FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 10, October, 2025, pp 243 – 248
DOI: https://doi.org/10.33003/fjs-2025-0910-4003

ASSESSMENT OF THE NASOPHARYNGEAL CARRIER RATE OF *STREPTOCOCCUS PYOGENES* AND *STREPTOCOCCUS PNEUMONIAE* AMONG APPARENTLY HEALTHY INDIVIDUALS IN ANYIGBA, KOGI STATE, NIGERIA

***[1]Daniel Makolo, [2]Moses Ode Odugbo and [3]Stephen Emmanuel**

[1]Department of Microbiology, Baze University, Abuja, Nigeria.
[2]National Veterinary Research Institute, Vom, Plateau State, Nigeria.
[3]Department of Microbiology, Taraba State University, Jalingo, Nigeria.

*Corresponding authors' email: daniel.makolo@bazeuniversity.edu.ng
Orchid iD: https://orcid.org/0000-0003-2461-2493

ABSTRACT

The aim of this study was to detect the carriage rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* among apparently healthy children and adults in Anyigba, Kogi State, Nigeria. Nasopharyngeal samples were aseptically collected and analyzed in accordance with standard bacteriological procedures. The target isolates were identified based on their colonial morphology and standard biochemical tests. Out of the 300 nasopharyngeal samples analyzed, 97 isolates of target bacteria were obtained, giving an overall prevalence rate of 32.3%. This consisted of *Streptococcus pyogenes* 49(16.3%) and *Streptococcus pneumoniae* 48(16.0%). Comparing the colonization rates between children and adults' samples, a total of 22.0% isolates of target organisms were obtained from children and 10.3% from adults. The carriage rates were higher in children than adults sampled. Also, comparing the colonization rates between the male and female subjects, 16.7% isolates of *Streptococcus pyogenes* and *Streptococcus pne*umoniae were obtained from the female participants and 15.7% from the male participants. The result showed that the samples collected from the female participants yielded higher isolates of *Streptococcus pyogenes* and *Streptococcus pne*umoniae than those from male participants. This study also established that samples from public schools yielded more isolates of *Streptococcus pyogenes* and *Streptococcus pneumoniae* (38.8%) than those from the private schools (25.6%). The asymptomatic carriage of these potential pathogens poses a potential public health threat to the people, as it could lead to epidemics of respiratory tract infections (RTIs) in future. Therefore, improved personal and public hygienic practices and decongestion of overcrowded classrooms are highly recommended.

Keywords: Carrier Rate, *Streptococcus pyogenes, Streptococcus pneumoniae*, Nasopharynx, Anyigba

INTRODUCTION

One of the few places in the human body where bacteria can enter directly is the nose. In addition to filtering the air we breathe; the nasal passage prevents microscopic foreign objects or microbes from entering the body (Çetinsu *et al*., 2023). Nonetheless, some bacteria find the nasal passages to be the ideal habitat (Bomar *et al*., 2018). Soon after birth, the normal flora of the upper respiratory tract begins to be acquired. Over time, the bacterial population grows in density and diversifies in a generally orderly manner, including both commensals and potentially harmful species (Maheshwari *et al*., 2024). Between the ages of six months and two years, the prevalence of mucosal-associated bacteria gradually increases before declining (García-Rodríguez *et al*., 2022; Pirker and Vogl, 2024).

As entry points to the trachea and pulmonary alveolar spaces, the sinuses, nasal passageway, pharynx, and larynx make up the upper respiratory tract (Paul, 2024). Respiratory tract infections (RTIs) are amongst the widest spread and serious infections that compel an individual to seek medical attention and prescription of antibiotics (El-Mahmood *et al*., 2010 ; Paul, 2024). In today's medical practice, it is among the most prevalent bacterial illnesses (Paul, 2024). According to Jafari *et al*. (2009) these infections are the main causes of morbidity and mortality among critically ill patients in developing nations (Jafari *et al*., 2009). Due to its direct contact with the physical environment and exposure to airborne microorganisms such as bacteria, fungi, viruses, and parasites, the respiratory tract is a common site of infection (Paul, 2024). The mucosa lining the upper airways is directly invaded by upper respiratory tract infections (Imani *et al*., 2007).

