregnant women, and adults in general (Doherty et al., 2016; Yamoah et al., 2019). Vaccination programs in West African countries like Nigeria and Ghana aim to protect children under the age of five from 12 different infectious diseases: yellow fever, rotavirus, hepatitis B, measles, rubella, pneumonia, diphtheria, pertussis, tetanus, and Haemophilus influenzae type b (Hib). According to Ladapo et al. (2013) and Yamoah et al. (2019), these vaccinations are given to children at different points in their development.

A vaccine's potency is its capacity to elicit a protective immune response and is influenced by storage temperature, transport, and expiration (Choudhury et al., 2020). Vaccine potency is the key determinant of the efficacy of vaccination, followed by proper cold chain maintenance and the ability of an individual to induce an adequate antibody response (Adewumi et al., 2021). Proper maintenance of the cold chain is crucial to vaccine potency since exposure to suboptimal temperatures can damage the antigens and reduce immunogenicity (Kim et al., 2017). It has been found in several developing countries, including Nigeria, that cold chain disruptions are a key factor in vaccine wastage and loss of potency (Adewumi et al., 2021). It has been proven by research that compromised cold chain facilities, poor handling procedures, and temperature excursions compromise vaccine efficacy and lead to suboptimal immunisation outcomes (Choudhury et al., 2020). Therefore, it is important to assess the strength of vaccines given in routine immunisation programs to check if they still have their desired immunogenicity.

No less important is the assessment of the antibody response following routine immunisation, as the immune response in people may vary according to age, nutritional status, genetic background, and pre-existing health conditions (Siegrist, 2018). Serological surveys among populations provide a measure of the degree of vaccine-induced immunity and can indicate gaps in protection that may require booster doses or alterations in immunisation schedules (Moss, 2020). In Nigeria, there have been different levels of herd immunity for VPDs, which raises questions about vaccine efficiency and the quality of immunisation coverage (Nwankwo et al., 2022).

Rivers State is located in the southern region of Nigeria and has an urban and semi-urban population whose socioeconomic status is different, influencing the accessibility and use of vaccines. Despite efforts by public health authorities to increase immunisation coverage, concern regarding vaccine quality, delivery, and the ensuing antibody response among immunized populations has existed. Few data have been thoroughly examined concerning these measures within the region, and an inquiry into vaccine strength used under routine immunisation and the stimulated antibody response within the population has been necessary.

This study aims to evaluate the seroprevalence of tetanus IgG antibodies in children, pregnant women, and a selected adult population in Port Harcourt, Nigeria, to establish the immunity status and effectiveness of tetanus immunisation.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was in University of Port Harcourt Teaching Hospital (UPTH), Rivers State University Teaching Hospital (RSUTH), Noble Medical Consultants & Fertility Hospital, Mgbuoba, all in Rivers State, Nigeria. Rivers State is one of the 36 states in Nigeria, located in the South-South geopolitical zone along the Atlantic seaboard. It is internationally recognized as the hub of Nigeria's oil and gas production and is among the most

economically significant states in Nigeria. Port Harcourt is the capital of Rivers State. Over 7 million people in estimated population. Ikwerre, Kalabari, Ogoni, Okrika, Opobo, Andoni, Ibani, and others are the principal ethnic groups. English is the official language; a few local languages like Ikwerre, Ogoni, Kalabari, etc are spoken in the state. The major religions were Christianity (dominant), Islam, and traditional. The timezone is West Africa Time (WAT), UTC +1. Rivers State is simply referred to as the "Treasure Base of the Nation" due to its vast oil and gas deposits.

The University of Port Harcourt Teaching Hospital (UPTH) is an international standard tertiary healthcare institution located in Port Harcourt, Rivers State, Nigeria. Established in April 1980 and commissioned in 1985, UPTH is a great medical education, research, and specialized health care services hub in the region. Located at East-West Road, Port Harcourt, Rivers State, Nigeria. Affiliation: University of Port Harcourt. Bed Capacity: 782 beds. Annual Patient Volume: Approximately 200,000 outpatient and inpatient consultations. Formerly known as Braithwaite Memorial Specialist Hospital (BMSH), the massive government-owned Rivers State University Teaching Hospital (RSUTH) is situated in Old GRA, Port Harcourt, Rivers State, Nigeria. Before being a general hospital and then a specialty health center, it was founded in March 1925 as a nursing home for colonial officers and senior government workers. As of 2018, it serves as a teaching hospital for Rivers State University, allowing it to educate future doctors and other medical workers. Located at Harley Street, Old GRA, Port Harcourt, Rivers State, Nigeria. Bed Capacity: Approximately 375 licensed beds. Medical Staff: Over 730 healthcare professionals. Noble Medical Consultants & Fertility Hospital is a specialist health facility in Mgbuoba, Port Harcourt, Rivers State, Nigeria. The hospital is specialized in the provision of complete fertility and general medical care to the society. Located at Mgbuoba, Port Harcourt, Rivers State, Nigeria. While specific information on the range of services is limited, the hospital is known for its focus on fertility treatment and general medical checkups. As an NHIS-accredited facility, it likely offers services covered under the National Health Insurance Scheme, which makes it more affordable for patients.

2.2. Study Design

The purpose of this research was to examine the effectiveness of vaccinations and the immune responses to vaccine-preventable viral infections in pregnant women and children in the Port Harcourt, Nigeria area. A cross-sectional study was conducted on children and expectant mothers follow-up at the University of Port Harcourt Teaching Hospital (UPTH), Rivers State University Teaching Hospital (RSUTH) and Noble Medical Consultants and Fertility Hospital from January 2020–April 2025.

2.3. Ethical considerations

Each participant provided written informed consent, and the study was approved by the research ethics committees of both the University of Port Harcourt (UPH) and the University of Port Harcourt Teaching Hospital (UPTH).

2.4. Study Population

A total of 282 samples were collected for this study. The research population consisted of children and expectant women from several medical facilities in Rivers State, Nigeria, including UPTH, RSUTH and Noble Medical Consultants & Fertility Hospital, Mgbuoba. Subjects included in the research were limited to pregnant women and children. Findings will be extended to the whole population of children and expecting moms in Port Harcourt, Rivers State, Nigeria. Data pertinent to the study's demographics were collected.

