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Antibiotic Resistance Profiles of Bacterial Isolates from Students' Hands: Implications for Public Health

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ABSTRACT

This study investigated the prevalence of bacterial contamination and patterns of antibiotic resistance on the hands of twenty randomly selected students at Sa'adu Zungur University, Bauchi. Samples were collected aseptically using sterile saline-moistened swabs, targeting both palmar and dorsal surfaces, and were processed within 2 hours of collection. Bacterial enumeration was performed using serial dilution and pour plate techniques, while identification involved standard cultural, morphological, and biochemical methods. The results revealed that all samples (100%) showed bacterial growth, with aerobic mesophilic bacterial counts ranging from 1.52×10^2 to 1.63×10^4 CFU/ml. The mean bacterial load was higher in male students ($3.43 \times 10^3 \pm 5.77 \times 10^3$ CFU/ml) than in females ($2.00 \times 10^3 \pm 4.61 \times 10^3$ CFU/ml), indicating moderate to high contamination levels. A total of 20 bacterial isolates were obtained, predominantly *Staphylococcus aureus* (10 isolates; 50%), *Escherichia coli* (7 isolates; 35%), and *Klebsiella* spp. (3 isolates; 15%). Antibiotic susceptibility testing, conducted using the Kirby-Bauer disc diffusion method, revealed that ciprofloxacin was the most effective antibiotic, with susceptibility rates of 60% for *S. aureus* and 57% for *E. coli*. In contrast, erythromycin demonstrated the lowest efficacy, particularly against *E. coli* and *Klebsiella* spp., with 0% susceptibility. Notably, *Klebsiella* isolates were entirely resistant to ciprofloxacin and tetracycline but showed 100% susceptibility to cefoxitin. The presence of multidrug-resistant bacteria on students' hands underscores the potential risk for cross-transmission of opportunistic pathogens in academic environments, reinforcing the importance of proper hand hygiene and antibiotic stewardship.

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Bacterial, antibiotic resistance, hand hygiene, multidrug resistance

1. Introduction

Contaminated hands are a major source of pathogenic microorganisms that can lead to respiratory and gastrointestinal infections, particularly in children (Ataee *et al*., 2017). The spread of these pathogens, often through the fecal-oral route, is common among children who do not wash their hands properly. Simple hand washing with soap and water can significantly prevent this transmission (Akyol, 2007; Burton *et al*., 2011; Cambell, 2010). Common transient bacteria found on contaminated hands include Escherichia coli, Salmonella species, Shigella species, and Klebsiella pneumoniae, which are spread via the fecal-oral route. Additionally, Staphylococcus species, Streptococcus species, Pseudomonas species, and Bacteroides species can also be sources of infection. While resident flora like Coagulase Negative Staphylococcus species and Bacillus species generally do not cause infections, they can still contribute to microbial load.

This study was aimed to examine the bacterial load on the hands of Saadu Zungur University students and assess the antibiotic susceptibility patterns of these bacteria. On the hands, Bacteria are categorized into resident and transient flora (Simmons *et al*., 1990). Resident flora, found under the skin's surface, includes species like *Staphylococcus epidermidis*, which is notably resistant to oxacillin, along with Corynebacteria and Micrococci. Hand hygiene practices; such as hand washing, antiseptic hand washing, and the use of alcohol-based hand rubs, are crucial for removing dirt and microorganisms (Cambell, 2010). Washing hands with soap and water is the most effective and cost-efficient method of hand hygiene. In higher institutions, promoting hand washing with soap or even water mixed with wood ash (where soap is unavailable) and ensuring proximity to water points are important steps in improving hygiene.

In Nigeria, the Federal Government, in partnership with UNICEF, has integrated hand washing into hygiene promotion strategies. While resident flora rarely cause infections in sterile body sites or non-intact skin, transient flora, which colonizes the skin's surface, is more susceptible to removal through routine hand hygiene. Normal skin is colonized by varying levels of bacteria, and healthcare workers (HCWs) often have higher bacterial counts on their hands, ranging from 3.9×10^4 to 4.6×10^6 CFU/cm². Transient bacteria, such as Staphylococcus aureus, are often acquired through direct contact with patients or contaminated surfaces and are associated with healthcare-associated infections (HCAIs) (Burns *et al*., 2018). These infections are notably concerning as they include serious conditions like sepsis and pneumonia, often exacerbated by multidrug-resistant bacteria. The prevalence of nosocomial infections, driven by the introduction of advanced medical technologies and resistance to multiple drugs, underscores the importance of effective hand hygiene in preventing the spread of infections (Bradley & Ayliffe, 2018; McGuckin, 2006).