Over 50 million deaths worldwide are attributed to respiratory tract infections, which can happen in both community and medical settings (El-Mahmood *et al*., 2010; Sirota *et al*., 2025). In the United States alone, they are responsible for a comparatively high amount of health care spending—more than 3.5 billion dollars annually. The most common infections of all human diseases, RTIs include sore throat, tuberculosis (TB), whooping cough (pertussis), pneumonia, pharyngitis, bronchitis, emphysema, earache, laryngitis, common cold, otitis media, and mastoiditis, among others (Ndip *et al*., 2008).

Most often, respiratory tract infections are acquired by direct contact and the air. It can be spread by kissing, direct inhalation of pathogens released by infected people when they cough, sneeze, or talk, or by inhaling tiny infectious nuclei containing the pathogenic organisms while sharing cups and other eating materials with infected people (Jafari *et al*., 2009**)**.

According to Aydemir *et al*. (2006) and Plut *et al*. (2024) respiratory tract infections are often diagnosed and treated only on the basis of clinical and radiological findings. However, the choice of empirical treatment of some respiratory tract pathogens with conventional agents has become more difficult in recent years due to the rise in antibiotic resistance rates among the major pathogens. As a result, a definitive bacteriological diagnosis and susceptibility testing are now necessary for the effective management of respiratory tract infections (Jafari *et al*., 2009; Paul, 2024**)**. The escalating prevalence of antibiotic resistance has initially

been documented in locations where the antimicrobial agent's penetration is limited, making it more challenging to attain therapeutic concentrations (Jafari *et al*., 2009; Brüssow, 2024**)**.

Bacterial pathogens causing RTIs have a multitude of pathogenicity mechanisms including the generation of Beta-lactamases and exchange of resistant markers such plasmids and transposons (Aydemir *et al*., 2006; Jafari *et al*., 2009**;** Panickar *et al*., 2024) . One important contributing cause to the emergence of bacterial resistance to antimicrobial drugs is the extensive and inappropriate use of antibiotics (Mincey, 2001; Halawa *et al*., 2024).

In developing countries, the severity and mortality rate among the elderly are higher; respiratory diseases have a substantial economic impact on the sick in terms of lost productivity as well as on physicians who, in most cases, must administer antibiotics even when the causative agents are not bacteria (Jafari *et al*., 2009).

Upper respiratory tract infections are the result of colonization by the "potential pathogens" of the nasopharynx microbiome, which is primarily asymptomatic (Bogaert *et al*., 2004; García-Rodríguez *et al*., 2002; Missa *et al*., 2024). The incapacity to remove encapsulated bacteria in early childhood due to a physiological delay in the maturation of the T-cell independent arm of the immune system, increasing socialization and exposure with age, and the disappearance of maternally derived antibodies all contribute to this pattern. Following immunological maturation, colonization rates and susceptibility to infection decrease, and bacterial clearance is promoted (García-Rodríguez *et al*., 2002).

The interface between humans and their environment is where bacterial colonization of respiratory mucosal surfaces occurs. A variety of factors, including host, microbial, environmental, and socioeconomic factors, influence the acquisition, composition, trafficking, and removal of residing organisms (Kastner and Guggenbichler, 2001; Barron *et al*., 2021).

Due to the extreme complexity of the interactions between these many different factors, multivariate analysis, careful control selection, and rigorous epidemiological techniques are required in order to evaluate the relative contributions of individual variables. Research also heavily depends on methodological considerations that may spuriously affect colonization rates, such as testing frequency, sampling site, specimen collection technique, fiber type in the swab, use of selective media, transit time to the laboratory, or number of colonies examined (Rapola *et al*., 1997; Barron *et al*., 2021).

The pathogenesis of antibiotic-resistant infections begins with their acquisition as commensals. The treatment choices for infections caused by colonization and infection with bacteria resistant to antibiotics will be drastically different. Complex interactions between an organism, its surroundings, and a prospective host are involved in the pathogenesis of RTIs (Grenet *et al*., 2004; Bhardwaj and Kadam, 2024). As a result, knowledge regarding the host, the organism, and the environment are crucial for managing RTIs (Oh, 1995; Paul, 2024).

However, this study was conducted to determine the carriage rate of *Streptococcus pneumoniae* and *Streptococcus pyogenes* among healthy adults and children in Anyigba, Dekina Local Government area of Kogi State, Nigeria. It is hoped that the result will provide useful information which would be used in the formulation of policies for proper management of respiratory tract infections.

