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Prevalence of Multidrug-Resistant Staphylococcus Aureus Among Adolescents in Warri, Delta State, Nigeria: A Cross-Sectional Study

Chukwurah, C.H.[1*], Uguana, E.Q.[1], Igiebor, F. A.[2]

[*1]Department of Science Laboratory Technology, Federal Polytechnic Orogun Delta State
[2]Department of Microbiology, Delta State University, Abraka
*Email: Chukwurah.chidiogo@fepo.edu.ng

ABSTRACT

Staphylococcusaureus is a significant human pathogen that is increasingly becoming known to be multidrug resistant, a significant public health concern. Although a lot of research has been done on nasal and throat carriage, there is little emphasis on other reservoirs, including stool, urine and ear sites, particularly in adolescents in Nigeria. A cross-sectional survey was done on 504 (13-17 years old) students in five secondary schools in Warri, Delta State. Ear swabs, nasal swabs, urine and stool samples were collected and cultured for *S. aureus*. Gram stain, catalase, DNase, and coagulase were used to confirm isolates. The agar dilution MIC and modified Kirby-Bauer disc diffusion methods were used to test 10 commonly used antibiotics with regard to antimicrobial susceptibility. Multidrug resistance (MDR) was defined as resistance to ≥3 antibiotic classes. Using SPSS, chi-square and logistic regression were used to analyse the data.Among 504 specimens, 317 (62.9%) were positive for*S. aureus*, and 153 (48.3%) of them were multidrug resistant (MDR). There was a significant difference in the carriage of MDRSA among schools ($\chi^2(4) = 21.33$, $p < 0.001$) but not by gender ($p = 0.55$). According to logistic regression, Ugbolokposo (OR = 3.75, 95% CI = 1.87-7.50, p = 0.001) and Ebrumede (OR = 2.31, 95% CI = 1.18-4.52, p = 0.015) students had higher odds of MDRSA carriage compared to College of Education. Most MDRSA were found in stool (84.8%) and urine (62.9%).The highest resistance was in the β-lactams, especially ampicillin + cloxacillin (90.2) and amoxicillin (85.0). Among the macrolides, erythromycin showed moderate resistance (65.4%). By contrast, isolates remained largely susceptible to the glycopeptide: vancomycin (94.8%), the β-lactam combination, Augmentin (92.2%), and the fluoroquinolone, ciprofloxacin (86.9%).The prevalence towards MDRSA amongst adolescents in Warri was noted to be high, with stool and urine being critical reservoirs. The differences at the school level imply environmental or behavioural motivation other than gender. The urgent need is to strengthen the antibiotic stewardship, surveillance, and awareness in schools and communities to curtail the spread of MDRSA.

Keywords: *Staphylococcus aureus*, multidrug resistance, adolescents,antibioticsusceptibility, reservoirs, students, β-lactams, macrolides, fluoroquinolones, glycopeptides, antibiotic resistance, Nigeria.

INTRODUCTION

Staphylococcus aureus, the golden cluster seed, is a spherical bacterium frequently found in the nose, throat, intestine, vagina, and skin of the human body (Weems, 2001). It is a pathogen of great concern because it has the potential to infect with great diversity as well as the capability to quickly adapt to changes in the environmental conditions (Lowe, 2003, and Chambers, 2005). Such properties have rendered *S. aureus*-induced infections all the more difficult to treat, particularly due to the rapid pace at which it becomes resistant to popular antimicrobial agents.

Multidrug antibiotic resistance is a significant epidemiological issue in the treatment of staphylococcal infections and especially methicillin-resistant *S. aureus* (MRSA), which occurs because of the widespread use of antimicrobial agents and person-to-person transmission of resistant strains (Okeke and Lamikanra, 2003). It is thus important to effectively control the use of antibiotics and also prevent the spread of these strains so as to curb the transmission of this infectious organism.

Antibiotic resistance occurs through a variety of mechanisms, including modified drug targets, enzymatic drug inactivation, increased efflux of antimicrobial compounds, and altered drug accessibility (Boyle-Vavra and Daum, 2016), and the dissemination of resistance is facilitated by a multiplicity of mobile genetic factors (Haaber *et al*., 2017). Despite the resistance that has been realized in virtually all compounds, there are no single strains that are resistant to all drugs.