2.5. Inclusion and exclusion criteria

All children and expectant mothers were eligible for the study. Only children and pregnant women with complete registration records were included in the research; those without permission or with partial records were excluded.

2.6. Sample Collection

Samples of blood were taken from pregnant women, children aged 1 to 10, and those with vein punctures (about 5 ml each) and sent to the Virus & Genomics Research Unit at the Department of Microbiology at the University of Port Harcourt in Nigeria to be tested for antibody responses and vaccine potency. The tubes used for the collection were EDTA BA Vacutainer TM anti-coagulant tubes manufactured by BD in Franklin Lakes, USA. For 5 minutes, plasma samples were spun at 300 rpm (revolutions per minute) in a centrifuge to separate them. The laboratory analyses made use of plasma that had been kept at -20°C.

2.7. Laboratory diagnosis and quality control

ELISA kits were used to test for the tetanus toxoid (TT). This was evaluated using fourth-generation ELISA kits [IgG antibodies against tetanus]. The laboratory analysis was conducted following the guidelines provided by the manufacturers. All tests were conducted utilising quality controls following

normal operating procedures. All samples with non-reactive results to ELISA kits were considered negative.

2.8. Serological Analysis

The virus and genomics research unit, microbiology department, University of Port Harcourt, Nigeria, conducted the serological analysis. The subjects' sera were analyzed in vitro for IgG antibodies to tetox using a commercial ELISA kit (DIA.PRO Diagnostic Bioprobes, Milano, Italy). DIA.PRO Tetox IgG ELISA is an indirect enzyme-linked immunosorbent test (ELISA) designed for the quantitative assessment of IgG antibodies to Tetanus Toxoid in human blood or plasma. The serological test and result interpretation were conducted following the manufacturer's instructions for the kit. Following the manufacturer's instructions, the colour intensity of the solution in each well was measured at two different wavelengths: 450 nm for reading and 630 nm for background removal, with the equipment blanked on Al. Optical signals produced in the microwells were measured at 450 nm using an ELISA plate reader (Optic Ivymen® System, Model 2100C; Biotech SL, Madrid, Spain). The maker of the ELISA kit supplied the method for computing the cut-off OD450nm (OD of the negative control + 0.250), which served as the threshold for distinguishing between reactive and non-reactive serum samples. Values ≥ 0.1 IU/mL indicate protective Tetanus immunity (as per WHO recommendations) and < 0.1 IU/mL indicates inadequate immunity; booster vaccination may be recommended.

2.9. Data management and analysis

A variety of socio-demographic variables were to be collected. We used the mean and standard deviation for continuous data and the frequencies and percentages for categorical data. Younger participants (<50 years) and older (>50 years) were compared using the chi-square test to see whether their demographic and clinical features were similar. The significance of the difference in mean values between the two groups was tested using Student's t-test and the Mann-Whitney test (for non-normally distributed variables). Results were deemed statistically significant if the p-value was less than 0.05.

3. RESULTS

There were 282 participants enrolled in this study (Table 1). Half of the tested individuals were between 21–30 years old (50.4%) as indicated in Table 1. The majority of the population tested were young adults, potentially reflecting the target population of the study — possibly a reproductive-age population. In this study, 93.7% were females and only 6.3% were males. The population studied was mostly female — extremely likely because the study was on pregnancy (supported by the gestational period), or a condition that largely affects women (Table 1). Most were married (75.2%), with a few singles (23.4%), separated, and widows (1.4%). Again, consistent with a study on pregnant women or women's health, where most of the subjects would be married (Table 1).

Table 1. Sociodemographic Characteristics of Participants

Variables	**No Tested** (%)
Age groups (Year)	
<10	28(9.9)
11 - 20	10(3.5)
21 – 30	142(50.4)
31 – 40	80(28.4)
41 – 50	17(6)
>50	5(1.8)
Sex	
Male	18(6.3)
Female	264(93.7)
Marital Status	
Married	212(75.2
Single	66(23.4)
Others	4(1.4)
Education	
Primary	49(17.4)
Secondary	76(26.9)
Tertiary	157(55.7)
Occupation	
Civil Servant	103(36.5)
Business	126(44.7)
Student	48(17.0)
Others	5(1.8)
Religion	
Christianity	222(78.7)
Islam	51(18.1)
Traditional	9(3.2)
Location	
Port Harcourt	235(83.3)
Others	47(16.7)
Tribe	
Igbo	240(85.1)
Hausa	23(8.2)
Yoruba	19(6.7)
Total	**282(100.00)**

Most had tertiary education (55.6%), followed by secondary education (26.9%) and primary education (17.4%). This population was relatively well-educated, which could impact health-seeking behaviour and

levels of awareness (Table 1). The most frequent occupations were business (44.7%), civil servants (36.5%) and students (17.0%). Many were in informal employment (business) or not actively working (students, unemployed), which could affect economic access to healthcare (Table 1). Most were Christians (78.7%), with a minority Muslim population (18.1%) and traditional (3.2%). It reflects the religious composition of the study population (southern Nigeria, presumably, Rivers State) as indicated in Table 1. Testing was evenly distributed between the University of Port Harcourt Teaching Hospital (UPTH), Rivers State University Teaching Hospital (RSUTH) and Noble Medical Consultants & Fertility Hospital. Each contributed exactly 33.33% of the respondents. Sampling was well distributed across the three centres, improving representativeness (Table 1). The largest groups were Igbo (85.1%), Hausa (8.2%) and Yoruba (6.7%). Indicates the ethnic composition of the region — Rivers State is an Igbo-speaking region as well as other ethnic groups.

3.2. Clinical Characteristics of Participants

In this study, 95% were asymptomatic (Table 2). Few had symptoms like pyrexia of unknown origin (13.5%), and others on routine check-up (11.1%) for fever, rash, cough, or sore throat. Most participants were asymptomatic at testing. This reflects either healthy population screening (e.g., prenatal screens) or an early stage of the disease. Most were in the 3rd trimester (33.4%), followed by the 2nd trimester (35.9%), then the first trimester (13.5%). Most participants were late in pregnancy at testing (Table 2). This could impact clinical care if the study is related to infection or pregnancy outcomes. The female population were mostly in late pregnancy. The low rate of symptoms implies screening instead of symptomatic diagnosis.