MATERIALS AND METHODS

Study Area

Anyigba is situated in Kogi State (Kogi East), Dekina Local Government Area. With an estimated 130,000 residents, Anyigba is home to most of Nigeria's ethnic groups. The majority ethnic group of Anyigba is the Igala group. The Yoruba, Igbo, Hausa, Fulani, Edo, Calabar, Idoma, TIV, and other ethnic groups are among the remaining groups [26]. With an average elevation of 420 meters above sea level, it is situated between latitudes 7°15᾽ and 7°29'N and longitudes 7°11' and 7° 32 E. It experiences 1016 to 1524 mm of yearly rainfall in a warm, humid climate. With an average yearly temperature of 25^0C, it has both dry and wet seasons (Ifatimehin *et al*., 2009; Makolo *et al*., 2021; Abosede *et al*., 2022).

Study Groups

The study groups were apparently healthy children (6-17 years old) and adults (18 years old and above) who attended the selected institutions within Anyigba town either as students, pupils or staff. This research was carried out in Anyigba and samples were collected from both public and private institutions. The public institutions studied were Kogi State University, CMML Primary School, RCM Primary School and Our Lady of Schools, while the private institutions were St. Thomas Moore Nursery and Primary School, , Living Stone Nursery and Primary School and Grace Academy Secondary School. All these schools are located in Anyigba town.

Sample Collection

The nasopharyngeal samples were aseptically collected weekly from 300 (150 children and 150 adults) apparently healthy students and pupils. Using a sterile thin flexible culture swab with synthetic fiber tip, the swab was gently inserted through both nasal apertures one after the other) into the posterior wall of the nasopharynx (approximately 1-2cm) and rotated over the nasopharyngeal surface. A slight pressure was applied with a finger on the outside of the nose to ensure good contact was made. The swab was withdrawn from the collection site and immediately inserted into the container and transported to the Microbiology Laboratory, Department of Microbiology, Kogi State University Anyigba for bacteriological analysis. On the labels were the name, age, sex and time of collection.

Analysis of Samples

In the Microbiology Laboratory of Kogi State University, Anyigba, each sample was inoculated on Blood and Chocolate agar plates (prepared according to the manufacturer's instructions) and incubated at 35^0C for 24 hours under capnophilic condition. Briefly, the inoculated plates were put inside the candle jar, and then a candle stick was lighted and enclosed inside the jar. The candle continued to burn until oxygen was removed from the jar, thereby, creating a carbon dioxide enriched environment under which the studied organisms grow best. Each sample was analyzed for the presence of *Streptococcus pyogenes* and *Streptococcus pneumoniae.* Each bacterial isolate was subcultured and identified by standard laboratory procedure described by Cheesborough (Cheesbrough, 2006). The isolates were phenotypically identified based on their colonial morphology, alpha-haemolysis, Gram staining, Catalase reaction, bile solubility test and Optochin susceptibility test.

Statistical Analysis
Differences in proportion were determined by chi square and the level of significance set at $p<0.05$. Statistical analyses were done using SPSS software, version 16.0.

Ethical Approval
This study protocol was approved by the Ethical Review Committee (ERC) of Kogi State University, Anyigba. The World Medical Association's Code of Ethics (Declaration of Helsinki) for studies involving human subjects and human specimens was strictly adhered to in the execution of this study. Also, Informed consents were obtained from the participants.

RESULTS AND DISCUSSION
Out of the 300 nasopharyngeal samples from apparently healthy children and adults in this study, 149 (49.7%) were from male subjects while 151 (50.3) were from female subjects. The difference was not statistically significant (Table 1).

Table 1: Age and Sex Distribution of the Subjects Sampled

Age Range	Male	Female
6-10	35 (11.7%)	33 (11.0%)
11-15	30 (10.0%)	32 (10.7%)
16-20	9 (3.0%)	11 (3.7%)
21-25	26 (8.7%)	28 (9.3%)
26-30	19 (6.3%)	18 (6.0%)
31-35	10 (3.3%)	10 (3.3%)
36-40	8 (2.7%)	6 (2.0%)
41-45	4 (1.3%)	7 (2.3%)
46-50	6 (2.0%)	5 (1.7%)
50-above	2 (0.7%)	1 (0.3%)
Total	**149 (49.7%)**	**151 (50.3%)**

(T- Value = -0.34, P-value = 0.743)

Out of the 300 nasopharyngeal samples analyzed, 49 (16.3%) tested positive for *Streptococcus pyogenes*, 48 (16.0%) were positive for S*treptococcus pneumoniae*. This gives a total carriage rate of 97 (32.2%) as shown in Table 2.