The gut and the other areas of the body, such as the nose, ear, and urinary tract, are other significant sites of bacteria, including S. *aureus*. Faecal-oral infection contributes significantly to the spread of these microorganisms, which may cause mild or severe illness in people who are susceptible or when present in places in which they are not normally found (Andargie *et al*., 2008). Its presence in the stool/faecal samples has been identified as a major contributor to antibiotic-associated diarrhoea and a source of antibiotic-resistant strains in humans (Boyce and Havill, 2015; Dominguez *et al*., 2022; Boyce *et al*., 2017).

Despite the preponderance of *S. aureus* research on vaginal, semen, nose, and throat positive samples, the colonization of the gut, ear, or urinary tract has little in-depth research available. This underscores a need to conduct more research on *S. aureus* of these body locations as reservoirs of multidrug-resistant varieties, especially in developing nations where the control of antibiotics is still poor.

This paper presents the prevalence of the multidrug-resistant *S. aureus* isolates in the nose, ear, urine, and fecal samples of healthy adolescents in five randomly chosen secondary schools in Warri, Delta State, Nigeria.

MATERIALS AND METHODS

Study Subjects

This was a cross-sectional study carried out on the students in a population of five secondary schools in Warri, Delta State, Nigeria, between the ages of 13 and 17 years. The procedure included the ear, nose, urine, and faecal (stool) samples, laboratory tests to determine the presence of Staphylococcus aureus, as well as, antibiotic resistance and susceptibility tests.

Study Area

The research took place in Warri (5.517° N, 5.750 ° E), an oil-rich city in Delta state, Nigeria, along the Warri River. Founded in the 15th century by Prince Ginuwa of Benin, Warri has developed into a big economic state, and its population is estimated to be 1.08 million. It shares continuous urban space with nearby towns such as Effurun, Udu, and Sapele. The city has a high level of ethnical variety as the predominant groups are Itsekiri, Urhobo and Ijaw. It has an economy based on oil and gas, maritime trade, agriculture and fishing. The climate of Warri is a tropical monsoon climate with high temperatures and a yearly rainfall of over 2,000mm, which sustains mangrove and rainforest.

Figure 1: The Map of Warri metropolis

Sampling and Isolation of *Staphylococcusaureus*

Nose and ear swabs were collected from students using sterile cotton swabs, while students were provided with sterile bottles to provide fresh fecal and urine samples. The samples were all taken within 24 hours and within an hour in iced packs to the laboratory. At arrival, the samples were directly inoculated on sterilized Mueller-Hinton agar plates (Oxoid, UK) and streaked. Then the plates were incubated at 37°C over a period of 24 hours.

Identification of Staphylococcus aureus

The identification and distinction of *Staphylococcusaureus* and related organisms were done based on the morphology of the colony on the Mannitol Salt Agar (MSA) plates (Oxoid,UK). The proliferated organisms were identified by:Gram staining (Gram-positive clustered cocci), Catalase production, DNase activity, Coagulase production (using human plasma).

Gram-positive coccobacilli that were positive on catalase, DNase, and coagulase tests were identified as *S. aureus*. Verified isolates were placed on nutrient agar slants at 4 °C until utilised to test antibiotic-susceptibility.

Antibiotic-Susceptibility Testing

Agar diffusion technique (zone of inhibition-measurement)

Staphylococcus aureus was identified and differentiated from related organisms based on colony morphology on Mannitol Salt Agar (MSA) plates (Oxoid, UK). Two discrete yellow colonies from each MSA plate were sub-cultured onto sterile nutrient agar slants (Oxoid, UK) and incubated at 37°C for 24 hours.Proliferated organisms were characterized by:Gram staining (Gram-positive clustered cocci), Catalase production, DNase activity, Coagulase production (using human plasma). Ten antibiotic discs were then aseptically placed on the surface of the agar, namely:

Vancomycin 30 µg (Novaplus, USA), *Ampicillin* 10 µg (Merck, Germany), *Amoxicillin* 25 µg (Merck, Germany), *Amoxicillin - Clavulanic acid* (Augmentin) 30 µg (GlaxoWellcome, UK), *Ampicillin + Cloxacillin* 10/5 µg (Merck, Germany*), Erythromycin* 15 µg (Merck, Germany), *Azithromycin* 15 µg (Merck, Germany), *Ciprofloxacin* 5 µg (Merck, Germany), *Gentamicin* 10 µg (Merck, Germany), *Cefuroxime* 30 µg (GlaxoWellcome, UK), *Ceftriaxone* 30 µg (GlaxoWellcome, UK).

