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High nasal MRSA colonisation in healthy and septicemic under-five-year-old children in Zaria, Nigeria

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ABSTRACT

Background:

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a high-priority bacterium and a significant global health threat that requires continuous surveillance, especially in vulnerable populations, such as children. This study determined the prevalence and antimicrobial resistance (AMR) profile of nasal *S. aureus*, as well as the factors associated with its presence, among healthy children (HC) in Zaria communities and septicemic children (SC) attending the Ahmadu Bello University Teaching Hospital (ABUTH), Nigeria.

Materials and methods

Nasal samples were collected from 71 HC and 40 SC from 2nd April to 30th July 2025. The samples were processed to recover and identify *S. aureus*, and to determine their AMR profiles using conventional bacteriological media and the automated VITEK II compact system. Pretested structured questionnaires were used to collect sociodemographic and epidemiological data from children's parents or guardians.

Results:

All the *S. aureus* were MRSA, and the nasal carriage was 27.9%, with 25.4% in HC and 32.5% in SC (OR= 1.42, 95% CI: 0.61-3.32, p=0.4213). Use of antibiotics at least three months before sample collection was a significant factor for nasal MRSA colonisation in healthy children (OR=137.19, 95% CI: 7.64-2464.38, p=0.00008). MRSA carriage appeared to increase with age among healthy children, with a significantly higher prevalence among children aged 3 years than those aged 1 year (40% *versus* 20.6%, OR=11.42, 95% CI: 1.09-120, p=0.043). Resistance to non-beta-lactam antibiotics was highest against tetracycline (90.3%), mupirocin (83.9%), and sulfamethoxazole-trimethoprim (54.8%), with 87.1% exhibiting a multidrug-resistant phenotype. Remarkably, 32.2% and 22.5% of the MRSA were resistant to linezolid and vancomycin-teicoplanin, respectively. Over 50% of the MRSA had multiple AMR indices of 0.5.

Conclusions:

This study found no difference in nasal MRSA carriage between healthy and septicemic children. However, findings indicate a high prevalence multidrug-resistant-MRSA strains in both groups, highlighting potential implications for infection control measures in paediatric healthcare facilities in resource-limited settings.

Keywords: Linezolid resistance, MRSA carriage, paediatric infectious diseases, Vancomycin-resistant *S. aureus*

INTRODUCTION

Staphylococcus aureus is a major coloniser of the skin and mucosal membranes of humans and animals [1]. However, it causes infections when it spreads from colonised areas to other parts of the body, particularly if the host has compromised physical barriers (like wounds or medical devices) or a weakened immune system [2]. Permanent nasal *S. aureus* colonisation occurs in approximately 20% (range 12–30%) of individuals, with approximately 30% being intermittent carriers (range 16–70%) [3, 4]. However, various variables influencing *S. aureus* carrier status have been identified; for example, hospitalised patients are more likely to be colonised than healthy individuals [5], and the carriage rate is higher in infancy than in adulthood [6].

Based on the 2024 International Consensus Criteria for Pediatric Sepsis and Septic Shock, pediatric sepsis is defined as life-threatening organ dysfunction in children (under 18) with suspected or confirmed infection identified by a Phoenix Sepsis Score of at least systems involvement from cardiovascular, respiratory, neurological, and coagulation [7]. According to a recent study done in Bauchi state (Nigeria), about 56.3% septicemic children were found to have MRSA infection [6]. In an earlier study in Turkey, 66.7% of paediatric patients with haematological malignancies had MRSA infections associated with central venous catheters [8]. In particular, the prevalence of MRSA in Chinese children increased progressively from 18% in 2006 to 33% in 2014 before gradually falling to 29.8% in 2017 [9]. This pattern emphasises the importance of continuous monitoring and the effectiveness of antimicrobial stewardship initiatives in reducing the prevalence of MRSA infections.

Seasonal variations, such as the shift from cold to warm/ moist (i.e., winter to spring) weather, as well as pollen or dust levels, may all impact nasal microbiota composition [10]. Children are more vulnerable to infection when *S. aureus* is acquired from an asymptomatic nasal carrier that carries clinically relevant virulence factors and antimicrobial resistance [11, 12, 13].

The rising incidence of infectious diseases caused by antimicrobial-resistant bacteria poses a considerable threat to global public health [14]. In this regard, *S. aureus* can develop resistance to several clinically relevant antimicrobial agents through genetic mutation, horizontal gene transfer, and selection pressure [15]. Several mechanisms are responsible for AMR in *S. aureus*; some mechanisms could lead to the development of a multidrug resistance (MDR) phenotype, of which methicillin resistance is considered the high-priority resistance trait [16]. In this regard, MRSA are classified into healthcare-associated (HA-MRSA), community-associated (CA-MRSA), and livestock-associated (LA-MRSA) [17]. This classification helps differentiate the strains' characteristics and epidemiology. MRSA is now one of the markers of AMR, as outlined in Sustainable Development Goal 3.d, linked to health objective 3.d, according to the World Health Organisation [18]. Vancomycin and oxazolidinones are considered a last-resort treatment for MRSA infections. In Nigeria, newer alternative antibiotics such as daptomycin, ceftaroline, telavancin, tigecycline, and linezolid are rarely utilized [19]. Nonetheless, there have been reports of MRSA that are resistant to both antibiotics isolated from clinical samples [19, 20].

As a cause of invasive infections, including sepsis, nasal MRSA carriage is a serious concern in paediatric healthcare [21]. Children in hospitals are especially at risk because of their developing immune systems and frequent exposure to medical procedures. According to studies, nasal carriage rates vary, and MRSA is highly prevalent in various communities, making treatment more difficult [22]. There is limited information on the relationship between sepsis and *S. aureus* nasal carriage among Nigerian paediatric patients, despite international surveillance efforts. Effective infection control and the prevention of antibiotic resistance depend on an understanding of this relationship. Undiscovered carriers could increase the risk of morbidity by facilitating the spread of resistant strains.

To determine the prevalence of nasal MRSA carriage and assess the factors associated with their carriage in healthy and septicemic children. Moreover, the study aims to compare AMR patterns of MRSA isolates from healthy and septicemic children at the household and hospital levels, respectively. The results could enhance clinical care, strengthen evidence-based infection control strategies, and contribute to the fight against antibiotic resistance.

MATERIALS AND METHODS

Study area

This study was conducted in communities in Zaria for healthy children and at the Ahmadu Bello University Teaching Hospital (ABUTH) for septicemic children. The 1000-bed capacity hospital is located along the Zaria-Funtua Road in Shika, Zaria, Nigeria. This hospital serves a population of 809,700 people residing in Zaria (https://worldpopulationreview.com/cities/nigeria/zaria) and its neighbouring states in northern Nigeria.

Data collection

Data from this study were collected using a structured questionnaire (supplementary material 1). The questionnaire was designed to gather relevant information from the participants' parents or guardians. It will include sections on demographic variables such as age, gender, parental occupation, and other factors pertinent to the research objectives.

Sample size and study population

As this is a comparative cross-sectional study, the sample size was determined based on two previous studies. The first was from the global pooled prevalence of asymptomatic colonization of MRSA in young children [23]. Using the 3.4% prevalence of nasal MRSA among asymptomatic children, a minimum sample size of 50 was calculated. The second sample size was calculated using the 5.3% prevalence of nasal MRSA among children in the hospital reported by Saduaki *et al* [24]; a minimum sample size of 40 was calculated.

Sampling method

Simple random sampling was used to avoid bias. A clear sampling frame was defined, and a probability-based method was used to ensure every child in the target population had an equal chance of being selected. We assign a unique number to every child listed from households and the paediatric registry. Subsequently, a computer-generated random number table was used to pick the participants.