Table 2: The Carriage Rate of *Streptococcus pyogenes* and S*treptococcus pneumoniae* among the Study Population

Number of Samples Collected	Number positive for *Streptococcus pyogenes*	Number positive for *Streptococcus pneumoniae*	Total carriage rate
300	49(16.3%)	48(16.0%)	97(32.2%)

The carrier rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* isolates according to age is shown in Table 3. The results obtained showed that children samples yielded a total carriage rate of 66 (22.0%) and 31 (10.3%) was obtained from adult samples. This indicated that the carriage rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* was higher in children than adults sampled.

Table 3: Total Case Number and Distribution of Isolates among Children and Adults Screened

Subjects	No. of samples taken	No. Positive for *S. pyogenes*	No. Positive for *S. pneumoniae*	Total carriage Rate	Percentage of carriage
Children	150	31	35	66	22.0
Adults	150	13	18	31	10.3
Total	**300**	**44**	**53**	**97**	**32.3**

The carrier rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* according to sex is depicted in Table 4. The result showed that the samples collected from the female subjects yielded higher carriage rate of 50 (16.7%) than those from the male subjects that recorded 47 (15.7%).

Table 4: Carrier Rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* According to Sex

Sex	Number of Samples Collected	Number of Samples Positive for *Streptococcus pyogenes* and *Streptococcus pneumoniae*	Percentage of carriage
Male	149	47	**15.7%**
Female	151	50	**16.7%**
Total	**300**	**97**	**32.3**

Table 5 shows the distribution of *Streptococcus pyogenes* and *Streptococcus pneumoniae* isolates among the studied public schools in Anyigba. The result showed that out of the 152 samples collected, 59 (38.8%) was positive for *Streptococcus pyogenes* and *Streptococcus pneumoniae*. Subjects from CMML Primary School, Anyigba recorded the highest carriage rate of 17 (28.8%), while the subjects from O.L.S. Anyigba recorded the least carriage rate of 13 (22.0%).
The distribution of *Streptococcus pyogenes* and *Streptococcus pneumoniae* isolates among the studied private schools in Anyigba is depicted in Table 6. The result revealed that out of the 148 samples collected, 38 (25.6%) was positive for *Streptococcus pyogenes* and *Streptococcus pneumoniae*.

Subjects from Living Stone Nursery and Primary School, Anyigba recorded the highest carriage rate of 12 (31.5%), while the subjects from Christ the Good Shepherd, Anyigba recorded the least carriage rate of 7 (18.4%).

Table 5: Carriage Rate of *Streptococcus Pyogenes* and *Streptococcus Pneumoniae* among Children and Adults in the Public Schools in Anyigba

School Names	No. of Samples collected	No. /Percentage of *S. pyogenes* isolated	No. /Percentage of *S. pneumoniae* isolated	Total isolates/ Percentage from each school
CMML Primary School, Anyigba	38	6 (10.2)	11 (18.6)	17 (28.8)
RCM Primary School, Anyigba	38	5 (8.5)	10 (16.9)	15 (25.4)
K.S.U, Anyigba	38	9 (15.3)	5 (8.5)	14 (23.7)
O.L.S, Anyigba	38	9 (15.3)	4 (6.7)	13 (22.0)
Total	**152**	**29 (19.0)**	**30 (19.7)**	**59 (38.8)**

Keys:
C.M.M.L = Christian Missions of Many Lands; R.C.M = Roman Catholic Mission; K.S.U = Kogi State University; O.L.S = Our Lady of Schools

Table 6: Carriage Rate of *Streptococcus Pyogenes* and *Streptococcus Pneumoniae* among Children and Adults in Private Schools in Anyigba

School Name	No. of Samples collected	No. /Percentage of *S. pyogenes* isolated	No. /Percentage of *S. pneumoniae* isolated	Total isolates/Percentage from each school
St. Thomas Moore Nursery and Primary School, Anyigba	37	5 (13.1)	4 (10.5)	9 (23.6)
Living Stone Nursery and Primary School, Anyigba	37	5 (13.1)	7 (18.4)	12 (31.5)
Grace Academy Secondary School, Anyigba	37	6 (15.7)	4 (10.5)	10 (26.3)
Christ the Good Shepherd, Anyigba	37	4 (10.5)	3 (7.8)	7 (18.4)
Total	**148**	**20 (13.5)**	**18 (12.1)**	**38 (25.6)**