The Plates were left to stand at room temperature (20-30 minutes) to allow the antibiotics to fully diffuse and then incubated at 35°C for 24 hours. The diameter of the zone of inhibition of each antibiotic disc was then measured in millimetres after incubation. Resistance and susceptibility were interpreted using the zone diameter interpretative standards of the Clinical and Laboratory Standards Institute (CLSI, 2023).

Quality Control: *Staphylococcusaureus* ATCC 25923 served as a control strain throughout all susceptibility testing batches to provide reliability and reproducibility of the outcomes. The range of zone diameters of this reference strain was checked with those of the CLSI standards.

Agar dilution method (MIC test)

Standards solutions of ten frequently used antibiotics: vancomycin (2-12 µg/mL; Novaplus, USA), ampicillin (0.25 µg/mL; Merck, Germany), amoxicillin (8 µg/mL; Merck, Germany), amoxicillin clavulanic acid/augmentin (4/2 µg/mL; GlaxoWellcome, UK), ampicillin+ cloxacillin (2/0.5 µg/m One CLSI breakpoint concentration agar plate was prepared at each of these concentrations, a spot-inoculation with standardized bacterial suspensions of each strain (0.5 McFarland = 1×10^8 CFU/mL) was placed, and the plate was incubated at 30°C with this spot-inoculation incubation lasting 24 hours. (British Society for Antimicrobial Chemotherapy Disc diffusion method for antimicrobial susceptibility testing (2002). Strains that showed visible growth on each antibiotic-containing agar plates at or above breakpoint concentrations were classified as resistant to the antibiotic using the CLSI breakpoint standards (CLSI, 2023).

Quality Control

In order to have reliability and reproducibility of the antimicrobial susceptibility testing, Staphylococcus aureus ATCC 25923 (American Type Culture Collection, Manassas, VA, USA) was used as a quality control strain in every batch. The growth patterns, inhibition zones, and values of MIC obtained of this reference strain were compared to the CLSI standard ranges to confirm the accuracy of all the test procedures and reagents.

Statistical analysis

The data were analyzed with the help of SPSS version 15 (IBM Corp., Armonk, NY, USA). All the variables in the study were computed in terms of frequencies and percentages. The chi-square test (X^2, two-tailed) was used to test the differences in categorical variables, such as demographic characteristics and trends in antimicrobial resistance between males and females.

The likelihoods of the associations between the possible risk factors and the carriage of the MDR *Staphylococcusaureus* were calculated as odds ratios (ORs) with 95% Confidence Intervals (CIs). Multivariate logistic regression was used to determine independent predictors of MDRSA carriage, and confounding variables were corrected. Variables that had $p\leq0.05$ in the univariate analysis were added to the regression model.

All the p-values were two-sided, and statistical significance was set at $p \leq 0.05$.

Results

Table 1: Distribution Of Specimens by School, Gender, and Type

Schools	Gender	Total specimen collected	Nasal Swab	Ear Swab	Urine samples	Stool samples
College of Edu. Sec. Sch, Warri	Male	50	23	13	10	4
	female	50	23	13	10	4
Federal Gov. College, Warri	Male	51	23	13	10	5
	Female	51	23	13	10	5
Nana model college, Warri	Male	50	22	13	10	5
	Female	51	22	13	10	6

Schools	Gender	Total specimen collected	Nasal Swab	Ear Swab	Urine samples	Stool samples
Ebrumede Sec. Sch, Effurun	Male	50	22	12	11	5
	Female	50	22	12	11	5
Ugbolokposo Sec. Sch. Effurun	Male	50	22	12	10	6
	Female	51	23	12	10	6
Total		**504**	**225**	**126**	**102**	**51**

Table 2: *S. aureus* Positive isolates by School, Gender and Specimen Type

Schools	Gender	Nasal Swab positives	Ear Swab positives	Urine samples positives	Stool samples positives
College of Edu. Sec. Sch, Warri	Male	21	9	10	4
	female	19	11	9	4
Federal Gov. College, Warri	Male	17	8	8	4
	Female	21	----------	7	3
Nana model college, Warri	Male	11	----------	5	1
	Female	14	----------	6	3
Ebrumede Sec. Sch, Effurun	Male	19	4	6	3
	Female	16	-----	8	4
Ugbolokposo Sec. Sch. Effurun	Male	18	8	5	3
	Female	11	7	6	4
Total		**167**	**47**	**70**	**33**
Grand Total Positives	**317**				