Children aged one to four years were enrolled. For the septicemic group, only patients presenting clinical symptoms of paediatric sepsis as diagnosed by paediatricians following the Phoenix Sepsis Score of at least 2 points were considered [7]. No laboratory tests were conducted to support the diagnosis of sepsis. For the healthy group, their parents or legal guardians must indicate that the children were not ill for at least 6 months before this study.

Sample Collections

From 2nd April to 30th July 2025, nasal samples from both nostrils of eligible participants were collected in batches and preserved in Amies transport media. Within 4 hours of collection, the nasal samples were transported to the laboratory under cold-chain conditions (2-8 °C), where they were processed for *S. aureus* recovery.

Laboratory analyses

The nasal swabs were inoculated onto mannitol salt agar. After incubation (24 h at 37 °C), a colony was collected from each sample. One colony per swab was analysed, and antimicrobial susceptibility results were obtained using VITEK *versus* the manual disc diffusion test. The colony was reisolated to obtain a pure *S. aureus* culture for identification. A rapid tube coagulation reaction and production of bright (intense) yellow color from mannitol fermentation were used to identify the *S. aureus* strains. Preliminary identification of isolates was carried out based on colony colour, size, hemolysis type, shape, catalase test, mannitol fermentation, and Gram staining in the microbiology laboratory at ABUTH, Zaria, Nigeria.

Vitek II compact equipment was used to confirm the *S. aureus* isolates. The VITEK operates on automated biochemical analysis and turbidimetric/colourimetric detection. It uses reagent cards with 64 wells containing different substrates, and an optical system measures bacterial growth by detecting changes in light transmission (turbidity) or colour development over time, comparing these patterns with a vast database to rapidly identify and test antibiotic susceptibility.

Antimicrobial Susceptibility Testing

The susceptibility of all identified *S. aureus* isolates to different antimicrobial agents was determined using automated equipment (VITEK II compact) based on minimum inhibitory concentration and manually by the Kirby-Bauer disk diffusion method on Mueller-Hinton agar (Oxoid, Manchester, UK). The manual disk diffusion tests were done using the following Oxoid® antibiotic discs (µg/disc): penicillin (1 unit), cefoxitin (30), mupirocin (200), gentamicin (10), clindamycin (2), erythromycin (15), ciprofloxacin (5), chloramphenicol (30), tetracycline (30), vancomycin (30), Trimethoprim/sulfamethoxazole (22.5) and linezolid (10). The 2024 European Committee on Antimicrobial Susceptibility Testing criteria were used to interpret breakpoints. The identification of the cefoxitin resistance phenotype on the MHA plate determined methicillin resistance. Furthermore, an MRSA isolate was considered MDR if it was resistant to ≥3 classes of the antimicrobial agents tested.

Statistical analysis

Categorical sociodemographic variables were expressed as frequencies. Bivariate logistic regression test was used to assess the association between risk factors, sociodemographic variables, and MRSA carriage rates, using MedCalc Version 23.0.2 (Ostend, Belgium). All analyses with p values <0.05 at 95% confidence intervals (CIs) were considered statistically significant.

RESULTS

Sociodemographic Characteristics of the Study Participants

This study enrolled 111 children, comprising 71 healthy controls and 40 children with septicemia. The sociodemographic characteristics of the participants are summarized in Supplementary Table S1. Among healthy children, 53.5% (38/71) were male, whereas among septicemic children, 57.5% (23/40) were male. The majority of children in both groups were one year old. Regarding residence, most participants lived in urban areas (63.4% of healthy children and 60% of septicemic children). Household density was variable, with the > 9 persons-per-household category predominant in the septicemic group (45%). The parents' educational backgrounds and household incomes showed diverse distributions across both groups (Supplementary Tables S1).

Prevalence and factors associated with nasal MRSA carriage among healthy and septicemic children

The overall prevalence of nasal MRSA among the study participants was 27.9% (31/111). As illustrated in Figure 1, the carriage rate was lower in healthy children (25.4%, 18/71) compared to septicemic children (32.5%, 13/40); however, this difference was not statistically significant (OR= 1.42, 95% CI: 0.61-3.32, p=0.4213).

The distribution of MRSA carriage across various sociodemographic factors is detailed in Table 1. Among healthy children, males had a lower MRSA carriage rate (15.2%) than females (34.2%), although this difference was not statistically significant (OR = 0.34, 95% CI: 0.11-1.09, p = 0.072). MRSA carriage appeared to increase with age among healthy children, with a significantly higher prevalence among children aged 3 years than those at 1 year (40% *versus* 20.6%, OR=11.42, 95% CI: 1.09-120, p=0.043). No other sociodemographic factors, including place of residence, child's education, parent's education level, or household income, showed a significant association with MRSA carriage in either group (p>0.05) (Table 1).

The analysis of factors associated with MRSA carriage is presented in Table 2. For healthy children, the use of antibiotics at least three months before sample collection was a significant factor. Children whose parents or guardians indicated use of antibiotics at least three months before sample collection had significantly higher nasal MRSA colonisation than those who did not (100% *versus* 23.3%, OR=137.19, 95% CI: 7.64-2464.38, p=0.00008) (Table 2). Recent antibiotic use, pet/livestock ownership, and knowledge of AMR among the parents or guardians of the children were not significantly associated with MRSA carriage in either group (p>0.05). Moreover, the duration of hospital stay was not significantly associated with MRSA carriage rates (p>0.05) (Table 2).

Antimicrobial resistance profiles of MRSA isolates from healthy and septicemic children

A comparative analysis of antimicrobial resistance phenotypes among MRSA isolates from both groups is shown in Figure 2. Notably, a significantly higher proportion of MRSA isolates from healthy children than the septicemic were resistant to linezolid (LZD) (55.6% *versus* 0%, OR=0.3, 95% CI: 0.0015-0.58, p=0.0204) and mupirocin (MUP) (100% *versus* 61.5%, OR=0.04, 95% CI: 0.002- 0.85, p=0.0385) (Table 3).

Multiple antimicrobial resistance indices and phenotypes of the MRSA isolates from healthy and septicemic children

The Multiple Antimicrobial Resistance (MAR) indices for MRSA isolates were calculated, and their distributions are presented in Supplementary Figure S1a (healthy children) and Figure S1b (septicemic children). The MAR indices for isolates from healthy children ranged from 0.33 to 0.75, with the most frequent indices being 0.58 and 0.75. For septicemic children, the MAR indices ranged from 0.17 to 0.67. The detailed antimicrobial resistance profiles and corresponding MAR indices for each MRSA isolate are presented in Supplementary Tables S2 (healthy children) and S3 (septicemic children). All the MRSA from both groups of children exhibited the MDR phenotype, except four from the septicemic children. Some MRSA strains

demonstrated simultaneous resistance to vancomycin and linezolid, as well as to seven other clinically relevant antibiotics (Supplementary Tables S2 and S3).