Table 2. Clinical Characteristics of Participants

Variables	**No Tested** (%)
Signs & Symptoms	
Pregnancy	213(75.5)
Pyrexia of Unknown Origin	38(13.5)
Routine	31(11)
Gestation Period	
First	68(31.9)
Second	74(34.7)
Three	71(33.4)
Total	**282(100.00)**

3.3. Overall prevalence of IgG antibodies against Tetanus

The overall IgG seropositivity rates indicated an increased but suboptimal immunity level in the study population (Figure 1). Tetanus toxoid antibody positivity was exceptionally high (90.8%), which points to excellent tetanus immunisation coverage through maternal immunisation programs (Figure 1). The study evaluated the seroprevalence of tetanus IgG antibodies in children, pregnant women, and a selected adult population in Port Harcourt, Nigeria, to establish the immunity status and effectiveness of tetanus immunisation. Results showed that 90.8% were immune, excellent, reflecting good tetanus vaccination coverage (likely through antenatal care programs).

3.4. Tetanus Toxoid IgG Antibody Prevalence with Sociodemographical Characteristics

The prevalence of Tetanus toxoid IgG antibodies was also reflected in demographic patterns. Females accounted for the majority of the seropositivity (93.2%) as displayed in Figure 2, and the 21–30 years age group had the highest prevalence (55.6%) as displayed in Figure 3.

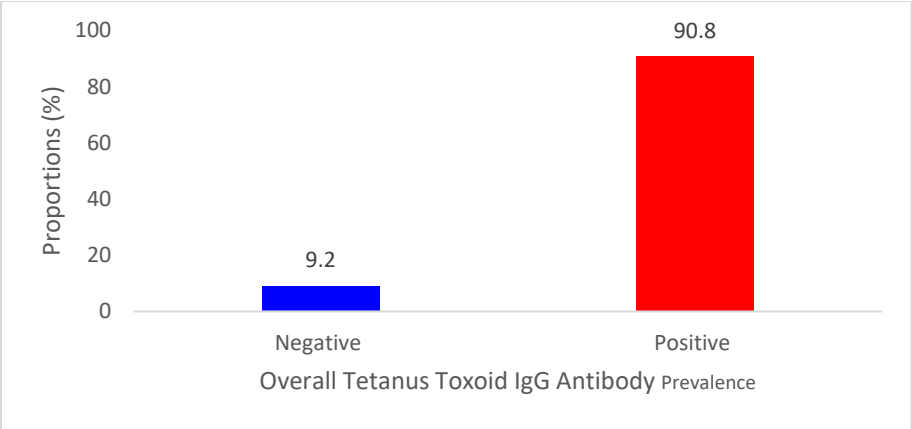

Fig. 1: Tetanus Toxoid IgG Antibody Prevalence

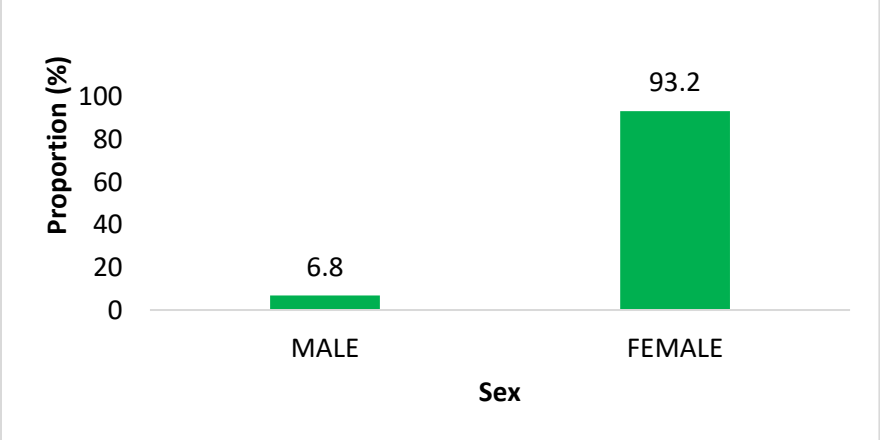

Fig. 2: Tetanus Toxoid IgG Antibody Prevalence with Gender Distribution

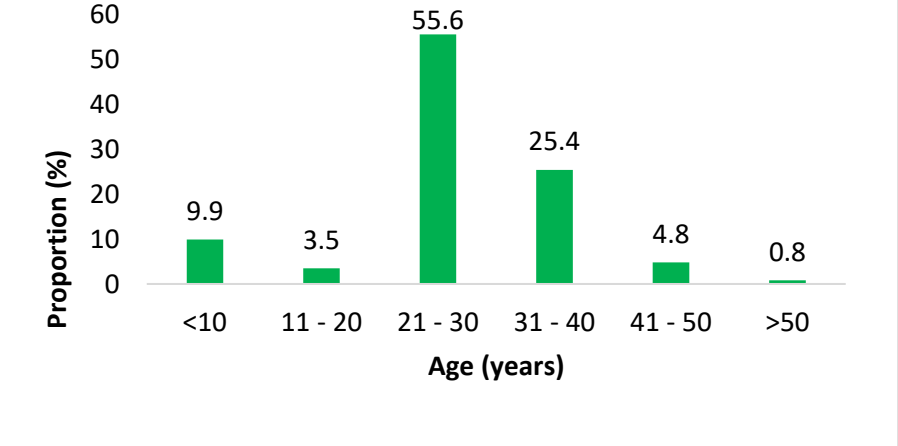

Fig. 3: Tetanus Toxoid IgG Antibody Prevalence with Age Distribution

Marital status data indicated that 79.4% of the seropositive population were married (Figure 4). The level of education played a role, with 54.0% of the tertiary educated and a lesser but important proportion (30.0%) with secondary education being positive (Figure 5).