Discussion

This study recorded a high carrier rate of *Streptococcus pneumoniae* and *Streptococcus pyogenes* among the study subjects in Anyigba, Kogi State, Nigeria. The finding is similar with the findings of previous investigations in Nigeria (Nwanze *et al*., 2007; Okesola and Oni, 2009) and is within the range of frequencies documented in other nations, like Cameroon (Ndip *et al*., 2008), South Africa (Liebowitz *et al*., 2003), Nepalese (Dumre *et al*., 2009), Mozambique (Braito *et al*., 2004), China (Wang *et al*., 2001), Japan (Wantanabe *et al*., 1995), Egypt (El Kholy *et al*., 2003) , Iran (Jafari *et al*., 2009) and Turkey (Aydemir *et al*., 2006).

However, this finding is in contrast with the results obtained in Marseille (Benkouiten *et al*., 2014) and Yola, Nigeria (Al-Khani *et al*., 2019) where 7.3% and 21.6% carriage rate for *S. pneumoniae* were reported. El-Mahmood et al. (2010) in Yola, Nigeria reported 9.7% carriage rates for *S. pyogenes* respectively, which are in contrast with the results obtained in this study. The reasons for the differences might be due to varied personal and public hygienic levels and the different levels of congestion or overcrowding of homes and classrooms within the study areas.

This study established that samples obtained from children yielded more of the *Streptococcus pyogenes* and *Streptococcus pneumoniae* than those from adults. This may be due to the fact that children are more prone to overcrowded classrooms, continuous close contacts at playing grounds and immature immune system; and they have been reported to be the major sources of infection for the adults. This agrees with the findings of Herruzo *et al*. (2022) who reported similar trends in Sana'a city, Yemen.

In this study, it was also established that samples from public schools yielded higher prevalence of *S. pyogenes* and *S. pneumoniae* than the private institutions. The finding in this study is similar with the reports of Herruzo *et al*. (2022) in Madrid; Thapa *et al*. (2017) in Nepal and Obajuluwa *et al*. (2024) in Kaduna, Nigeria. This difference might be due to the overcrowded classrooms and poor hygienic conditions as evident in the study area.

In this study, females showed higher nasopharyngeal carriage of *Streptococcus pneumoniae* and *Streptococcus pyogenes* than males. Several school-based surveys have reported equal or higher carriage among girls. An Ethiopian study of school children by Gashaw *et al*. (2025) found *S. pyogenes* carriage significantly more common in females than males and discussed social/behavioral factors (household roles, contact intensity) as possible contributors. However, studies in Iraq by Ali and Wadi, (2025) showed higher male carriage of *Streptococcus pyogenes* than females.

Streptococcus pneumoniae evidence on sex differences is mixed and context-dependent. A Malawian community study by Sibale, (2025) in adults and children reported males were significantly less likely to be colonized than females, which is consistent with the findings in this study. In contrast, other investigations have shown the opposite or no difference (Falagas *et al*., 2007; Liu *et al*., 2025; Zhao *et al*., 2025).

CONCLUSION

Considering the findings of this investigation, it is hereby concluded that *Streptococcus pyogenes* and *Streptococcus pneumoniae* which are potential pathogens of upper respiratory tract infections were isolated from the nasopharynx of some healthy children and adults in Anyigba, Kogi State, Nigeria. The findings in this study have clinical and epidemiological significance: The asymptomatic carriage of these potential pathogens in Anyigba poses a potential threat to the people, as it could precipitate sporadic epidemic outbreaks of respiratory tract infections in the future.