2. Materials and Methods

2.1 Research Design

This study utilized a cross-sectional design to examine bacterial species on human hands and their antibiotic susceptibility. The research was conducted between September and November 2023 in a community-based setting.

2.2 Study Area

The research was performed at Sa'adu Zungur University Bauchi, specifically at the GADAU main campus in Bauchi State, Nigeria. Gadau, a small town in the Itas/Gadau LGA in Katagum zone of Bauchi State, is situated at latitude of 11°N and a longitude of 10°E. Hand swabs were collected from students within the campus, which includes both the new and old sections of the school.

2.3 Study Population

Twenty samples were randomly collected from Sa'adu Zungur University Bauchi, Gadau main campus, with ten samples each obtained from female and male students. The samples were collected aseptically using swab sticks, labeled, and promptly transported to the laboratory for bacterial analysis.

2.4 Sample Processing

Samples were collected from the hands of 20 randomly selected BASUG students, starting with the palmar surface of the wrist—including the palms, thumbs, creases, and nail beds—and ending with the dorsal surface. Sterile saline-moistened cotton swabs were used, following aseptic techniques, and the samples were transported to the Microbiology Laboratory within 1-2 hours. Each sample was assigned a unique identification number, and details such as the student's age and sex were recorded. In the laboratory, serial dilutions were prepared and the samples were inoculated onto MacConkey agar and Nutrient agar using the streaking method. The plates were incubated at 37°C overnight. Bacterial colonies were inspected, and potential bacterial strains were identified using standard microbiological procedures, including Gram staining and routine biochemical tests (such as; catalase, coagulase, citrate, oxidase, and indole tests) (Chesebrough, 2000).

2.5 Identification of Bacterial Isolates

Identification of bacterial isolates was conducted by analyzing their cultural, morphological, and biochemical characteristics following established protocols (Brown *et al*., 2005). Biochemical tests were used to confirm the identity of each isolate, with tests varying based on the Gram reaction of the isolates.

2.6 Antibiotic Susceptibility Testing

Inoculum standardization was performed according to Cheesbrough (2000). Antibiotic susceptibility was tested using the disc-diffusion method (Kirby-Bauer, 1996). A bacterial colony was emulsified in 3.0 ml of normal saline, and turbidity was adjusted to match the 0.5 McFarland standard. A swab of the suspension was streaked onto nutrient agar, and antibiotic discs were placed on the surface. After incubation at 37°C for 24 hours, the diameter of the zones of inhibition was measured in millimeters and interpreted according to Clinical and Laboratory Standards Institute (CLSI, 2007) guidelines.

2.7 Statistical analysis

The data obtained from total aerobic bacterial counts and antibiotic susceptibility tests were analyzed using descriptive and inferential statistical methods. Bacterial count results were expressed as mean ± standard deviation (SD) to evaluate central tendencies and dispersion among male and female samples. The independent samples t-test was employed to compare the mean bacterial loads between the two gender groups, with statistical significance set at $p < 0.05$.

For antibiotic susceptibility data, frequency distributions and percentages were used to summarize resistance, intermediate, and susceptibility patterns for each bacterial species against the antibiotics tested. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) version 29.0.

3. Results and Discussion

The aerobic bacterial counts from surface swab samples collected from male and female students are presented in Tables 1 and 2, respectively. The mean total aerobic mesophilic bacterial load for samples from male students was $3.43 \times 10^3 \pm 5.77 \times 10^3$ CFU/ml, while that for female students was $2.00 \times 10^3 \pm 4.61 \times 10^3$ CFU/ml. These values indicate a moderate to high level of bacterial contamination on the surfaces sampled, with male student samples showing a higher mean load and greater variability, likely due to one or two high-count outliers (e.g., 1.63×10^4 CFU/ml). Although the mean count in males appeared higher, an independent samples t-test (Welch's t-test) indicated that this difference was not statistically significant ($t = 0.434$, $df \approx 0.43$, $p = 0.670$). This suggests that, despite observed variability, there is no meaningful difference in bacterial burden between male and female students in this sample population. Nonetheless, the presence of counts in the order of 10^4 CFU/ml in both groups suggests a potential public health concern due to the likelihood of pathogen presence in environments frequented by students.

As detailed in Table 3, 100% of the samples tested positive for bacterial growth, yielding a total of 20 isolates distributed among three bacterial genera. Staphylococcus aureus was the most frequently isolated species (10 isolates; 50%), followed by Escherichia coli (7 isolates; 35%) and Klebsiella species (3 isolates; 15%). The dominance of *S. aureus* and *E. coli* aligns with previous findings from studies on microbial contamination of communal surfaces, where these species are frequently implicated due to their ability to survive on inanimate surfaces and their association with human skin and fecal contamination, respectively.