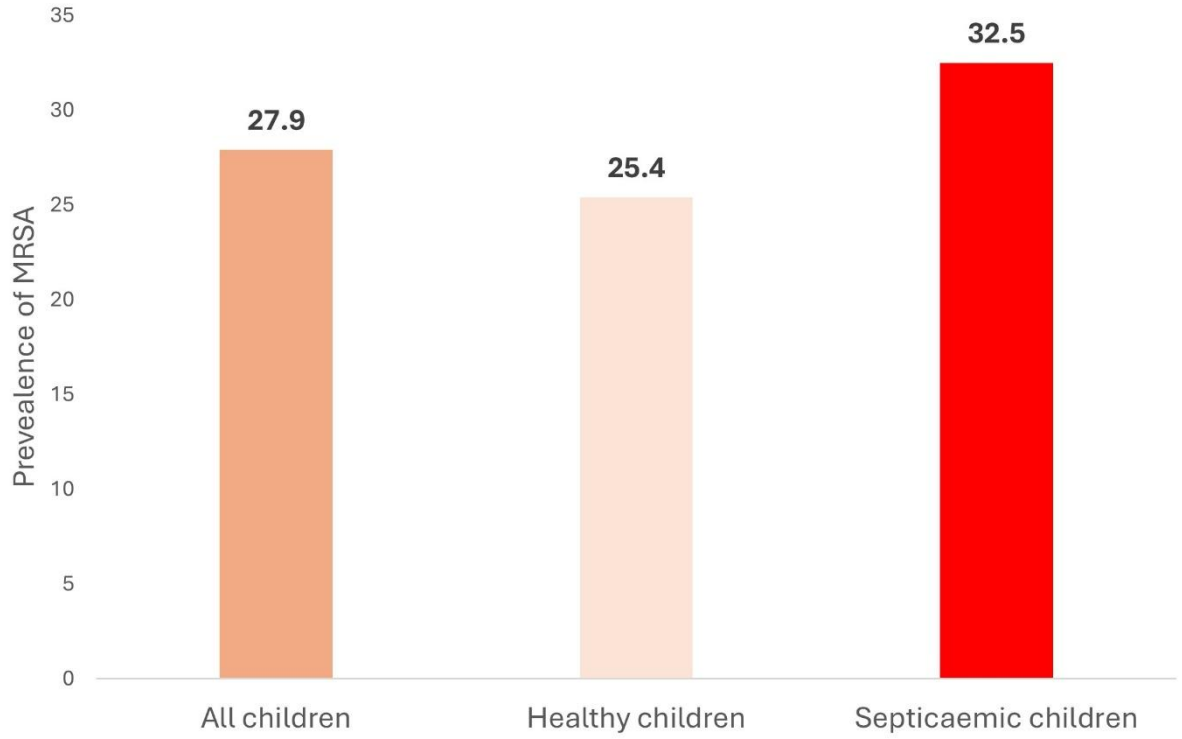


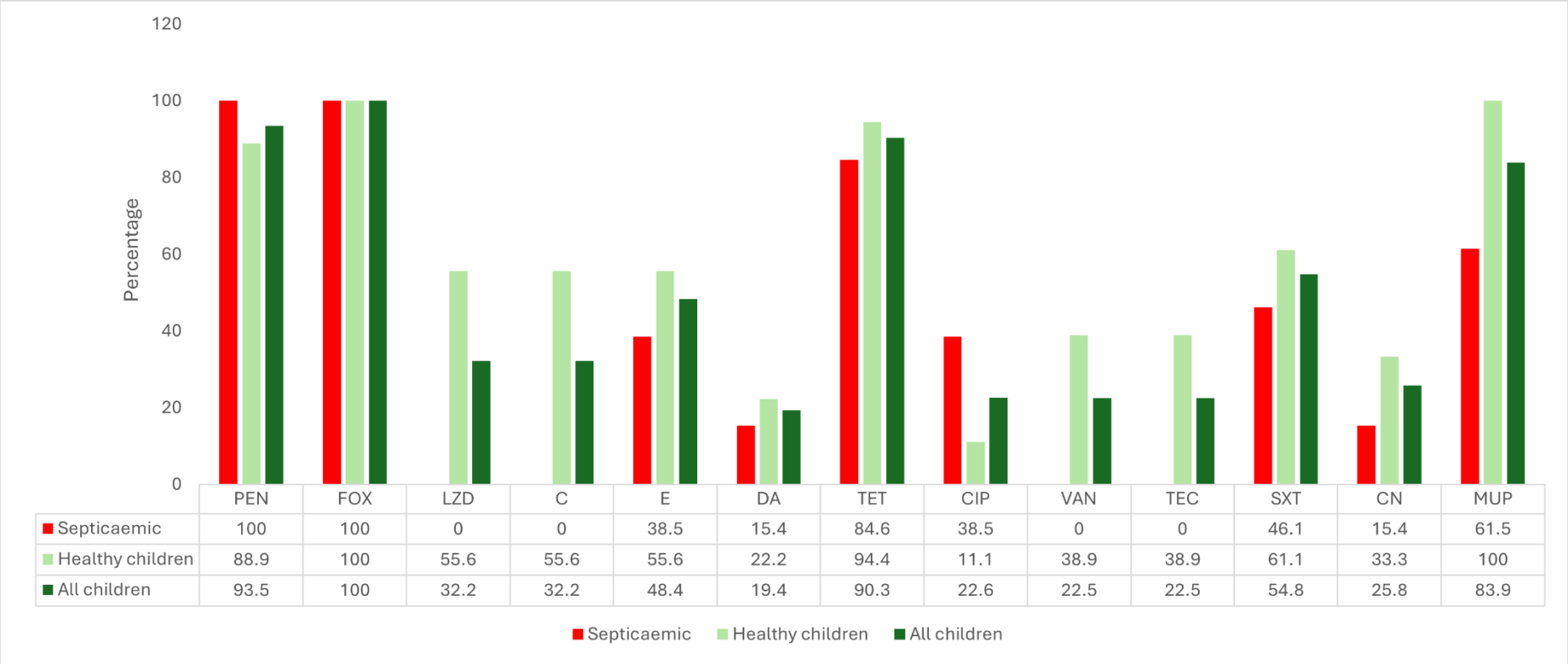
Figure 1. Prevalence of MRSA among the healthy and septicemic children

Table 1. Prevalence of nasal MRSA by sociodemographic factors of healthy and septicemic children

Variables	Healthy children (n, %)			Septicemic children (n, %)		
	Nº. (%) with MRSA	OR (95% CI)	*p* value	Nº. (%) with MRSA	OR (95% CI)	*p* value
Sex						
Male	5 (15.2)	1	1	5 (21.7)	1	1
Female	13 (34.2)	0.34 (0.11- 1.09)	0.072	8 (50)	0.31 (0.08-1.24)	0.097
Age (years)						
1	7 (20.6)	1	1	7 (25)	1	1
2	6 (23.1)	1.22 (0.34-4.43)	0.757	4 (40)	3.14 (0.62-15.9)	0.167
3	4 (40)	11.42 (1.09-120)	0.043*	2 (66.7)	6.21 (0.49- 80.2)	0.157
4	1 (100)	8.2 (0.3- 224)	0.212	0	-	-
Place of residence						
Rural	5 (21.7)	1	1	6 (37.5)	1	1
Urban	11 (24.4)	1.16 (0.35-3.87)	0.803	7 (29.2)	0.69 (0.18-2.62)	0.582
Not indicated	2 (66.7)	7.21 (0.54-96.64)	0.136	0	-	-
Level of education of the child						
Non formal	2 (22.2)	1		8 (38.1)		
Nursery	7 (25)	1.17 (0.19-6.98)	0.865	1 (50)	1.62 (0.09- 29.78)	0.744
Primary	9 (26.5)	1.26 (0.22-7.23)	0.795	4 (23.5)	0.5 (0.12-2.07)	0.341
Household density (number of persons)						
(1-4)	5 (26.3)	1	1	5 (38.5)	1	1
(5-8)	6 (28.6)	0.88 (0.21-3.66)	0.8733	2 (22.2)	0.46 (0.07-3.14)	0.4262
>9	4 (21.1)	0.75 (0.17-3.36)	0.7032	6 (35.3)	0.8 (0.18- 3.54)	0.7685
Not indicated	3 (25)	0.93 (0.18-4.9)	0.9350	0	0.683	0.711
Level of education of the father						
Non-formal	7 (30.4)	1	1	0	1	1
Primary	0	0.14 (0.01-2.75)	0.1378	0	0.56 (0.01-37.57)	0.7845
Secondary	1 (33.3)	0.14 (0.02-1.31)	0.0850	6 (40)	2.82 (0.12- 68.3)	0.5226
Tertiary	8 (20)	1.42 (0.33-3.96)	0.8330	7 (33.3)	3.95 (0.16-95.28)	0.3980
Not indicated	2 (100)	4.405	0.354	0	-	-