RECOMMENDATIONS

In-view of the high carriage rate of *Streptococcus pyogenes* and *Streptococcus pneumoniae* established in this study, the following recommendations are made:

i. Periodic monitoring of carriage rate of potentially pathogenic bacteria should be encouraged.

ii. The living conditions of both the public and private schools in Anyigba should be properly monitored and improved by the government. Overcrowded classrooms, hostels and poor hygienic conditions may have contributed to the high carriage rate of the studied organisms recorded in some schools.
iii. Individuals in this area should also improve on their living and hygienic conditions as overcrowded homes were linked to the high carriage rates of *S. pneumoniae* and *S. pyogenes* recoded in this study
iv. Students or pupils showing symptoms of respiratory tract infections should be quickly isolated and given adequate treatment to avoid transferring the pathogens to others.
v. More research is needed in the area of vaccine development against *Streptococcus pyogenes* which is currently not available.

ACKNOWLEDGEMENT
The authors are grateful to the adults and children participants who gave their consents to participate in this study.

REFERENCES

Abosede, E. A., Daniel, M., & Emmanuel, A. D. (2022). A spatial analysis of health care accessibility and utilization among rural households in Kogi State, Nigeria.

Al-Khani, A. M., Sarhandi, M. I., Zaghloul, M. S., Ewid, M., & Saquib, N. (2019). A cross-sectional survey on sleep quality, mental health, and academic performance among medical students in Saudi Arabia. *BMC research notes*, *12*(1), 665.

Awulu, O. F., Aminu, M., Suleiman, A. B., & Makolo, D. (2020). Seroprevalence and Risk Factors Associated with HPV Infections among Patients in Kogi East Senatorial Zone. *FUDMA Journal of Sciences*, *4*(3), 645-655.

Aydemir, S., Tunger, A., & Cilli, F. (2006). In vitro activity of fluoroquinolones against common respiratory pathogens. *West indian medical journal*, *55*(1), 9.

Barron, S. L., Saez, J., & Owens, R. M. (2021). In vitro models for studying respiratory host–pathogen interactions. *Advanced biology*, *5*(6), 2000624.

Benkouiten, S., Gautret, P., Belhouchat, K., Drali, T., Salez, N., Memish, Z. A., ... & Brouqui, P. (2014). Acquisition of Streptococcus pneumoniae carriage in pilgrims during the 2012 Hajj. *Clinical Infectious Diseases*, *58*(4), e106-e109.

Bhardwaj, Y., & Kadam, S. N. (2024). Antibiotic Resistance: A Growing Threat to Public Health. *Research Journal of Pharmacy and Technology*, *17*(7), 3473-3479.

Bogaert, D., De Groot, R., & Hermans, P. W. M. (2004). Streptococcus pneumoniae colonisation: the key to pneumococcal disease. *The Lancet infectious diseases*, *4*(3), 144-154.

Bomar, L., Brugger, S. D., & Lemon, K. P. (2018). Bacterial microbiota of the nasal passages across the span of human life. *Current opinion in microbiology*, *41*, 8-14.

Braito, A., Galgani, I., Mohammed, M. R., Iozzi, C., Ame, S. M., Haji, H. S., & Zanchi, A. (2004). Epidemiology of streptococcus group A in school aged children in Pemba. *East African medical journal*, *81*(6), 307-312.

Brüssow, H. (2024). The antibiotic resistance crisis and the development of new antibiotics. *Microbial Biotechnology*, *17*(7), e14510.

Çetinsu, V., & Çelik, M. (2023). Steps to Respiratory Health. In *Airway Disease* (pp. 2541-2551). Cham: Springer International Publishing.

Cheesbrough, M. (2006). District laboratory practice in tropical countries: Part 2.

Dumre, S. P., Sapkota, K., Adhikari, M., Acharya, D., Karki, M., Bista, S., ... & Joshi, S. K. (2009). Asymptomatic throat carriage rate and antimicrobial resistance pattern of Streptococcus pyogenes in Nepalese school children. *Kathmandu University Medical Journal*, *7*(4), 392-396.

El Kholy, A., Baseem, H., Hall, G. S., Procop, G. W., & Longworth, D. L. (2003). Antimicrobial resistance in Cairo, Egypt 1999–2000: a survey of five hospitals. *Journal of Antimicrobial Chemotherapy*, *51*(3), 625-630.

El-Mahmood, A. M., Isa, H., Mohammed, A., & Tirmidhi, A. B. (2010). Antimicrobial susceptibility of some respiratory tract pathogens to commonly used antibiotics at the Specialist Hospital, Yola, Adamawa State, Nigeria. *Journal of Clinical Medicine and Research*, *2*(8), 135-142.