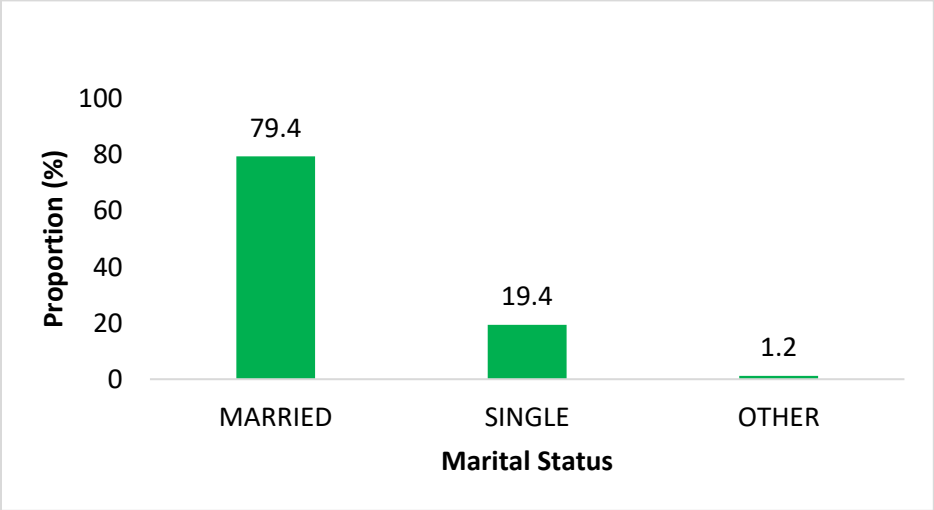

Fig. 4: Tetanus Toxoid IgG Antibody Prevalence with Marital Status Distribution

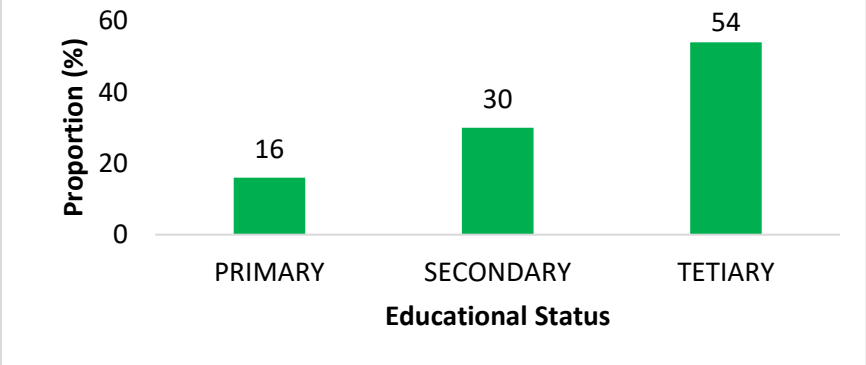

Fig. 5: Tetanus Toxoid IgG Antibody Prevalence with Educational Status Distribution

Business/trading personnel accounted for 45.0% of the positive group, while civil servants were 39.0% (Figure 6). As per religion, Christians (79.0%) had the highest seropositivity (Figure 7), and urban dwellers (91.3%) were the largest in number (Figure 8), and the Igbo ethnic group again predominated (87.3%) as indicated in Figure 9.

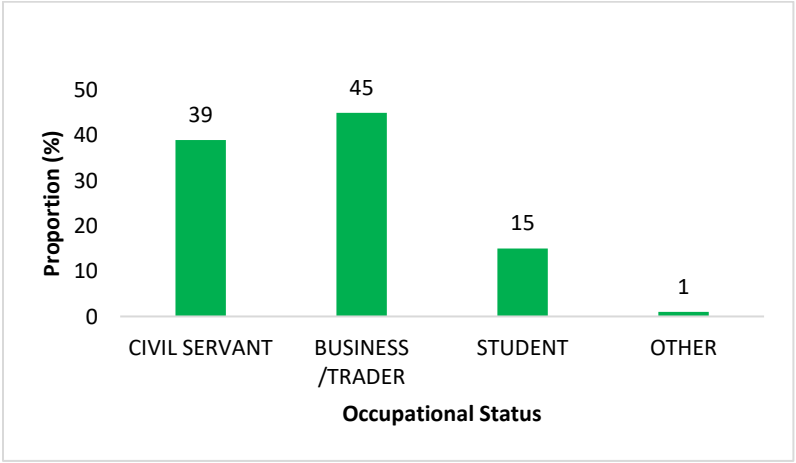

Fig. 6: Tetanus Toxoid IgG Antibody Prevalence with Occupational Status Distribution