Level of education of the mother						
Non-formal	7 (31.8)	1	1	0	1	1
Primary	0	0.14 (0.01-2.75)	0.1942	1 (25)	2.14 (0.06-77.54)	0.6772
Secondary	6 (37.5)	1.23 (0.33-4.97)	0.7157	6 (35.3)	2.82 (0.12- 68.3)	0.5226
Tertiary	3 (13)	0.32 (0.07- 1.45)	0.1405	6 (37.3)	3-09 (0.13- 75.19)	0.4876
Not indicated	2 (66.7)	4.29 (0.33-55.59)	0.2657	0	-	-
Household income per month						
<50 USD	9 (34.6)	1	1	5 (35.7)	1	1
51-75 USD	2 (10)	0.21 (0.04-1.11)	0.0668	3 (33.3)	0.8 (0.13-4.75)	0.8059
76- 150 USD	3 (25)	0.63 (0.14-2.93)	0.5550	1 (20)	0.4 (0.03-4.68)	0.4653
> 150 USD	3 (25)	0.94 (0.19-4.69)	0.9443	1 (33.3)	0.8 (0.06-11.29)	0.8688
Not indicated	2 (50)	11.89 (0.23-15.74)	0.5565	3 (33.3)	-	-

Key: USD= United States Dollars



	PEN	FOX	LZD	C	E	DA	TET	CIP	VAN	TEC	SXT	CN	MUP
Septicaemic	100	100	0	0	38.5	15.4	84.6	38.5	0	0	46.1	15.4	61.5
Healthy children	88.9	100	55.6	55.6	55.6	22.2	94.4	11.1	38.9	38.9	61.1	33.3	100
All children	93.5	100	32.2	32.2	48.4	19.4	90.3	22.6	22.5	22.5	54.8	25.8	83.9

Figure 2. Antimicrobial resistance rate in 31 MRSA strains obtained from the study participants
Abbreviation: PEN: penicillin, C: chloramphenicol, CIP: ciprofloxacin, E: erythromycin, DA: clindamycin, FOX: Cefoxitin, MUP: mupirocin, LZD: linezolid, SXT: Sulfamethoxazole and trimethoprim, CN: gentamicin, TEC: Teicoplanin, TET: tetracycline, VAN: Vancomycin

Table 2. Factors associated with nasal MRSA in healthy and septicemic children

Variables	Healthy children (n, %)				Septicemic children (n, %)			
	Nº. of response	No. (%) with MRSA	OR (95% CI)	*p* value	Nº. of response	No. (%) with MRSA	OR (95% CI)	*p* value
Use of antibiotics at least three months before sample collection								
No	43	10 (23.3)	1	1	25	10 (40)	1	1
Yes	21	21 (100)	137.19 (7.64-2464.38)	0.0008	15	3 (20)	0.38 (0.08-1.68)	0.1991
Not indicated	7	3 (42.9)	2.4750 (0.47- 12.96)	0.2834	0	0	-	-
Knowledge of AMR by the parents or guardians of the child								
No	56	13 (23.2)	1	1	25	10 (40)	1	1
Yes	11	2 (18.2)	0.74 (0.14-3.84)	0.7151	15	3 (20)	0.38 (0.08- 1.68)	0.1991
Not indicated	4	3 (75)	9.92 (0.95- 103.71)	0.0553	0	0	-	-
Do you have pets or livestock at home								
No	24	5 (20.8)	1	1	18	6 (33.3)	1	1
Yes	44	11 (25)	1.27 (0.38- 4.19)	0.6990	22	7 (31.8)	0.93 (0.25- 3.52)	0.9189
Not indicated	3	2 (66.7)	7.6 (0.58- 101.79)	0.1255	0	0	-	-
Duration in the hospital (weeks)								
1	NA	NA			19	5 (26.3)	1	1
2	NA	NA			9	3 (33.3)	1.4 (0.25-7.83)	0.7017
3	NA	NA			2	1 (50)	0.47 (0.04-4.89)	0.5251
4	NA	NA			5	1 (20)	0.7 (0.06- 7.86)	0.7725
5	NA	NA	NA	NA	5	3 (60)	4.2 (0.54-32.96)	0.1721

Key: NA= Not applicable

Table 3. Comparison of the frequencies of antimicrobial resistance phenotypes among MRSA isolates from healthy and septicemic children

Antibiotics	N$^{o.}$ (%) of resistance in MRSA among healthy children	N$^{o.}$ (%) of resistance in MRSA among septicemic children (referent group)	OR (95% CI)	*p* value
PEN	16 (88.9)	13 (100)	4.09 (0.18- 92.69)	0.3762
FOX	18 (100)	13 (100)	0.73 (0.01- 39.14)	0.8768
LZD	10 (55.6)	0	0.3 (0.0015-0.58)	0.0204*
C	10 (55.6)	0	0.3 (0.0015-0.58)	0.0204*
E	10 (55.6)	5 (38.5)	0.5 (0.12-2.14)	0.3500
VAN	5 (27.8)	0	0.09 (0.005-1.81)	0.1162
TEC	5 (27.8)	0	0.09 (0.005-1.81)	0.1162
MUP	18 (100)	8 (61.5)	0.04 (0.002- 0.85)	0.0385*
CIP	2 (11.1)	5 (15.4)	5 (0.79-31.69)	0.0876
TET	17 (94.4)	11 (84.6)	0.32 (0.02- 4.01)	0.3796
DA	4 (22.2)	2 (15.4)	0.64 (0.09- 4.14)	0.6361
SXT	11 (61.1)	6 (46.2)	0.55 (0.13-2.31)	0.4109
CN	6 (33.3)	2 (15.4)	0.36 (0.06-2.19)	0.2700

The number of MRSA isolates from healthy and septicemic children was 18 and 13, respectively.
Abbreviation: PEN: penicillin, C: chloramphenicol, CIP: ciprofloxacin, E: erythromycin, DA: clindamycin, MUP: mupirocin, LZD: linezolid, SXT: Sulfamethoxazole and trimethoprim, CN: gentamicin, TEC: Teicoplanin, TET: tetracycline, VAN: Vancomycin
*Significant association determined by two-tailed chi-squared test at 95% CI.

DISCUSSIONS

Nasal MRSA carriage increases the risk of subsequent infections, and most children who develop life-threatening MRSA infections are young and previously healthy [25, 26]. Accordingly, the surveillance of MRSA colonisation in children is essential. In this study, the overall prevalence of MRSA was 27.9% in the children. The septicemic children had a relatively higher prevalence of MRSA than the healthy children (32.5% *versus* 25.4%). This finding is supported by a study that indicated more MRSA nasal colonisation is found in sick children than in their healthy counterparts [27].

The overall prevalence obtained in this study corroborated the 27.3% MRSA prevalence reported in ill and healthy children in Port Harcourt (Nigeria) [28] and the 29.4% reported among young children in Taiwan [29]. The MRSA prevalence obtained among the septicemic children in this study is similar to the 35.5% reported by Zani *et al* [30] among critically ill children in the USA. However, it was lower than the 2.8% prevalence reported by Sadauki *et al* [24] among children living with HIV and AIDS in Kano (Nigeria) and 1.5% reported by Othman *et al* [31] in Yemeni school children, 1.44% in Spanish Children [32], and 17.1% in Ghanaian infants [33]. This difference in nasal MRSA may be because some studies included children up to 14 years old, a wider age range than in this study, which focused on younger children. Indeed, age has been identified as an essential determinant of *S. aureus* carriage [34]. Other factors that influence the wide disparity in nasal MRSA carriage in children include the health status of the children and the endemicity of the bacterium in the community and healthcare settings. Moreover, differences in the laboratory methods used to isolate and identify MRSA could contribute to variation in the prevalence.