The antibiotic susceptibility profiles in Table 4 further reveal concerning patterns of antimicrobial resistance among the isolates. Ciprofloxacin emerged as the most effective antibiotic, with 60% susceptibility among *S. aureus* and 57% among *E. coli*, though *Klebsiella spp.* showed complete resistance. In contrast, erythromycin exhibited the lowest efficacy, with only 20% of *S. aureus* isolates susceptible and no susceptibility observed in *E. coli*. Resistance to tetracycline was particularly high across all isolates, especially among *Klebsiella spp.*, which were 100% resistant. Moderate susceptibility levels were noted for gentamicin and ceftriaxone, though resistance remained substantial. Cefoxitin demonstrated relatively higher activity against *Klebsiella* isolates (100% susceptibility), but lower efficacy in *S. aureus* and *E. coli*.

Table 1: Aerobic bacterial count (cfu/ml) for sample from male students.

Samples	Total bacterial count (CFU/ml)
1	$1.52X10^2$
2	$1.45X10^2$
3	$1.22X10^3$
4	$1.56X10^2$
5	$1.20X10^2$
6	$1.63X10^4$
7	$1.36X10^2$
8	$1.45X10^2$
9	$1.51X10^2$
10	$1.23X10^4$
Mean ± SD	$3.43 \times 10^3 \pm 5.77 \times 10^3$

Table 2: Aerobic bacterial count in cfu/ml for sample from female students.

Samples	Total bacterial count (CFU/ml)
1	$1.22x10^2$
2	$1.18x10^3$
3	$1.45x10^2$
4	$2.28x10^3$
5	$1.65x10^2$
6	$2.25x10^2$
7	$2.32x10^2$
8	$1.56x10^4$
9	$1.63x10^2$
10	$1.56x10^2$
Mean ± SD	$2.00 \times 10^3 \pm 4.61 \times 10^3$

Table 3: Prevalence of bacteria isolates from the samples.

Isolates	Frequency of Occurrence	Percentage of Occurrence
Staphylococcus aureus	10	50%
Klebsiella species	3	15%
Escherichia coli	7	35%

Table 4: Antibiotic susceptibility profile of the bacteria isolates (figures in brackets are percentage).

	S. aureus **(n=10)**			***E. coli*** **(n=7)**			***Klebsiella spp.*** **(n=3)**		
Antibiotic	S	I	R	S	I	R	S	I	R
Ciprofloxacin	6 (60%)	0 (0%)	4 (40%)	4 (57%)	0 (0%)	3 (43%)	0 (0%)	0 (0%)	3 (100%)
Gentamicin	3 (30%)	2 (20%)	5 (50%)	2 (29%)	1 (14%),	4 (57%)	1 (33%)	2 (67%)	0 (0%)
Tetracycline	2 (20%)	0 (0%)	8 (80%)	1 (14%)	0 (0%)	6 (86%)	0 (0%)	0 (0%)	3 (100%)
Ceftriaxone	3 (30%)	0 (0%)	7 (70%)	2 (29%)	0 (0%)	5 (71%)	2 (67%)	0 (0%)	1 (33%)
Cefoxitin	4 (40%)	0 (0%)	6 (60%)	3 (43%)	4 (57%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)
Erythromycin	2 (20%)	1 (10%)	7 (70%)	0 (0%)	1 (14%),	6 (86%)	2 (67%)	1 (33%)	0 (0%)

Key: S=Sensitive, I=Intermediate, R=Resistance.

The mean aerobic mesophilic bacterial counts from hand swabs of randomly selected male and female students were 1.52×10^2, 1.45×10^2, 1.22×10^2, 1.56×10^3, 1.21×10^2, and 1.63×10^4 cfu/ml. The lack of a statistically significant difference in bacterial load between sexes contrasts with some studies suggesting that gender-specific behaviors (e.g., hygiene practices, surface contact frequency) might influence microbial carriage. However, our results support findings from similar studies (Kampf & Löffler, 2010; Ott & French, 2009; Ray *et al*., 2011) where such differences were also not statistically significant, possibly due to overlapping exposure risks in a shared academic environment or the small sample size limiting statistical power. All examined samples yielded positive bacterial growth, with *Staphylococcus aureus* emerging as the predominant isolate, followed by *Escherichia coli* and *Klebsiella* spp. The high recovery rate of these bacteria may be attributed to the students' frequent engagement with contaminated surfaces and poor hygienic practices, especially after contact with shared materials and communal environments (Akinyemi *et al*., 2009; Famurewa & David, 2009). Notably, the extent of microbial contamination appears to correlate with the frequency of contact with fomites, inter-personal physical interactions, and suboptimal hand hygiene compliance (Nazarko, 2009). Furthermore, infrequent or improper use of hand sanitizers, particularly before and after academic activities such as lectures and laboratory sessions, may have exacerbated microbial load on the students' hands. This observation aligns with Brady *et al*. (2007), who reported that persistent handling of objects and skin warmth can facilitate bacterial growth. Although all bacterial counts remained below the World Health Organization's (WHO, 1980) threshold of 3.20 $\times 10^6$ cfu/ml for surface contamination, these findings differ from those of Tagoe *et al*. (2011), who observed a significantly higher contamination burden on both personal and commercial mobile phones—a discrepancy likely attributable to variations in sample size, study population, or sampling context.