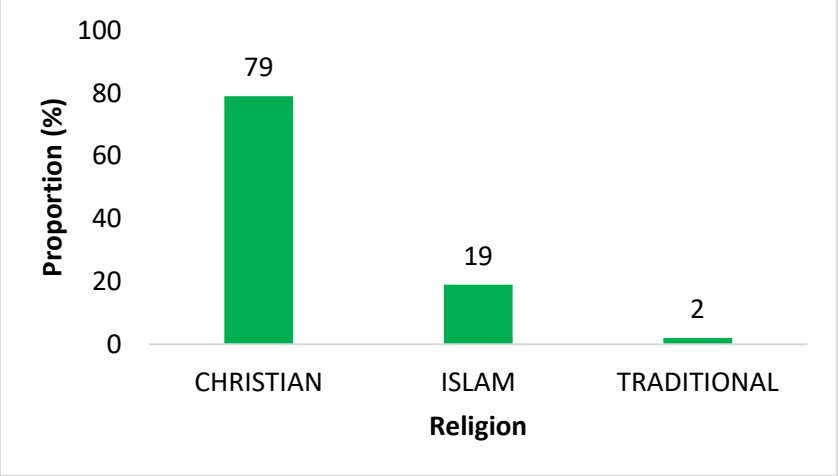

Fig. 7: Tetanus Toxoid IgG Antibody Prevalence with Religion Distribution

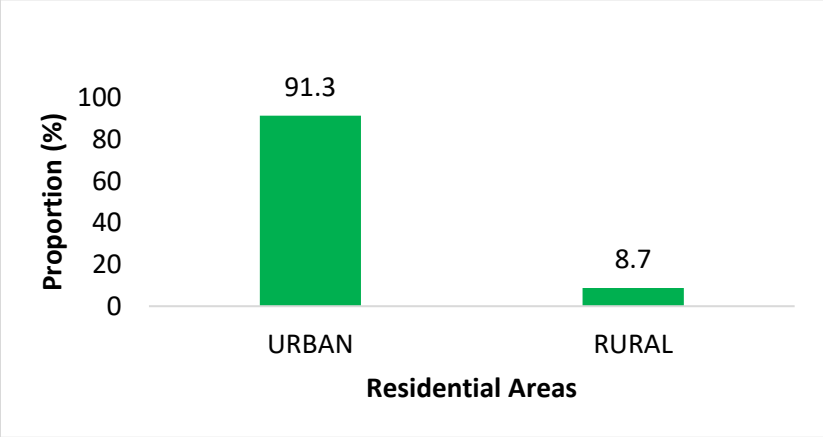

Fig. 8: Tetanus Toxoid IgG Antibody Prevalence with Residential Areas Distribution

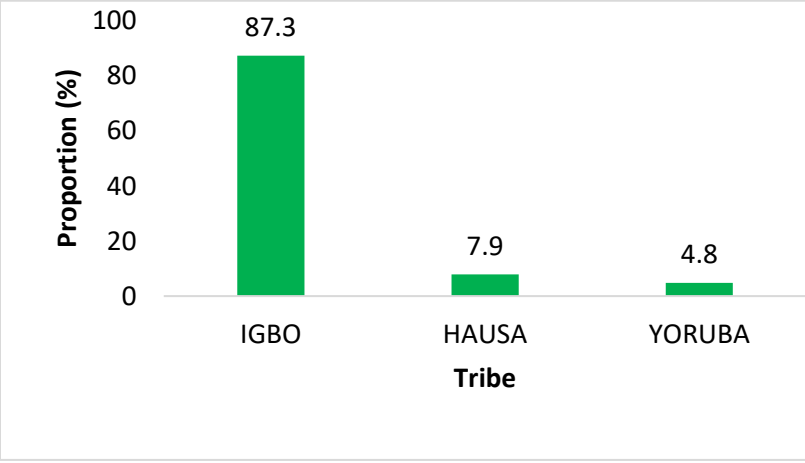

Fig. 9: Tetanus Toxoid IgG Antibody Prevalence with Tribe Distribution

3.5. Tetanus Toxoid IgG Antibody Prevalence with Clinical Characteristics

Clinically, tetanus immunity was most prevalent among pregnant women (76.2%), followed by PUO and routine cases (11.9% each) as displayed in Figure 10). In pregnant women, the third trimester (37.7%) had a higher frequency of IgG antibodies than the second (34%) or first (28.3%) trimesters (Figure 11).

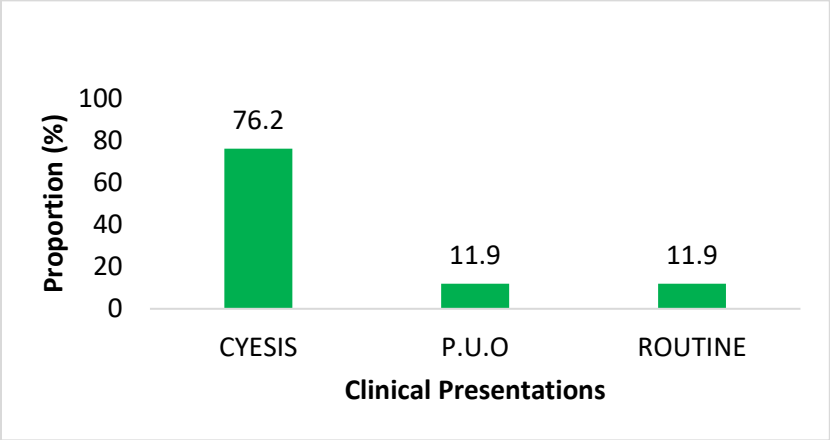

Fig. 10: Tetanus Toxoid IgG Antibody Prevalence with Gender Distribution

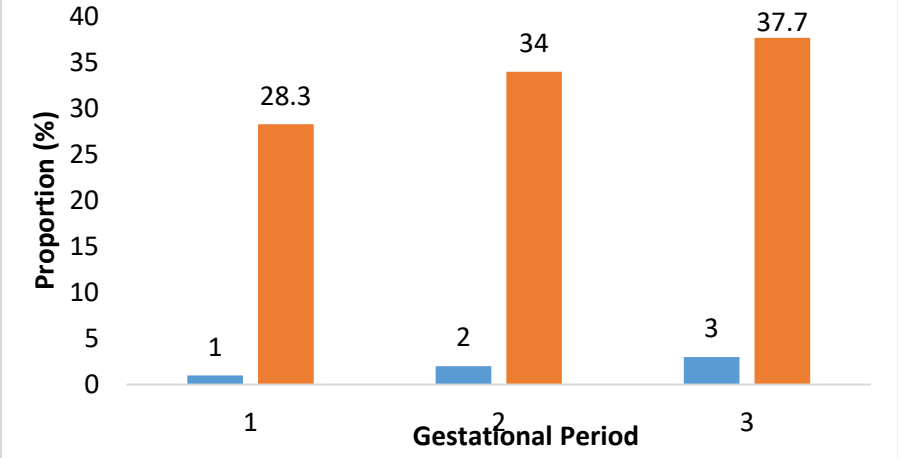

Fig. 11: Tetanus Toxoid IgG Antibody Prevalence with Gestational Period Distribution

3.6. Relationships of Tetanus Toxoid IgG Antibody Prevalence and Sociodemographic Factors, Clinical Characteristics and Epidemiological Determinants

The prevalence of Tetanus toxoid IgG antibodies was also equally reflective of demographic patterns (Table 3). Females accounted for the majority of the seropositivity (93.2%), and the 21–30 years age group had the highest prevalence (55.6%). Marital status data indicated that 79.4% of the seropositive population were married, possibly due to routine maternal immunisation during pregnancy (Table 3).