None of the sociodemographic variables was associated with MRSA carriage in the children, except that antibiotic use three months before sample collection in healthy children was significantly associated with MRSA carriage. Antibiotic exposure prior to testing promotes the selection of resistant strains. Similar findings were reported by Soltani *et al* [35] in Iran and Lemma *et al* [36] in Ethiopia. The use of antibiotics, particularly broad-spectrum agents, can destroy the natural nasal flora that competes with *S. aureus*, allowing MRSA to colonize, especially after using broad-spectrum antibiotics [30].

The very high resistance rates (>40%) observed against penicillin, trimethoprim-sulfamethoxazole, tetracycline, and erythromycin align with findings from other studies in Nigeria [37, 38, 39]. It can be attributed to their increased use over the years. Specifically, exceptionally high tetracycline resistance suggested that livestock might be the source of the

MRSA strains [40]. This is because more children who had prior contact with livestock and pets have a relatively higher prevalence of MRSA than those who did not. Our study revealed a notable prevalence of trimethoprim-sulfamethoxazole resistance among the MRSA from healthy children in the community compared to the septicemic ones in healthcare facilities. This contrasts with the common observation that such resistance is typically associated with hospital-acquired MRSA [41, 42]. This observation may stem from several factors; the frequent routine use of trimethoprim-sulfamethoxazole in both hospital and community settings has often fostered resistance to the antibiotic among circulating MRSA in the country. The observation may potentially indicate a shift in the epidemiology of MRSA in both hospital and community environments. Additional investigations employing molecular techniques are necessary.

It is essential to remark the detection of high frequencies of vancomycin- and linezolid-resistance among many of the MRSA among healthy children, highlighting a serious threat and the need for better antibiotic stewardship and surveillance in the country. The high prevalence of last-line antibiotics against MRSA is not unexpected, as several studies have demonstrated the continuous circulation and persistence of these strains in clinical, animal, food, and environmental samples across all regions of Nigeria [43, 44, 45, 46, 47, 48, 49].

The consequences of mupirocin resistance generally relate to its reduced effectiveness as a topical antibiotic. Mupirocin is commonly used to treat *S. aureus* (including MRSA) skin infections and to decolonise nasal MRSA carriers [50]. When bacteria become resistant, several health and economic issues arise. This can lead to persistent MRSA carriage and a higher risk of ongoing transmission in hospitals or communities. If MRSA carriers cannot be effectively decolonised, outbreaks in healthcare facilities (ICUs, nursing homes, surgical wards) become more challenging to control. Moreover, mupirocin-resistant MRSA can spread more easily among patients and staff [51].

All the MRSA from both groups of children exhibited the MDR phenotype, except four from the septicemic children. Some strains demonstrated simultaneous resistance to vancomycin and linezolid, as well as to seven other clinically relevant antibiotics. Most of the MRSA isolates from healthy children had MAR indices of 0.75 (22.2%) and 0.58 (22.2%), whereas the most frequent MRSA isolates had an MAR index of 0.48 (23.1%). Consequently, these MRSA strains pose a significant clinical and public health concern. A high MAR index indicates that the bacteria are resistant to multiple classes of antibiotics, making infections more difficult to treat and potentially more severe.

Healthy children can show significantly higher rates of MRSA with resistance to linezolid, chloramphenicol, and mupirocin than septicemic children ($p<0.05$). This counterintuitive pattern is driven by differences in ecological niches, mechanisms of transmission, and antibiotic selective pressures. Healthy children carry superficial, community-acquired strains (CA-MRSA) exposed to repeated topical creams for skin lesions (such as mupirocin) and low-cost locally applied outpatient treatments (such as chloramphenicol eye and ear drops for household remedy), whereas septicemic children infected by highly virulent MRSA are less MDR, a phenomenon driven by an evolutionary biological trade-off between bacterial fitness and AMR [51, 52, 53]. Most chloramphenicol resistance determinants are notorious for mediating cross-resistance to linezolid in staphylococci [54]. Household children who are repeatedly exposed to cheap over-the-counter chloramphenicol automatically develop resistance to linezolid, even if the child has never taken linezolid. There is a need to integrate whole-genome sequencing into mechanisms of resistance and co-resistance (as in the case of chloramphenicol and linezolid), and to characterize the transmission pathways, dynamics, virulence and mobile genetic elements of MDR strains.

The authors explicitly acknowledge the absence of nucleic acid amplification tests to detect genes associated with the priority resistance in the *S. aureus* isolates. However, it is important

to remark that the broth dilution test for minimum inhibitory concentration (MIC) of *S. aureus* is the gold standard for detecting vancomycin and linezolid resistance in clinical diagnostic microbiology. PCR is generally not required for routine clinical management of infections caused by these strains. The operating principle of the VITEK 2 compact in this study uses a miniaturized version of the broth microdilution. It is a fully automated system for bacterial identification and antibiotic susceptibility testing (AST) that utilizes specialized reagent cards. Given that cultural perspectives could shape people's understanding of AMR, the absence of more questions that directly assessed or tested parents' and guardians' knowledge and understanding of AMR limits the power of inference from the variable. Moreover, risk-factor analysis of small subgroups could limit the generalizability of the findings from this study.

CONCLUSIONS

This study found no difference in nasal MRSA carriage between healthy and septicemic children. However, findings indicate a high prevalence of multidrug-resistant-MRSA strains in both groups, highlighting potential implications for infection control measures in paediatric healthcare facilities.

The high prevalence of MDR strains is particularly concerning because it narrows the window for effective empiric antibiotic treatments. Collectively, continuous surveillance and improved hand hygiene and other infection control procedures in children could help minimise MRSA transmission. Since the nose acts as a primary reservoir, these findings reinforce that hand hygiene and surveillance aren't just for sick wards—they are essential across all paediatric touchpoints to prevent localized carriage from turning into systemic infection.

Abbreviations

ABUTH: Ahmadu Bello University Teaching Hospital

AMR: Antimicrobial resistance

C: Chloramphenicol

CA-MRSA: Community-associated Methicillin-resistant *Staphylococcus aureus*

CI: Confidence interval

CIP: Ciprofloxacin

CN: Gentamicin

DA: Clindamycin

E: Erythromycin

HA-MRSA: Healthcare-associated Methicillin-resistant *Staphylococcus aureus*

HC: Healthy children

LA-MRSA: Livestock-associated Methicillin-resistant *Staphylococcus aureus*

LZD: Linezolid

MAR: Multiple Antimicrobial Resistance

MDR: Multidrug resistance

MRSA: Methicillin-resistant *Staphylococcus aureus*

MUP: Mupirocin

PEN: Penicillin

SC: Septicemic children

SXT: Sulfamethoxazole and trimethoprim

TEC: Teicoplanin

TET: Tetracycline

USD: United States Dollars

VAN: Vancomycin

Ethics approval and consent to participate

This study protocol was approved by the Human Ethics Research Committee of Ahmadu Bello University Teaching Hospital (Approval number: NHREC/ABUTH-NHREC/29/08/24). Samples and data collection from participants were performed in accordance with the Declaration of Helsinki, as revised in 2024. Written informed consent was obtained from the children's parents or legal guardians.