Falagas, M. E., Mourtzoukou, E. G., & Vardakas, K. Z. (2007). Sex differences in the incidence and severity of respiratory tract infections. *Respiratory medicine*, *101*(9), 1845-1863.

García-Rodríguez, J. Á., & Fresnadillo Martínez, M. J. (2002). Dynamics of nasopharyngeal colonization by potential respiratory pathogens. *Journal of Antimicrobial Chemotherapy*, *50*(suppl_3), 59-74.

Gashaw, Y., Getaneh, A., Kasew, D., Tigabie, M., & Gelaw, B. (2025). Streptococcus pyogenes carriage rate, associated factors and antimicrobial susceptibility profiles among urban and rural schoolchildren at Gondar city, Northwest Ethiopia. *Scientific Reports*, *15*(1), 2057.

Grenet, K., Guillemot, D., Jarlier, V., Moreau, B., Dubourdieu, S., Ruimy, R., ... & Andremont, A. (2004). Antibacterial resistance, wayampis amerindians, French Guyana. *Emerging Infectious Diseases*, *10*(6), 1150.

Halawa, E. M., Fadel, M., Al-Rabia, M. W., Behairy, A., Nouh, N. A., Abdo, M., ... & Abdeen, A. (2024). Antibiotic action and resistance: updated review of mechanisms, spread, influencing factors, and alternative approaches for combating resistance. *Frontiers in Pharmacology*, *14*, 1305294.

Herruzo, R., Chamorro, L., García, M. E., Gonzalez, M. C., Lopez, A. M., Mancenido, N., & Yebenes, L. (2002). Prevalence and antimicrobial-resistance of S. pneumoniae and S. pyogenes in healthy children in the region of Madrid. *International journal of pediatric otorhinolaryngology*, *65*(2), 117-123.

Ifatimehin, O. O., Musa, S. D., & Adeyemi, J. O. (2009). An analysis of the changing land use and its impact on the environment of Anyigba town, Nigeria. *Journal of sustainable Development in Africa*, *10*(4), 357-364.

Imani, R., Rouhi, H., & Ganji, F. (2007). Prevalence of antibiotic résistances among bacteria isolates of lower respiratory tract infections in COPD Shahrekord, Iran. *J. Med. Sci*, *23*(3), 438-440.

Jafari, N. J., Ranjbar, R., Haghi-Ashtiani, M. T., Abedini, M., & Izadi, M. (2009). The study of prevalence and antimicrobial susceptibility of tracheal bacterial strains isolated from pediatric patients.

Kastner, U., & Guggenbichler, J. P. (2001). Influence of macrolide antibiotics on promotion of resistance in the oral flora of children. *Infection*, *29*(5), 251-256.

Liebowitz, L. D., Slabbert, M., & Huisamen, A. (2003). National surveillance programme on susceptibility patterns of respiratory pathogens in South Africa: moxifloxacin compared with eight other antimicrobial agents. *Journal of clinical pathology*, *56*(5), 344-347.

Liu, J., Bao, B., Zhang, T., Jia, W., Guo, C., & Song, C. (2025). Comparative analysis of the clinical characteristics of severe Mycoplasma pneumoniae pneumonia and severe bacterial pneumonia in children. *BMC pediatrics*, *25*(1), 439.

Maheshwari, K., Gupta, R., Sharma, R., Kaur, A., Vashist, A., & Aggarwal, G. (2024). Nasal microbiome dynamics: decoding the intricate nexus in the progression of respiratory and neurological diseases. *Critical Reviews in Microbiology*, 1-16.

Makolo, D., Alkali, D. E., & Egbunu, A. A. (2021). Epidemiological Survey of Knowledge, Attitudes and Practices towards COVID-19 pandemic in Kogi state, Nigeria. *Int. J. Adv. Multidiscip. Res*, *8*(10), 31-42.

Mincey, B. A., & Parkulo, M. A. (2001). Antibiotic prescribing practices in a teaching clinic: comparison of resident and staff physicians. *Southern medical journal*, *94*(4), 365-369.

Missa, K. F., Diallo, K., Bla, K. B., Tuo, K. J., Gboko, K. D. T., Tiémélé, L. S., ... & Bonfoh, B. (2024). Association of symptomatic upper respiratory tract infections with the alteration of the oropharyngeal microbiome in a cohort of school children in Côte d'Ivoire. *Frontiers in Microbiology*, *15*, 1412923.