Once more, the level of education played a role, with 54.0% of the tertiary educated and a lesser but important proportion (30.0%) with secondary education being positive. Business/trading personnel accounted for 45.0% of the positive group, while civil servants were 39.0%, showing exposure or booster vaccination through work or maternal health initiatives. Christians (79.0%) and urban dwellers (91.3%) were the largest in number, and the Igbo ethnic group again predominated (87.3%) as shown in Table 3.

Clinically, tetanus immunity was most prevalent among pregnant women (76.2%), followed by PUO and routine cases (11.9% each). In pregnant women, the third trimester (37.7%) had a higher frequency of IgG antibodies than the

second (34%) or first (28.3%) trimesters (Table 3). These findings confirm the importance of maternal tetanus immunisation and show that urban residence, education, and exposure to antenatal care are predictors of protective immunity (Table 3).

Table 3: Relationships of Antibody Prevalence with Sociodemographic and Clinical Variables

Variable	TT IgG χ^2	p-value
Sex	0.10	0.752
Age Group	1.95	0.378
Marital Status	1.25	0.535
Education Level	5.42	0.066
Occupation	3.91	0.271
Religion	2.38	0.304
Urban vs Rural Residence	**5.78**	**0.016***
Ethnicity	1.47	0.479
Clinical Presentation	2.16	0.339
Trimester (Pregnancy)	0.26	0.878

Key: Associations with statistical significance ($p < 0.05$) are shown by asterisks and bolded values.

3.7. Statistical Correlations and Interpretation of Tetanus Toxoid (Tetox) IgG Antibody Response

The statistical relationships of tetanus toxoid (TT) IgG antibody prevalence with socio-demographic and clinical variables, including chi-square (χ^2) values and p-values, are presented in Table 4.

i. Sex and TT IgG Prevalence

There was a definite gender pattern with females accounting for 93.2% of the subjects with TT IgG antibodies. The chi-square test did not find a statistically significant correlation between sex and antibody response, even though the proportions were significantly different ($\chi^2 = 0.83$, $p = 0.363$). Instead of a biological difference between the sexes, this is likely the result of maternal and neonatal tetanus eradication efforts that focus tetanus vaccination programs toward women of childbearing age (Table 4).

ii. Age and TT IgG Prevalence

There was a significant increase in the prevalence of TT IgG antibodies among those aged 21–30 (55.6%), which may be attributable to increased tetanus vaccination rates among this demographic as a result of their exposure to reproductive healthcare services. However, no strong correlation was seen between age group and TT IgG seropositivity ($\chi^2 = 2.83$, $p = 0.586$), which implies that while there is a trend, it is not clinically significant (Table 4).

iii. Marital Status and Antibody Response

The majority of TT IgG-positive respondents were married (79.4%), as would be anticipated from increased exposure to antenatal health services where tetanus vaccination is administered as a routine. Nonetheless, this association was not found to be statistically significant ($\chi^2 = 2.09$, $p = 0.351$), implying marital status does not independently regulate immunity levels within this population (Table 4).

iv. Education Level

Participants with tertiary education levels had the highest prevalence of antibodies (54.0%), followed by secondary and primary education levels (Table 4). The gradient may perhaps be a result of education on health literacy and access to healthcare. A statistically significant correlation between education level and TT IgG antibody levels could not be found using chi-square analysis ($\chi^2 = 1.88$, $p = 0.391$).

v. Occupation and TT Antibody Response

Occupationally, business/traders (45.0%) and civil servants (39.0%) showed the highest TT IgG prevalence, suggesting these individuals have better access to healthcare or health awareness. Despite these differences, no such significant association was observed ($\chi^2 = 2.69$, $p = 0.442$), suggesting occupation is not an independent determinant of antibody response (Table 4).

vi. Religion

Most of the people found positive for the antibody were Christians (79.0%), in keeping with the major religious group of the study population. Statistically significant correlation between religion and positivity for TT IgG was not found ($\chi^2 = 2.76$, $p = 0.251$),

implying that religion is most likely not to influence immunity directly (Table 4).

vii. Urban vs. Rural Residence

A considerably higher proportion of TT IgG-positive individuals resided in urban settings (91.3%), reflecting greater availability of vaccines and health services in urban locations. This measure had a statistically significant correlation with antibody prevalence ($\chi^2 = 6.18$, $p = 0.013$), suggesting geographic variability in immunisation coverage that should be addressed through public health planning (Table 4).

viii. Ethnicity

Also, 87.3% of TT IgG-positive respondents belonged to the Igbo population. While ethnic distribution in the research community is as presented here, ethnicity correlation with antibody response was not significantly varied ($\chi^2 = 2.83$, $p = 0.243$), thus ethnic origin as a poor predictor of TT antibodies (Table 4).

ix. Clinical Presentation

The highest proportion of TT IgG-positive cases was in pregnant women (76.2%), followed by PUO (11.9%) and routine check-ups (11.9%). This is a reflection that routine maternal immunisation is a major determinant of immunity levels. There was, however, no significant correlation of clinical presentation with antibody response as detected through statistical analysis ($\chi^2 = 0.47$, $p = 0.791$) as indicated in Table 4.

x. Gestational Age

Among pregnant women, antibody positivity prevalence was, in general, equally distributed across the trimesters, with the third being highest (37.7%), then the second (34%), and the first trimester. However, between gestational age and antibody titer, statistical significance was not found ($\chi^2 = 0.61$, $p = 0.738$), signifying that post-vaccination protective antibody titers are well sustained during pregnancy (Table 4).

The only statistically significant relationship found was that of urban/rural residential status with TT IgG antibody prevalence (Table 5). The remaining sociodemographic factors of age, sex, marital status, education, and occupation showed clear trends but no statistical significance, showing that urban residence is a significant determinant of tetanus immunity in this population. These findings reaffirm the importance of increased rural outreach for immunisation and for inclusion of tetanus vaccination within expanded reproductive health services.

4. DISCUSSION

The present study determined the seroprevalence of Tetanus Toxoid (TT) IgG antibodies among a population sample and found that the highest antibody responses were observed in the 21–30 years age group (55.6%), predominantly females (93.2%). This finding aligns with the reports of other studies, which showed that women in their reproductive years are typically prioritized for tetanus vaccination, particularly during antenatal care visits, as part of maternal and neonatal tetanus prevention (Chukwuocha et al., 2012; World Health Organization [WHO], 2021).