Consent for publication

Not applicable

Availability of data and materials

The tables, figures, and supplementary materials presented all the data generated from this study. However, further requests could be made through the corresponding author.

Competing interests

None declared by the authors.

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Authors' contributions

Idris Nasir Abdullahi: Conceptualization, Methodology, Validation, Software, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing, Supervision, Project administration

Shamsu Almustapha, Islem Trabelsi, Hauwa'u Umaru Makarfi, Aisha Muhammad Auwal, Attahiru Muhammad, Shamsuddeen Abdurrazaq, Musa Mohammed, Kabir Umar: Methodology, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review.

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REFERENCES

1. Touaitia R, Mairi A, Ibrahim NA, Basher NS, Idres T, Touati A. *Staphylococcus aureus*: A Review of the Pathogenesis and Virulence Mechanisms. Antibiotics (Basel). 2025 May 6;14(5):470. doi: 10.3390/antibiotics14050470. PMID: 40426537; PMCID: PMC12108373.
2. Raineri EJM, Altulea D, van Dijl JM. Staphylococcal trafficking and infection-from 'nose to gut' and back. FEMS Microbiol Rev. 2022 Jan 18;46(1):fuab041. doi: 10.1093/femsre/fuab041. PMID: 34259843; PMCID: PMC8767451.
3. CDC. *Staphylococcus aureus* Basics. Key Points. Available from: https://www.cdc.gov/staphylococcus-aureus/about/index.html . Retrieved on 6th December 2025.
4. Piewngam P, Otto M. *Staphylococcus aureus* colonisation and strategies for decolonisation. Lancet Microbe. 2024;5(6):e606–e618. doi: 10.1016/S2666-5247(24)00040-5.
5. Fariñas-Guerrero F, Villatoro AJ, Martinez-Manzanares E, López-Gigosos R. Occurrence of *Staphylococcus aureus, Staphylococcus epidermidis,* and *Staphylococcus pseudintermedius* colonization among veterinarians in the province of Malaga, Spain. Vet World. 2024 Dec;17(12):2719-2724. doi: 10.14202/vetworld.2024.2719-2724. Epub 2024 Dec 6. PMID: 39897375; PMCID: PMC11784035.
6. Mustapha SS, Zaidu MA, Yusuf MS, Aliyu S, Abdulkadir I. Methicillin resistant *Staphylococcus aureus* infection in neonates- a major concern and a call for action. Niger Med J. 2024 Sep 26;65(4):503-511. doi: 10.60787/nmj-v65i3-496. PMID: 39398402; PMCID: PMC11470269.
7. Schlapbach LJ, Watson RS, Sorce LR, Argent AC, Menon K, Hall MW, Akech S, Albers DJ, Alpern ER, Balamuth F, Bembea M, Biban P, Carrol ED, Chiotos K, Chisti MJ, DeWitt PE, Evans I, Flauzino de Oliveira C, Horvat CM, Inwald D, Ishimine P, Jaramillo-Bustamante JC, Levin M, Lodha R, Martin B, Nadel S, Nakagawa S, Peters MJ, Randolph AG, Ranjit S, Rebull MN, Russell S, Scott HF, de Souza DC, Tissieres P, Weiss SL, Wiens MO, Wynn JL, Kissoon N, Zimmerman JJ, Sanchez-Pinto LN, Bennett TD; Society of Critical Care Medicine Pediatric Sepsis Definition Task Force. International Consensus Criteria for Pediatric Sepsis and Septic Shock. JAMA. 2024 Feb 27;331(8):665-674. doi: 10.1001/jama.2024.0179. PMID: 38245889; PMCID: PMC10900966.
8. Celebi S, Sezgin ME, Cakır D, Baytan B, Demirkaya M, Sevinir B, Bozdemir SE, Gunes AM, Hacimustafaoglu M. Catheter-associated bloodstream infections in pediatric hematology-oncology patients. Pediatr Hematol Oncol. 2013 Apr;30(3):187-94. doi: 10.3109/08880018.2013.772683. Epub 2013 Mar 4. PMID: 23458064.
9. Wang L, Zhen JH, Dong F, Lyu ZY. Cross-sectional Hospital-based Investigation on Clinical Characteristics of Pediatric *Staphylococcus aureus* Isolates in a Beijing

Hospital from 2013 to 2022. Infect Drug Resist. 2024 Nov 6;17:4899-4912. doi: 10.2147/IDR.S486832. PMID: 39524977; PMCID: PMC11550683.
10. Boniardi L, Solazzo G, Favero C, Campo L, Ferrari L, Fustinoni S. Short-term personal exposure to multiple air pollutants affects nasal microbiota in school-age children. Sci Total Environ. 2025 Jun 15;981:179588. doi: 10.1016/j.scitotenv.2025.179588. Epub 2025 May 6. PMID: 40334460.
11. Habibi N, Mustafa AS, Khan MW. Composition of nasal bacterial community and its seasonal variation in health care workers stationed in a clinical research laboratory. PLoS One. 2021 Nov 24;16(11):e0260314. doi: 10.1371/journal.pone.0260314. Erratum in: PLoS One. 2023 Oct 9;18(10):e0292828. doi: 10.1371/journal.pone.0292828. PMID: 34818371; PMCID: PMC8612574.
12. Islam S, Nasrin N, Tithi NS, Khatun F, Asaduzzaman M, Topa AF, Kabir MF, Haque FKM, Jubair M, Rahman M, Lehmann C. Antimicrobial Susceptibility and Genomic Profiles of Multidrug-Resistant *Staphylococcus aureus* from Nasopharynx of Asymptomatic Children in Dhaka, Bangladesh. Life (Basel). 2024 Aug 2;14(8):971. doi: 10.3390/life14080971. PMID: 39202713; PMCID: PMC11355696.
13. Touaitia R, Mairi A, Ibrahim NA, Basher NS, Idres T, Touati A. *Staphylococcus aureus*: A Review of the Pathogenesis and Virulence Mechanisms. Antibiotics (Basel). 2025 May 6;14(5):470. doi: 10.3390/antibiotics14050470. PMID: 40426537; PMCID: PMC12108373.
14. Salam MA, Al-Amin MY, Salam MT, Pawar JS, Akhter N, Rabaan AA, Alqumber MAA. Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. Healthcare (Basel). 2023 Jul 5;11(13):1946. doi: 10.3390/healthcare11131946. PMID: 37444780; PMCID: PMC10340576.
15. Mohammed MM, Isa MA, Abubakar MB, Dikwa ASB, Kappo AP. Molecular detection of *mecA* gene from methicillin-resistant *Staphylococcus aureus* isolated from clinical and environmental samples and its potential inhibition by phytochemicals using in vitro and in silico approach. In Silico Pharmacol. 2025 Feb 10;13(1):26. doi: 10.1007/s40203-024-00297-y. PMID: 39936169; PMCID: PMC11811340.
16. WHO Bacterial Priority Pathogens List, 2024: bacterial pathogens of public health importance to guide research, development and strategies to prevent and control antimicrobial resistance. Geneva: World Health Organization; 2024. Licence: CC BY-NC-SA 3.0 IGO.
17. Abdullahi IN, Lozano C, Zarazaga M, Simón C, Höfle U, Sieber RN, Latorre-Fernández J, Stegger M, Torres C. Comparative genomics of *Staphylococcus aureus* strains from wild birds and pig farms elucidates levels of mobilomes, antibiotic pressure and host adaptation. J Glob Antimicrob Resist. 2024 Mar;36:142-150. doi: 10.1016/j.jgar.2023.12.003. Epub 2023 Dec 19. PMID: 38128728.
18. WHO (2023). SDG Target 3.d.2. Bloodstream infections due to selected antimicrobial-resistant organisms. https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/sdg-target-3.d.2---bloodstream-infections-due-to-selected-antimicrobial-resistant-organisms