Ndip, R. N., Ntiege, E. A., Ndip, L. M., Nkwelang, G., Akoachere, J. T., & Nkuo, A. T. (2008). Antimicrobial resistance of bacterial agents of the upper respiratory tract of school children in Buea, Cameroon. *Journal of health, population, and nutrition*, *26*(4), 397.

Nwanze, P. I., Nwaru, L. M., Oranusi, S., Dimkpa, U., Okwu, M. U., Babatunde, B. B., ... & Asagwara, C. E. (2007). Urinary tract infection in Okada village: Prevalence and Antimicrobial Susceptibility Pattern. *Sci Res Essays*, *2*(4), 112-6.

Obajuluwa, A. F., Akanni, I. O., & Bege, K. B. (2024). Microbiological Assessment of Indoor Air Quality of Student Hostels and Canteens in a Nigerian University Campus : Risks on Students' Health. *Fudma journal of sciences*, *8*(2), 73-78.

Oh, H. M. (1995). Upper respiratory tract infections-otitis media, sinusitis and pharyngitis. *Singapore medical journal*, *36*(4), 428-431.

Okesola, A. O., & Oni, A. A. (2009). Antimicrobial resistance among common bacterial pathogens in South Western Nigeria.

Panickar, A., Manoharan, A., Anbarasu, A., & Ramaiah, S. (2024). Respiratory tract infections: an update on the complexity of bacterial diversity, therapeutic interventions and breakthroughs. *Archives of Microbiology*, *206*(9), 382.

Paul, J. (2024). Respiratory tract infections. In *Disease Causing Microbes* (pp. 99-148). Cham: Springer International Publishing.

Pirker, A. L., & Vogl, T. (2024). Development of systemic and mucosal immune responses against gut microbiota in early life and implications for the onset of allergies. *Frontiers in Allergy*, *5*, 1439303.

Plut, D., Winant, A. J., Mahomed, N., Sodhi, K. S., Kasznia-Brown, J., Williams-Weekes, T., ... & Lee, E. Y. (2024). Unusual pediatric lung infections: imaging findings. *Pediatric Radiology*, *54*(4), 516-529.

Rapola, S., Salo, E., Kiiski, P., Leinonen, M., & Takala, A. K. (1997). Comparison of four different sampling methods for detecting pharyngeal carriage of Streptococcus pneumoniae and Haemophilus influenzae in children. *Journal of Clinical Microbiology*, *35*(5), 1077-1079.

Sibale, L. (2024). *Streptococcus pneumoniae carriage diversity, evolution and transmission among adults living with or without HIV in Malawi* (Doctoral dissertation, Liverpool School of Tropical Medicine).

Sirota, S. B., Doxey, M. C., Dominguez, R. M. V., Bender, R. G., Vongpradith, A., Albertson, S. B., ... & Ed-Dra, A. (2025). Global, regional, and national burden of upper respiratory infections and otitis media, 1990–2021: a systematic analysis from the Global Burden of Disease Study 2021. *The Lancet Infectious Diseases*, *25*(1), 36-51.

Thapa, S., Gokhale, S., Sharma, A. L., Sapkota, L. B., Ansari, S., Gautam, R., ... & Neopane, P. (2017). Burden of bacterial upper respiratory tract pathogens in school children of Nepal. *BMJ open respiratory research*, *4*(1).

Wang, F., Zhu, D. M., Hu, F. P., & Zhang, Y. Y. (2001). Surveillance of bacterial resistance among isolates in Shanghai in 1999. *Journal of infection and chemotherapy*, *7*(2), 117-120.

Watanabe, A., Oizumi, K., Matsuno, K., Nishino, T., Motomiy, M., & Nukiwa, T. (1995). Antibiotic Susceptibility of the sputum pathogens and throat swab pathogens isolated from the patients undergoing treatment in twenty-one private clinics in Japan. *The Tohoku Journal of Experimental Medicine*, *175*(4), 235-247.

Zhao, C., Zhang, F., Wang, Z., Yang, S., Chen, H., & Wang, H. (2025). Distribution of serotypes and antibiotic resistance profiles of Streptococcus pneumoniae in hospitalized adult patients: aretrospective multicenter surveillance in China (2018–2019). *BMC Infectious Diseases*, *25*(1), 980.

©2025 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via https://creativecommons.org/licenses/by/4.0/ which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.