Table 3: Total *S.aureus* positives and MDRSA distribution By Schools and Gender

Schools	Gender	Total Positives to *S. aureus*	MDRSA Positives
College of Edu. Sec. Sch, Warri	Male	44	14
	Female	43	19
Federal Gov. College, Warri	Male	37	11
	Female	31	14
Nana model college, Warri	Male	17	10
	Female	23	7
Ebrumede Sec. Sch, Effurun	Male	32	13
	Female	28	22

Schools	**Gender**	**Total Positives to *S. aureus***	**MDRSA Positives**
Ugboloso Sec. Sch. Effurun	Male	34	28
	Female	28	15
Total		**317**	**153**

Table 4: Overall Multidrug Resistance Staphylococcus Aureusby Specimen Type

Specimen Type	**Total Tested**	**Total *S. aureus* Positives**	**MDRSA Positives**
Nasal swabs	225	167	66
Ear swabs	126	47	15
Urine swabs	102	70	44
Stool Samples	51	33	28
Total	**504**	**317**	**153**

Table 5: MDRSA Prevalence (%)by Schools and Gender

Schools	**Gender**	**Total specimen collected**	**MDRSA Positives**	**MDRSA Prevalence (%)**
College of Edu. Sec. Sch, Warri	Male	50	14	**28%**
	Female	50	19	**38%**
Federal Gov. College, Warri	Male	51	11	**21.6%**
	Female	51	14	**27.5%**
Nana model college, Warri	Male	50	10	**20%**
	Female	51	7	**13.7%**
Ebrumede Sec. Sch, Effurun	Male	50	13	**26%**
	Female	50	22	**44%**
Ugbolokposo Sec. Sch. Effurun	Male	50	28	**56%**
	Female	51	15	**29.4%**

$$\text{MDRSA Prevalence (\%)} = \frac{\text{MDRSA Positive}}{\text{Total Specimens collected}} \times 100$$

Table 6: Overall prevalence of *Staphylococcus aureus* and multidrug-resistant *S. aureus* (MDRSA) among students

MDRSA was defined as resistance to ≥3 antibiotic classes. Values are counts (n) and percentages (%).

Category	**Total Students (n)**	***S. aureus* Positive (n, %)**	**MDRSA (n, %) among *S. aureus***
All students	504	317 (62.9%)	153 (48.3%)

Table 7: Antibiotic resistance and susceptibility profile of MDRSA isolates (N = 153)

Resistance to individual antibiotics among MDRSA isolates, using generic names. Values are counts (n) and percentages (%).

Antibiotics (Genericnames)	**Resistant (n, %)**	**Susceptibility (n, %)**
Macrolides:		
Erythromycin	100 (65.4%)	53 (34.6%)

Antibiotics (Genericnames)	Resistant (n, %)	Susceptibility (n, %)
Azithromycin	69(45.1%)	84 (54.9%)
β-lactams (Penicillinsand Combinations):		
Amoxicillin	130 (85.0%)	23 (15.0%)
Ampicillin + Cloxacillin	138 (90.2%)	15 (9.8%)
Augmentin (Amox-Clav)	12 (7.8%)	141 (92.2%)
Cephalosporins:		
Cefuroxime	107(69.9%)	46 (30.1%)
Ceftriaxone	92(60.1%)	61 (39.9%)
Glycopeptides:		
Vancomycin	8 (5.2%)	145 (94.8%)
Aminoglycosides:		
Gentamicin	20 (13.1%)	133 (86.9%)
Fluoroquinolones:		
Ciprofloxacin	15 (9.8%)	138 (90.2%)

Table 8. Antimicrobial resistance profile of MDRSA isolates by gender

Overall MDRSA isolates = 153. Males = 76; Females = 77. MDRSA was defined as resistance to ≥3 antibiotic classes. Resistance values are expressed as counts (n). Chi-square tests compare resistance between males and females.

β-lactams (Penicillinand Combinations)

Antimicrobial agent/ MIC conc.	Overall resistant (n, %)	Males (n = 76)	Females (n = 77)	p-value
Amoxicillin (8 µg/ml)	130 (85.0%)	64 (84.2%)	66 (85.7%)	0.79
Ampicillin + Cloxacillin (2/0.5 µg/ml)	138 (90.2%)	69 (90.8%)	69 (89.6%)	0.81
Augmentin (Amoxicillin/Clavulanic acid, 4/2 µg/ml)	12 (7.8%)	6 (7.9%)	6 (7.8%)	0.97

Cephalosporins

Cefuroxime (8 µg/ml)	107 (69.9%)	53 (69.7%)	54 (70.1%)	0.96
Ceftriaxone (1µg/ml)	92 (60.1%)	45 (59.2%)	47 (61.0%)	0.83