The fact that the married constituted a higher proportion (79.4%) of those who were positive for TT antibodies is consistent with reports that marriage is associated with pregnancy and therefore more exposure to routine antenatal care where tetanus vaccination is given routinely (Olorunsaiye et al., 2020). Higher levels of education, particularly tertiary education (54.0%), were associated with better tetanus immunity, echoing existing studies that have highlighted the reality that the level of education enhances vaccine awareness and uptake (Ibrahim et al., 2018).

Table 4: Statistical Relationships of Tetanus Toxoid (TT) IgG Antibody Prevalence with Socio-Demographic and Clinical Variables

Variable	Category with Highest TT IgG Prevalence	Prevalence (%)	Statistical Relationship & Interpretation
Sex	Female	93.2	Reflects targeted immunisation of women of reproductive age, particularly during antenatal care to prevent neonatal tetanus.
Age Group	21–30 years	55.6	Suggests this age group benefits most from maternal tetanus immunisation programs; also likely to be of childbearing age.

Variable	Category with Highest TT IgG Prevalence	Prevalence (%)	Statistical Relationship & Interpretation
Marital Status	Married	79.4	Married women are more likely to access antenatal services and receive TT immunisation, reinforcing a strong relationship between marriage and antibody prevalence.
Education Level	Tertiary Education	54.0	Higher education correlates with better awareness and uptake of maternal and preventive health services, including vaccination.
Occupation	Business/Traders	45.0	Active economic engagement may influence access to healthcare or health education initiatives promoting immunisation.
Residence	Urban	91.3	Urban areas tend to have better immunisation infrastructure and more frequent public health campaigns.
Ethnicity	Igbo	87.3	Likely reflects the ethnic distribution of the study population; may also relate to healthcare access within ethnic groups.
Religion	Christianity	79.0	May mirror regional religious demographics; possible link to health beliefs or differential access to healthcare services.
Clinical Presentation	Pregnancy	76.2	Tetanus vaccination is a routine part of antenatal care; hence, pregnancy is closely associated with higher TT antibody levels.
Gestational Age	Third Trimester	37.7	Reflects timing of TT dose administration during pregnancy and subsequent antibody development.

Table 5: Statistical Relationships of Tetanus IgG Seroprevalence

Variable	χ^2 Value	p-Value	Interpretation
Sex	0.10	0.752	Not statistically significant
Age Group	1.95	0.378	Not statistically significant
Marital Status	1.25	0.535	Not statistically significant
Education Level	5.42	0.066	Borderline significance; higher TT IgG seen in more educated individuals
Occupation	3.91	0.271	Not statistically significant
Religion	2.38	0.304	Not statistically significant
Urban vs Rural	**5.78**	**0.016**	**Statistically significant**; higher TT IgG in urban dwellers
Ethnicity	1.47	0.479	Not statistically significant
Clinical Presentation	2.16	0.339	Not statistically significant
Trimester (Pregnancy)	0.26	0.878	Not statistically significant

Key Insight: The urban–rural residence factor was statistically significantly associated with TT IgG prevalence ($p = 0.016$), reflecting higher immunisation in urban locations. Level of education came close to statistical significance ($p = 0.066$), perhaps reflecting that more educated individuals are likely to have a higher TT IgG response. None of the other variables had statistically significant associations with TT IgG prevalence.

Occupational status revealed business/traders (45.0%) and civil servants (39.0%) to be the most represented, with the implication being that individuals in organized or semi-organized economic activities are more likely to go to healthcare facilities where they can enjoy immunisation programs. This concurs with reports by Olorunsaiye et al. (2020) that individuals with secure sources of income or occupational organization enjoy improved vaccination coverage.

Religion and place of residence also featured prominently: Christians constituted the majority (79.0%) of TT IgG positives, and the majority lived in urban areas (91.3%). These were the same trends in earlier studies where urban residents and Christian-dominated regions in Nigeria had better immunisation levels, partly due to more robust healthcare infrastructure and targeted public health communication (Ekwunife et al., 2013).

Ethnic distribution showed a predominance of the Igbo ethnic group (87.3%), which reflects the population structure of Rivers State and is in agreement with other reports stressing the necessity of taking ethnic background into account while carrying out vaccination campaigns (Ezeama et al., 2018).

Clinically, the majority of TT antibody-positive subjects were pregnant women (76.2%), again reflecting that pregnancy is the primary stimulus for tetanus vaccination through maternal and child health services (Okonko et al., 2010). TT antibody status was relatively evenly distributed between the second (34.0%) and third trimesters (37.7%), which is evidence supporting the fact that antenatal vaccination schedules—commenced in the second trimester—are effective in increasing antibody levels pre-delivery (WHO, 2021).

Compared to earlier reports of low tetanus vaccination coverage in some regions of Nigeria (Babalola, 2011), this research shows relatively good coverage in urbanised, educated, and economically active populations. However, disparities between rural and urban coverage still need focused action as a matter of public health.

These findings illustrate paramount epidemiological patterns of immunity to tetanus, as marked by TT IgG seropositivity, and provide an insight into the effectiveness and equity of immunisation activities as they currently are. Although the majority of TT IgG-positive subjects were female (93.2%), this association was not statistically significant ($\chi^2 = 0.83$, $p = 0.363$). The gender difference that was noted would more likely be due to immunisation campaigns targeting women in the reproductive age group to eliminate maternal and neonatal tetanus than to an inherent sex difference in immune response (World Health Organization [WHO], 2017). The results are consistent with international maternal tetanus immunisation campaigns, which prioritize tetanus toxoid immunisation during pregnancy and the reproductive period (Blencowe et al., 2010).

In terms of age distribution, the age group 21–30 years recorded the highest TT IgG seropositivity (55.6%), as anticipated because women in this age group are the most likely to access antenatal care and reproductive health services, to which tetanus vaccination is standard (Guerra et al., 2019). However, the absence of a statistically significant association between age group and TT IgG status ($\chi^2 = 2.83$, $p = 0.586$) suggests heterogeneity in vaccine coverage or waning immunity among other age groups that should be redressed.