19. Ezeh CK, Eze CN, Dibua MEU, Emencheta SC. A meta-analysis on the prevalence of resistance of *Staphylococcus aureus* to different antibiotics in Nigeria. Antimicrob Resist Infect Control. 2023 Apr 25;12(1):40. doi: 10.1186/s13756-023-01243-x. PMID: 37098614; PMCID: PMC10127087.
20. Azzam A, Khaled H, Fayed HM, Mansour Y, Eldalil M, Elshennawy E, Salem H, Elkatan HA. Prevalence, antibiogram, and risk factors of methicillin-resistant *Staphylococcus aureus* (MRSA) asymptomatic carriage in Africa: a systematic review and meta-analysis. BMC Infect Dis. 2025 Apr 11;25(1):505. doi: 10.1186/s12879-025-10819-4. PMID: 40217166; PMCID: PMC11987463.
21. Adeyanju A, Schaumburg F, Onayade A, Akinyoola A, Adeyemi T, Ugbo O, Köck R, Amusa Y, Lawal O, Adeyanju T, Torimiro N, Akinpelu D, Kolawole D, Kohler C, Becker K. Local Epidemiology of Nosocomial *Staphylococcus aureus* Infection in a Nigerian University Teaching Hospital. Antibiotics (Basel). 2022 Oct 7;11(10):1372. doi: 10.3390/antibiotics11101372. PMID: 36290030; PMCID: PMC9598115.
22. Weldegebreal F, Urgesa K, Ayele F, Bogale K, Shume T, Ahmed M, Debebe S, Tebeje F, Asmerom H, Tesfa T, Mekonnen S. Nasal carriage rate, associated factors, and antimicrobial susceptibility patterns of methicillin resistance *Staphylococcus aureus* among pre-clinical undergraduate students at the College of Health and Medical Sciences, Haramaya University, Ethiopia. Front Public Health. 2024 May 23;12:1354461. doi: 10.3389/fpubh.2024.1354461. PMID: 38846602; PMCID: PMC11155450.
23. Yang L, Dharmaratne P, Zhu C, Sapugahawatte DN, Rahman N, Barua N, Li C, Kwok KO, Luo M, Liyanapathirana V, Ip M. Global epidemiology of asymptomatic colonisation of methicillin-resistant *Staphylococcus aureus* in the upper respiratory tract of young children: a systematic review and meta-analysis. Arch Dis Child. 2024 Mar 19;109(4):267-274. doi: 10.1136/archdischild-2023-326124. PMID: 38296611; PMCID: PMC10958260.
24. Sadauki AH, Olorukooba AA, Balogun MS, Dalhat MM, Waziri H, Abdulaziz MM, Umeokonkwo CD, Hassan-Hanga F, Sabitu K. Nasal carriage of meticillin-resistant *Staphylococcus aureus* among children living with HIV attending Infectious Diseases Clinics in Kano, Nigeria. Infect Prev Pract. 2022 Apr 22;4(2):100213. doi: 10.1016/j.infpip.2022.100213. PMID: 35574215; PMCID: PMC9095741.
25. Sutter DE, Milburn E, Chukwuma U, Dzialowy N, Maranich AM, Hospenthal DR. Changing Susceptibility of *Staphylococcus aureus* in a US Pediatric Population. Pediatrics. 2016 Apr;137(4):e20153099. doi: 10.1542/peds.2015-3099. Epub 2016 Mar 1. PMID: 26933211.
26. Immergluck LC, Leong T, Malhotra K, Parker TC, Ali F, Jerris RC, Rust GS. Correction to: Geographic surveillance of community associated MRSA infections in children using electronic health record data. BMC Infect Dis. 2019 May 9;19(1):396. doi: 10.1186/s12879-019-3972-9. Erratum for: BMC Infect Dis. 2019 Feb 18;19(1):170. doi: 10.1186/s12879-019-3682-3. PMID: 31072308; PMCID: PMC6507021.
27. Gesualdo F, Bongiorno D, Rizzo C, Bella A, Menichella D, Stefani S, Tozzi AE. MRSA nasal colonization in children: prevalence meta-analysis, review of risk factors and

molecular genetics. Pediatr Infect Dis J. 2013 May;32(5):479-85. doi: 10.1097/INF.0b013e3182864e4c. PMID: 23340553.

28. Oreh CN. P18 Prevalence and risk factors for nasal colonization with MRSA among children attending immunization in Port Harcourt, Nigeria, *JAC-Antimicrobial Resistance*, Volume 4, Issue Supplement_1, February 2022, dlac004.017, https://doi.org/10.1093/jacamr/dlac004.017
29. Tsai MH, Chiu CY, Shih HJ, Liao SL, Hua MC, Huang SH, Yao TC, Lai SH, Huang TS, Yeh KW, Chen LC, Su KW, Lim WH, Chang YJ, Chiang CH, Huang SY, Huang JL. Longitudinal investigation of nasopharyngeal methicillin-resistant *Staphylococcus aureus* colonization in early infancy: The PATCH birth cohort study. Clin Microbiol Infect. 2017 Feb;23(2):121.e1-121.e7. doi: 10.1016/j.cmi.2016.10.020. Epub 2016 Oct 26. PMID: 27793735.
30. Zani K, Hobeika J, Sun Y, Kohler C, Cherian A, Fields T, Jia Q, Tang L, Hysmith ND, Margolis EB. Nasal microbiota predictors for methicillin resistant Staphylococcus colonization in critically ill children. PLoS One. 2025 Jan 15;20(1):e0316460. doi: 10.1371/journal.pone.0316460. PMID: 39813207; PMCID: PMC11734933.
31. Othman AM, Al-Huraibi BS, Assayaghi RM, Al-Shami HZ. Nasal Carriage and Methicillin Resistance of *Staphylococcus aureus* among Schoolchildren in Sana'a City, Yemen. Int J Microbiol. 2021 May 6;2021:5518317. doi: 10.1155/2021/5518317. PMID: 34035816; PMCID: PMC8121562.
32. Del Rosal T, Méndez-Echevarría A, Garcia-Vera C, Escosa-Garcia L, Agud M, Chaves F, Román F, Gutierrez-Fernandez J, Ruiz de Gopegui E, Ruiz-Carrascoso G, Ruiz-Gallego MDC, Bernet A, Quevedo SM, Fernández-Verdugo AM, Díez-Sebastian J, Calvo C; COSACO Study Group. *Staphylococcus aureus* Nasal Colonization in Spanish Children. The COSACO Nationwide Surveillance Study. Infect Drug Resist. 2020 Dec 23;13:4643-4651. doi: 10.2147/IDR.S282880. PMID: 33380814; PMCID: PMC7767716.
33. Kotey FC, Awugah SA, Dayie NT, Tetteh-Quarcoo PB, Duodu S, Osei MM, Bentum JN, Nyarko MY, Neizer ML, Alsharif KF, Halawani IF, Alzahrani KJ, Donkor ES. High prevalence of methicillin-resistant *Staphylococcus aureus* carriage among infants at the Children's Hospital, Accra, Ghana. J Infect Dev Ctries. 2022 Sep 30;16(9):1450-1457. doi: 10.3855/jidc.14839. PMID: 36223621.
34. Eibach D, Nagel M, Hogan B, Azuure C, Krumkamp R, Dekker D, Gajdiss M, Brunke M, Sarpong N, Owusu-Dabo E, May J. Nasal Carriage of *Staphylococcus aureus* among Children in the Ashanti Region of Ghana. PLoS One. 2017 Jan 20;12(1):e0170320. doi: 10.1371/journal.pone.0170320. PMID: 28107412; PMCID: PMC5249101.
35. Soltani B, Taghavi Ardakani A, Moravveji A, Erami M, Haji Rezaei M, Moniri R, Namazi M. Risk Factors for Methicillin Resistant Staphylococcus aureus Nasal Colonization of Healthy Children. Jundishapur J Microbiol. 2014 Sep;7(9):e20025. doi: 10.5812/jjm.20025. Epub 2014 Sep 1. PMID: 25485071; PMCID: PMC4255386.
36. Lemma MT, Zenebe Y, Tulu B, Mekonnen D, Mekonnen Z. Methicillin Resistant Staphylococcus aureus among HIV Infected Pediatric Patients in Northwest Ethiopia:

Carriage Rates and Antibiotic Co-Resistance Profiles. PLoS One. 2015 Sep 30;10(9):e0137254. doi: 10.1371/journal.pone.0137254. PMID: 26421927; PMCID: PMC4589400.