Macrolides

Erythromycin (0.5µg/ml)	100 (65.4%)	49 (64.5%)	51 (66.2%)	0.83
Azithromycin (0.5µg/ml)	69 (45.1%)	33 (43.4%)	36 (46.8%)	0.68

Aminoglycosides

Gentamicin (4 µg/ml)	20(13.1%)	10 (13.2%)	10 (13.0%)	0.95

Fluoroquinolones

Ciprofloxacin (1µg/ml)	15 (9.8%)	7(9.2%)	8 (10.4%)	0.84

Glycopeptides

Vancomycin (2 - 12 µg/ml)	8 (5.2%)	4(5.3%)	4(5.2%)	0.98

Table 9: Distribution of MDRSA among *S. aureus* positive students by school

MDRSA was defined as resistance to ≥3 antibiotic classes. Chi-square (χ^2) test evaluates differences in MDRSA carriage rates across schools.

School	MDRSA(n)	Susceptibility	Total (n)
College of Education			
Aminoglycosides	33	54	87
Secondary School			
Federal Government College, Ogunu	25	43	68
Nana Model College	17	23	40
Ebrumede Secondary School	35	25	60
Ugbolokposo Secondary School	43	19	62

Overall school effect: $\chi^2(4) = 21.33$, $p = .00027$ (significant differences across schools).

Table 10: Distribution of MDRSA among *S. aureus* positive students by gender

MDRSA was defined as resistance to ≥3 antibiotic classes. Chi-square (χ^2) test evaluates differences in MDRSA carriage rates by gender.

Gender	MDRSA (n)	Non-MDRSA (n)	Total (n)
Male	76	88	164
Female	77	76	153

Overall gender effect: χ^2 (1) = 0.36, p = .55 (no significant difference between males and females).

Table 11: Logistic regression predictors of MDRSA carriage by school and gender

Reference group: College of Education Secondary School (female students). Odds ratios (ORs) with 95% confidence intervals (CIs) quantify associations between school, gender, and MDRSA carriage. Significant associations are in bold.

Predictor	OR	95% CI	p-value
Ugbolokposo vs College of Education	**3.75**	1.87 - 7.50	**0.00019**
Ebrumede vs College of Education	**2.31**	1.18 - 4.52	**0.0148**
Male vs Female	0.81	0.51 - 1.29	0.38
Nana Model vs College of Education	1.19	0.55 - 2.55	0.66
Federal Govt. College vs College of Education	0.96	0.50 - 1.85	0.90

χ^2 (4) = 21.33, p = .00027 (overall school effect). Gender effect nonsignificant (χ^2 (1) =0.36, p=.55).

Table 12: MDRSA carriage by specimen type among *S. aureus*positive samples

MDRSA was defined as resistance to ≥3 antibiotic classes. Chi-square (χ^2) test evaluates differences in MDRSA carriage rates by anatomical site.

Specimen Type	MDRSA (n)	Non-MDRSA (n)	Total (n)
Nasal swabs	66	101	167
Ear swabs	15	32	47
Urine swabs	44	26	70
Stool samples	28	5	33

Overall specimen effect: χ^2 (3) = 33.80, p < .000001 (significant differences across specimen types).

Table 13: Pairwise odds ratios for MDRSA carriage by specimen type (vs. ear swabs)

Ear swabs are the reference group. Odds ratios (ORs) with 95% confidence intervals (CIs) and p-values are from Fisher's exact tests. Significant associations are in bold.

Comparison	OR	95% CI	p-value
Nasal vs Ear	1.39	0.70 – 2.77	0.40
Urine vs Ear	**3.61**	1.65 – 7.89	**0.0013**
Stool vs Ear	**11.95**	3.85 – 37.06	**0.000003**

Table 14. Resistance categories of MDRSA isolates among male and female students (n = 153)

Resistance categories are defined by the number of antibiotics (out of 11 tested) to which isolates showed resistance. MDRSA was defined as resistance to ≥3 antibiotic classes.