Staphylococcus aureus was isolated from 50% of all hand swabs, corroborating the findings of Famurewa and David (2009), who reported a 32.9% prevalence in similar studies. Akinyemi *et al*. (2009) attributed the widespread occurrence of *S. aureus* to its adaptability to warm, moist skin environments and its status as a commensal organism in the nasal cavities of 40–50% of individuals (Kluytmans *et al*., 1997). The relatively lower isolation rate of *Klebsiella* spp. may reflect its limited colonization, typically observed in the respiratory tract and intestinal flora of roughly 5% of healthy individuals (Cheesbrough, 2000). The isolation of *E. coli*—a common enteric bacterium implicated in community-acquired infections—points to potential cross-contamination from fecal sources, clothing, or contact with contaminated hands and surfaces ((Kluytmans *et al*., 1997).

All bacterial isolates identified in this study have well-documented pathogenic potential. *S. aureus*, for instance, is capable of producing enterotoxins that can result in foodborne intoxication and poisoning (Kampf & Löffler, 2010; Nazarko, 2009; Wieneke *et al*., 1993), while *E. coli* and *Klebsiella* spp. are known agents of gastrointestinal and respiratory infections, respectively (Penzias, 2010). The involvement of these organisms in both healthcare-associated and community-acquired infections is supported by existing literature (Akinyemi *et al*., 2007; Alexander, 1978; Brady *et* *al*., 2007; Ogunsola & Adesiji, 2008; Pittet *et al*., 2006; Willmott *et al*., 2016).

Antibiotic susceptibility testing (Table 4) revealed multidrug resistance among the isolates. Notably, *S. aureus*, *E. coli*, and *Klebsiella* spp. exhibited high resistance to tetracycline (80%, 86%, and 100%, respectively) and erythromycin (70%, 86%, and 0%, though *Klebsiella* spp. showed 67% sensitivity and 33% intermediate). *S. aureus* and *E. coli* also demonstrated considerable resistance to ceftriaxone (70% and 71%, respectively), while *Klebsiella* spp. were largely sensitive (67%). The reduced susceptibility of these pathogens to tetracycline and erythromycin, in particular, aligns with previous reports on antimicrobial resistance trends (Stefańska *et al*., 2022). Such resistance patterns may be indicative of the indiscriminate use or misuse of these antibiotics within the region (Hailesilase *et al*., 2026). Specifically, ciprofloxacin (CIP) was effective against the majority of *S. aureus* (60% sensitive) and *E. coli* (57% sensitive) isolates, but all *Klebsiella* spp. were resistant (100%). Gentamicin (CN) exhibited intermediate activity against *S. aureus* (20%) and *Klebsiella* spp. (67%), while *E. coli* showed intermediate susceptibility in one isolate (14%) and resistance in the majority (57%). Tetracycline (TE) was largely ineffective across all species, with only 20% of *S. aureus* and 14% of *E. coli* showing sensitivity, and all *Klebsiella* spp. being resistant. Cefoxitin (FOX) was effective against all *Klebsiella* spp. (100% sensitive) and *E. coli* (43% sensitive, 57% intermediate), whereas *S. aureus* showed significant resistance (60%). Erythromycin (E) retained activity against two-thirds of *Klebsiella* spp. (67% sensitive), but the majority of *S. aureus* (70%) and *E. coli* (86%) isolates were resistant. Ceftriaxone (CRO) was largely ineffective against *S. aureus* (70% resistant) and *E. coli* (71% resistant), while *Klebsiella* spp. showed predominantly sensitive responses (67%).

4. Conclusion

This study underscores the high prevalence of bacterial contamination on students' hands, with significant representation by potential pathogens such as *S. aureus*, *E. coli*, and *Klebsiella* spp. The findings highlight the role of hand-to-hand contact as a conduit for microbial transmission and emphasize the health risks associated with poor personal hygiene practices. The presence of multidrug-resistant strains further exacerbates public health concerns, calling for enhanced hygiene education, regular use of hand sanitizers, and prudent antibiotic stewardship. These interventions are critical for curtailing the spread of pathogenic bacteria and mitigating the risk of infection within academic and community settings.

Conflict of interest

The authors declare no conflict of interest.

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