37. Abdullahi S, Abdullahi IN, Adekola HA, Baamlong N, Dangana A, Usman Y, Ahmad AE, Salisu S, Abdulaziz MM. Nasal carriage rate and multiple antimicrobial resistance indices of *Staphylococcus aureus* among healthcare students at the Ahmadu Bello University, Nigeria. Afr J Lab Med. 2025 Jun 27;14(1):2667. doi: 10.4102/ajlm.v14i1.2667. PMID: 40612402; PMCID: PMC12223919.
38. Olalekan A, Boutin S, Watson CM, Galarion L, Adesida S, Iwalokun B, Popoola O, Esemu S, Adegbola R, Nurjadi D. Molecular landscape of methicillin-resistant *Staphylococcus aureus* strains in clinical infections from hospitals in Lagos, Nigeria. JAC Antimicrob Resist. 2025 Sep 19;7(5):dlaf161. doi: 10.1093/jacamr/dlaf161. PMID: 40980595; PMCID: PMC12449137.
39. Abubakar U, Sulaiman SAS. Prevalence, trend and antimicrobial susceptibility of Methicillin Resistant *Staphylococcus aureus* in Nigeria: a systematic review. J Infect Public Health. 2018 Nov-Dec;11(6):763-770. doi: 10.1016/j.jiph.2018.05.013. Epub 2018 Jun 19. PMID: 29933910.
40. Chen Y, Sun L, Hong Y, Chen M, Zhang H, Peng Y, Liao K, Wang H, Zhu F, Zhuang H, Wang Z, Jiang S, Yu Y, Chen Y. Exploring the third-generation tetracycline resistance of multidrug-resistant livestock-associated methicillin-resistant *Staphylococcus aureus* ST9 across healthcare settings in China. J Antimicrob Chemother. 2023 Aug 2;78(8):1871-1881. doi: 10.1093/jac/dkad174. PMID: 37287125; PMCID: PMC10393890.
41. Emilda JKV, Kumari J, Shenoy MS, Vidyalakshmi K, Bhat KG. Comparison of community-associated methicillin resistant *Staphylococcus aureus* (CA-MRSA) and healthcare-associated MRSA (HA-MRSA) infections in Mangalore, South India. Res J Pharm Biol Chem Sci, 2016. 7: 2008-2013.
42. Samaranayake WAMP, Karunanayake L, Patabendige CGUA (2019) Characteristics of community acquired and hospital acquired methicillin resistant *Staphylococcus aureus* isolates in the National Hospital of Sri Lanka. Sri Lankan Journal of Infectious Diseases 9: 24-31.
43. Alo M, Ugah U, Okoro N. Epidemiology of vancomycin resistant *Staphylococcus aureus* among clinical isolates in a tertiary hospital in Abakaliki, Nigeria. Am J Epidemiol Infect Dis. 2013;1:24–6
44. Umaru GA, Kabir J, Umoh VJ, Bello M, Kwaga JKP. Occurrence of vancomycin resistant *Staphylococcus aureus* (VRSA) in fresh and fermented milk in Nigeria: a preliminary report. Int J Pub Hlth Epidemiol. 2013;3:54–8.
45. Abdu A, Lamikanra A. Linezolid and Methicillin Resistances in *S. aureus* Isolated from the Anterior Nares of Apparently Healthy Undergraduates of the Niger Delta

University, Nigeria. British Microbiology Research Journal [Internet]. 2016 Jan 10;15(6):1–10. Available from: https://doi.org/10.9734/bmrj/2016/27202
46. Bamigboye BT, Olowe OA, Taiwo SS. Phenotypic and Molecular Identification of Vancomycin Resistance in Clinical *Staphylococcus aureus* Isolates in Osogbo, Nigeria. Eur J Microbiol Immunol (Bp). 2018 Mar 9;8(1):25-30. doi: 10.1556/1886.2018.00003. PMID: 29760962; PMCID: PMC5944423.
47. Ebede, S., Okechukwu, A. M., Maduakor, U., Eberechukwu, C. L., & Mba, G. (2024). Occurrence and Antimicrobial Susceptibility Profile of Vancomycin Resistance among Clinical Isolates of *Staphylococcus aureus* in Enugu Metropolis, Nigeria. *International Journal of Pathogen Research*, *13*(5), 32–40. https://doi.org/10.9734/ijpr/2024/v13i5307
48. Adamu H, Otegwu CT, Abdullahi FB, Tytler BA, Olayinka BO. Incidence of methicillin, inducible clindamycin, and vancomycin resistance in *Staphylococcus aureus* clinical isolates in Gombe, Northeastern Nigeria. The Microbe. 2025 Feb 7;6:100255. Available from: https://doi.org/10.1016/j.microb.2025.100255
49. Okojokwu OJ, Cirfat NA, Gwan IJ, Orah IC. Vancomycin-Resistant *Staphylococcus aureus* in Abattoir Workers in Jos, Nigeria: Prevalence and Public Health Implications. IPS Journal of Applied Microbiology and Biotechnology [Internet]. 2025 Nov 7;4(4):265–70. Available from: https://doi.org/10.54117/ijamb.v4i4.101
50. Piewngam P, Otto M. *Staphylococcus aureus* colonisation and strategies for decolonisation. Lancet Microbe. 2024 Jun;5(6):e606-e618. doi: 10.1016/S2666-5247(24)00040-5. Epub 2024 Mar 19. PMID: 38518792; PMCID: PMC11162333.
51. Dadashi M, Hajikhani B, Darban-Sarokhalil D, van Belkum A, Goudarzi M. Mupirocin resistance in *Staphylococcus aureus*: A systematic review and meta-analysis. J Glob Antimicrob Resist. 2020 Mar;20:238-247. doi: 10.1016/j.jgar.2019.07.032. Epub 2019 Aug 20. PMID: 31442624.
52. Ahmad NJ, Abdullah IH, Nawaf B, Hesham AA, Menshawy AM. The Use of Topical Chloramphenicol for Eye Diseases in the Outpatient Setting. J Pharm Res Int, 2021: 33 (60B):1970-74. https://doi.org/10.9734/jpri/2021/v33i60B34832.
53. Cassat JE, Thomsen I. Staphylococcus aureus infections in children. Curr Opin Infect Dis. 2021 Oct 1;34(5):510-518. doi: 10.1097/QCO.0000000000000752. PMID: 34524201; PMCID: PMC8630804.
54. Han X, Zou G, Liu J, Yang C, Du X, Chen G, Sun Z, Zhang X, Sun Y, Zhang W, Jiang X. Mechanisms of linezolid resistance in Staphylococcus capitis with the novel mutation C2128T in the 23S rRNA gene in China. BMC Microbiol. 2022 Aug 20;22(1):203. doi: 10.1186/s12866-022-02616-9. PMID: 35987607; PMCID: PMC9392311.

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