Resistance Category	Females (n = 77)		Males (n = 76)		Total (n = 153)	
	No.	%	No.	%	No.	%
Resistant to 3 agents	19	24.7	18	23.7	37	24.2
Resistant to 4 agents	22	28.6	21	27.6	43	28.1
Resistant to 5 agents	16	20.8	15	19.7	31	20.3
Resistant to 6 agents	12	15.6	13	17.1	25	16.3
Resistant to 7 agents	8	10.4	9	11.8	17	11.1
Resistance to 8 agents	0	(0.0%)	0	(0.0%)	0	(0.0%)
Resistance to 9 agents	0	(0.0%)	0	(0.0%)	0	(0.0%)
Resistance to 10 agents	0	(0.0%)	0	(0.0%)	0	(0.0%)
Resistant to ≥3 agents (MDRSA)	**77**	**100.0**	**76**	**100.0**	**153**	**100.0**

Multidrug-Resistant Staphylococcus aureus (MDRSA) Carriage by School and Gender

The MDRSA carriage in *S. aureus*-positive students also differed by school (2(4) = 21.33, p = 0.00027) but not by gender ($X^2(1) = 0.36$, P= 0.55) as seen in Table 9. Logistic regression, when school and gender were adjusted together, proved that Ugbolokposo Secondary School (OR = 3.75, 95% CI = 1.877.50, p = 0.00019) and Ebrumede Secondary School (OR = 2.31, 95% CI = 1.187.52, p = 0.0148) experienced a much greater likelihood of MDRSA carriage than College of Education Secondary School. Conversely, Federal Government College (P = 0.90), Nana Model College (P = 0.66), and sex of students (P= 0.38) were not important predictors (Table 11). These observations suggest that the prevalence of MDRSA in this cohort is possibly due to site-level factors and not sex distribution (Agresti, 2013; Hosmer *et al*., 2013).

MDRSA Carriage by Type of Specimen

There was also a significant difference in MDRSA prevalence depending on specimen type ($X^2(3) = 33.80$, p < 0.000001). A pairwise odds ratio (ear swabs as the reference) analysis revealed that urine swabs (OR = 3.61, 95% CI = 1.65-7.89, p = 0.0013) and stool samples (OR = 11.95, 95% CI = 3.85-37.06, p = 0.000003) carried a significantly larger odds ratio of MDRSA, but nasal swabs did not differ significantly (OR = 1. These gradients

might indicate anatomical and ecological niches with an impact on previous exposure to antibiotics, which may favour MDRSA colonization of urinary and gastrointestinal tracts.

Antimicrobial Resistance Profile

The antimicrobial resistance profile of MDRSA isolates is summarized in Table 8. The isolates demonstrated high resistance across several antibiotic classes.Among the β-lactams, resistance was highest with ampicillin + cloxacillin (90.2%), followed by amoxicillin (85.0%), cefuroxime (69.9%), and ceftriaxone (60.1%). In the macrolide class, erythromycin showed a resistance rate of 65.4%, whereas azithromycin was lower at 45.1%. Regarding the aminoglycosides, gentamicin resistance was observed in 13.1% of isolates. In the fluoroquinolone group, ciprofloxacin resistance was relatively low at 9.8%. For the glycopeptides, vancomycin resistance remained rare at 5.2%. Among the β-lactam/β-lactamase inhibitor combinations, Augmentin resistance was also low at 7.8%. Generally, the differences in resistance between male and female students were not statistically significant ($p>0.05$). Both genders exhibited the highest resistance to ampicillin + cloxacillin

DISCUSSION

The research showed a high rate of *Staphylococcusaureus* carriage among the secondary students, with 317 (62.9) students positive, and 153 (48.3) of the positive isolates being multidrug-resistant (MDRSA). *S. aureus* is also a flexible and powerful pathogen among people, as it is one of the most common causes of nosocomial or community-acquired infections (Rajbhandari *et al*., 2013). The fact that MDRSA is very prevalent in seemingly healthy adolescents is alarming because colonization creates a pool of subsequent infection and transmission both at school and at home.

The antibiotic resistance profile of the isolates indicated significant resistance towards a number of the first-line antimicrobial agents. Essentially, the most resistance was noted against ampicillin + cloxacillin (90.2) and amoxicillin (85.0), then cefuroxime (69.9) and ceftriaxone (60.1). Augmentin (amoxicillin-clavulanate acid) had a relatively low resistance rate, indicating the efficiency of β-lactamase inhibitors in overcoming penicillinase-mediated resistance.In the case of the macrolides, resistance was high with erythromycin (65.4%) and moderate with azithromycin (45.1%). Gentamicin, which was also one of the aminoglycosides, had moderate resistance levels, indicating that it still retains partial activity against *S. aureus* isolates resistant to this class of agents in this context.Notably, there was no evidence of resistance in glycopeptides like vancomycin, as a result of which this group of aminoglycosides remains an active agent of treatment in this indication when susceptibility is confirmed. The findings are also aligned with past reports in Nigeria that highlight high β-lactam resistance as a result of extensive use of drugs based on penicillin, as well as the presence of 8-lactamase enzymes (McNulty *et al*., 2017; Pechere, 2021; Nester *et al*., 2024). It is also worth mentioning that the resistance to ampicillin + cloxacillin (a methicillin analogue) amounted to 90.2%, which was significantly higher than that observed in Canada (62%) and Benin (62%), respectively (Currie *et al*., 2018; Baba-Moussa *et al*., 2020). This dramatic difference could be indicative of the disparity in the regulation of antibiotics, prescribing patterns, and self-medication patterns among the populations.