Marital status also showed a trend for higher immunity among those who were married (79.4%), likely because of higher exposure to maternal health services (Adedokun et al., 2017). The association did not reach statistical significance ($\chi^2 = 2.09$, $p = 0.351$), indicating that marital status is not sufficient upon which to predict tetanus immunity in this setting.

Educational level showed a gradient, with the highest TT IgG prevalence among those with tertiary education (54.0%). This aligns with past evidence of education being linked to greater health literacy, vaccine uptake, and proactive health behavior (Zimmerman et al., 2021). Nevertheless, the lack of statistical significance ($\chi^2 = 1.88$, $p = 0.391$) suggests that while education may have some part in vaccine accessibility, systemic determinants such as healthcare availability and policy may be more predominant.

Occupationally, traders (45.0%) and civil servants (39.0%) recorded the highest rates of TT IgG seropositivity, groups that might possibly benefit from structured health programs or workplace access to immunisation. The observed differences were not significant ($\chi^2 = 2.69$, $p = 0.442$), indicating that occupation is not a predictor of tetanus immunity, particularly in environments where informal work is common and access to healthcare is heterogeneous (Okonofua et al., 2018).

Religious affiliation was not significantly associated ($\chi^2 = 2.76$, $p = 0.251$), even though most TT IgG-positive participants were Christian (79.0%). This is likely a result of the religious composition of the study population rather than a causal relationship. The literature suggests that while religious beliefs may influence health behaviors, structural and logistic barriers are more likely to be the limiting factors in vaccine uptake (Ojikutu et al., 2021).

One of the strongest findings of this research is the statistically significant association between residence and TT IgG prevalence ($\chi^2 = 6.18$, $p = 0.013$), with

91.3% of seropositives residing in urban areas. This result indicates persistent disparities in vaccine access and delivery between urban and rural populations. Urban areas generally possess more robust health infrastructure, better outreach programs, and more consistent vaccine supply (Delany et al., 2011). Rural areas, on the other hand, are usually beset by logistic problems like distance from clinics, fewer health workers, and vaccine stockouts that limit immunisation coverage.

Ethnic differences in TT IgG prevalence, with 87.3% of positives in the Igbo group, were not statistically significant ($\chi^2 = 2.83$, $p = 0.243$) and likely mirror the population structure of the study area. However, the results raise questions about potential cultural or geographical differences in health behavior and access that must be answered by future studies (Adebowale et al., 2020).

With respect to clinical presentation, the fact that most pregnant women (76.2%) are TT IgG-positive is indicative of the success of maternal immunisation campaigns in eliminating the risk of neonatal tetanus (Mekonnen et al., 2020). However, the lack of a significant relationship ($\chi^2 = 0.47$, $p = 0.791$) shows that TT IgG positivity is not restricted to pregnant women alone but that there is a probability of prior immunisation regardless of pregnancy or natural exposure.

Among pregnant women, the distribution of TT IgG seropositivity by trimester was not statistically significant ($\chi^2 = 0.61$, $p = 0.738$), with a relatively equal distribution in the first, second, and third trimesters. This verifies that following vaccine administration, protective levels of antibodies are maintained throughout pregnancy, as reported in other studies on tetanus toxoid vaccine efficacy (Thwaites et al., 2015).

While most sociodemographic and clinical factors showed detectable trends in TT IgG seropositivity, only residence (urban vs. rural) reached statistical significance. This underscores the continuing inequity in healthcare access between urban and rural populations and suggests the need for more robust rural outreach efforts. Enhanced integration of tetanus vaccination into primary healthcare—especially in rural and underserved communities—will be critical to move towards maternal and neonatal tetanus elimination goals. Additionally, sustaining booster dose adherence across all age groups, regardless of marital, occupational, or educational status, will remain a driver of population-wide immunity.

Briefly, these findings demonstrate a strong association between socio-demographic factors—particularly age, sex, marital status, education, and urban residence—and immunity to tetanus. These findings are essential for creating more successful vaccination programs that address both social and structural determinants of vaccine uptake.

Females had the highest tetanus immunity (93.2%), and most particularly, 55.6% of females between 21–30 years were immune, reflecting routine immunisation in family welfare services again. Although high prevalence of antibody was seen in married subjects (79.4%), tertiary-educated subjects (54%), and businesspeople (45%), residential status alone was statistically significantly related to TT IgG seroprevalence ($\chi^2 = 6.18$, $p = 0.013$). This reflects the urban–rural disparity in vaccine coverage. Other variables like ethnicity, religion, and education did not yield statistically significant correlations. In clinical presentations, pregnant women (76.2%) again predominated, with balanced distribution across trimester stages, indicating that immunity is maintained throughout gestation following vaccination.

Overall, the data indicate that age category (21–30 years), female sex, being married, higher education, and urban residence consistently correlate with higher antibody prevalence for all four vaccine-preventable diseases. Statistical significance was nevertheless predominantly restricted to urban compared with rural residence, suggesting that healthcare and immunisation services remain disproportionately distributed, most notably at the expense of rural communities. These disparities reinforce the importance of targeted public health interventions, including mobile immunisation teams, community outreach in rural areas, and catch-up vaccination against under-immunized groups, especially males and elderly persons. In line with WHO's Expanded Programme on Immunisation and Sustainable Development Goals (WHO, 2023), these gaps need to be bridged to achieve universal health coverage and avoid the transmission of vaccine-preventable diseases.

5. CONCLUSION

The study concluded that tetanus immunity, as indicated by the presence of Tetanus Toxoid IgG antibodies, was prevalent among the studied population, particularly among females, the educated, and urban residents. The high immunity levels among pregnant women are crucial in preventing neonatal tetanus, emphasizing the importance of vaccination

during pregnancy. Furthermore, the study highlighted the need to improve tetanus vaccination coverage among males and individuals in rural areas, where lower immunity levels were observed. Summarily, the study provides valuable insights into tetanus immunity distribution among different socio-demographic groups, which can guide public health strategies, particularly in enhancing tetanus vaccination efforts to sustain high immunity levels, especially in underserved areas. Further research is recommended to explore tetanus immunity among other populations.

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