The occurrence of multidrug resistance (resistance to 3 or more classes of antibiotics) was validated in 153 isolates (48.3%). One-third of these had resistance to four antibiotics of differing combinations.Ampicillin was the most commonly found in resistance patterns, most commonly in combination with amoxicillin, cefuroxime, and ceftriaxone. The resistance to ampicillin + cloxacillin (a methicillin analogue) also presented the resistance with males demonstrating a little more resistance than females, but the difference was not significant ($p = 0.96$) (Table 8). Augmentin, a β-lactam/ β-lactamase inhibitor, had lower rates of resistance than the other 8-lactams, although it was still found in several combinations of multidrug resistance. Erythromycin was also commonly used as a contributor to resistance patterns within the macrolide group, highlighting its falling efficacy. Among the aminoglycosides, gentamicin had relatively lower overall levels of resistance, yet was reported in some multidrug resistance patterns, indicating emerging reduced susceptibility.Among fluoroquinolones, ciprofloxacin had low resistance when compared to β-lactams and macrolides, but in some cases was observed in a multidrug resistance pattern. Glycopeptide resistance, e.g. vancomycin resistance, was not common, but severe and has clinical implications because low resistance levels increase the question of treatment. Nevertheless, the fact that most multidrug resistance cases involve β-lactams and macrolides underscores the impact of their overuse, whereas the presence of aminoglycosides, fluoroquinolones, and glycopeptides in cases of resistance underscores the distressing nature of the decreasing susceptibility in various drugs.

Positively, the isolates were highly susceptible to various groups of antibiotics. Vancomycin was found to have the highest activity with 94.8 percent of the isolates susceptible; only 8 isolates (5.2 percent) had reduced resistance (VISA). This rate is greater than the 2.97% observed in healthy children in Zaria (Olonitola*et al*., 2017), which implies the possibility of emerging vancomycin resistance in society.

Co-colonization of *S. aureus* with Enterococcus species in the gastrointestinal tract may facilitate genetic transfer, contributing to the emergence of VISA strains (Ray *et al.,* 2013).Within the β-lactams, Augmentin retained strong activity (92.2% susceptible), contrasting with the marked resistance observed to other β-lactams such as amoxicillin, ampicillin + cloxacillin, cefuroxime, and ceftriaxone. This highlights Augmentin's continued relevance in empirical therapy despite widespread misuse of penicillin derivatives and cephalosporins.The fluoroquinolone ciprofloxacin (90.2% susceptible) and the aminoglycoside gentamicin (86.9% susceptible) also performed well. The preserved susceptibility to these two agents is in agreement with reports from other Nigerian and international studies (Onanuga*et al*., 2015; Oguzkaya-Artan *et al*., 2018) and might be associated with their relative underutilization relative to β-lactams. Generally, these agents, especially vancomycin, ciprofloxacin, gentamicin and Augmentin,are useful in the empirical treatment of S. aureus infections in school-aged populations, with the majority of isolates resistant to three to seven agents and none being resistant to eight or more agents. This is in line with regional resistance trends: a meta-analysis in Nigeria has shown low pooled vancomycin resistance (13%; 95% CI 7-21%), and even lower rates after sensitivity adjustment, emphasizing its retained use (Ezeh *et al*., 2023). On the same note, gentamicin and ciprofloxacin are always found to be less resistant and this supports their continued use in empirical care (Agbo *et al*., 2024; Brown, 2007).

The fact that the 3-5 range (3, representing the highest resistance and the lowest resistance) of strains comprises the majority of resistance (72.6 percent) indicates intermediate multidrug resistance, which is common to strains in the community, and the fact that a minority of strains are resistant to 6-7 agents (27.4 percent) indicates more widespread, but not pan-resistance. The findings are also reflected in other parts of the world: MDRSA strains are often resistant to more than two classes but rarely more than six (Jahanshahi *et al*., 2018; Vestergaard *et al*., 2018). This resistance pattern is promising in terms of the public health: the lack of resistance to eight or more agents is the indicator that vancomycin, ciprofloxacin, Augmentin and gentamicin are still effective. It highlights the significance of conserving these agents with strong antimicrobial stewardship and observation in institutions such as schools, where self-medication and abuse of antibiotics are widespread.

Assessment of self-medication among the students showed a high prevalence of self-medication (45%), lack of complete dosage-taking, and use of unlicensed drug peddlers. Factors that contribute to it include a lack of access to health facilities, poverty, and a lack of awareness of the risks of antimicrobial resistance (Okeke *et al*., 2021 and Pechere 2021). The most common antibiotics used improperly are: Penicillins (ampicillin and amoxicillin); Cephalosporins (ceftriaxone and ceftriaxime); Macrolides(erythromycin). This is also in line with the strongest resistance rates in this research. This finding reinforces the association between irrational antibiotic consumption and selection pressure that is driving the development of MDRSA.

There was a difference in colonization rates based on the anatomic site, with isolates being taken at the nose, ear, urine, and stool. Although the nose continues to be the most important reservoir of S. aureus, the introduction of extra-nasal sites enhanced the process of detection as well as giving a more precise estimate of carriage burden. Other researchers have noted that stool and ear carriage are also less explored but can play a major role in transmission in the community and hospitals (Bhalla *et al*., 2017; Squier *et al*., 2022; Boyce*et al*., 2015 and Donskey, 2014). *S. aureus*mainly thrives in the nasal carriage, the ecological niche that is well-known to promote the risk of infection (Wertheim *et al*., 2005). The relevant carriage site in adolescents is the ear canal, as such behaviours such as earbud sharing, swimming, and minor abrasions may occur (Roland and Stroman, 2002). To establish urinary tract infection, although less frequent, *S. aureus* bacteriuria can indicate peri-urethral colonisation, or urine hematogenous transmission (Rowe and Juthani-Mehta, 2013). Stool as reservoir: S. *aureus* intestinal carriage has been identified as a potentially significant reservoir with ramifications to environmental contamination and recolonisation (Bhalla *et al*., 2007). Such a multi-site methodology was more informative on epidemiology compared to nose-only sampling and identified further sources of MDRSA in adolescents through stool and urine.

The fact that MDRSA is highly prevalent among seemingly healthy students is a strong indication of the urgency of antibiotic stewardship programs in schools and communities. The awareness, regulation of drug suppliers, and better access to medical care a crucial measure to diminish misuse and self-medication (Okeke *et al*., 2005; Laxminarayan *et al*., 2013). Monitoring of nasal and extra-nasal sites should be integrated into monitoring systems to more effectively inform interventions, since carriage dynamics also play a significant role in maintaining *S. aureus* transmission (Wertheim *et al*., 2005). Unless a decisive action is taken to reduce antibiotic misuse, the rest of the effective agents may end up compromised (WHO, 2022).

CONCLUSION

The research indicates a high rate of *Staphylococcusaureus* (62.9%) among students, with almost half of the cases (48.3) being multidrug resistant. The most resistance was demonstrated to common β-lactam antibiotics, with vancomycin, ciprofloxacin, Augmentin, and gentamicin being mostly effective. Vancomycin-intermediate strains have been detected, and this makes a case for constant monitoring, wise use of antibiotics, and enhanced infection-control practices at school.

RECOMMENDATIONS

i. Regulate the rational prescription and sale of antibiotics over the counter.

ii. Create regular monitoring of antimicrobial resistance both in schools and communities.

iii. Train students and parents about the harms of self-medicating and misusing antibiotics.

iv. Encourage hygiene and infection-prevention in schools to prevent spread.

v. Enhance the partnership of the health authorities, schools, and communities in case of effective intervention programs.

Author Declarations

Ethics approval

Not applicable

Consent to participate

In this study, participation was completely voluntary. All participating students' parents or legal guardians provided written informed consent, and prior to sample collection, the students' verbal consent was also obtained. The goal of the study, the methods used, and the participants' freedom to leave at any time without incurring any fees were all explained to them. All provided information was kept completely confidential.

Consent for publication

Every author has given their approval for this manuscript to be published.

Data Availability

Upon reasonable request, the corresponding author will make the datasets created and/or analyzed during the current study available.

Competing interests

There are no conflicting interests, according to the authors.

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