International Health 2026; **18**: 369–380
https://doi.org/10.1093/inthealth/ihaf077 Advance Access publication 11 November 2025

REVIEW ARTICLE

Pneumonia in Ghana: prevalence, mortality and antimicrobial resistance—a systematic review and meta-analysis

Frederick Kungu, Aaron Awere-Duodu and Eric S. Donkor*

Department of Medical Microbiology, University of Ghana Medical School, P.O. Box KB 4236, Accra, Ghana

*Corresponding author: Tel: +233 553 527140; E-mail: esampane-donkor@ug.edu.gh

Received 4 January 2025; revised 6 April 2025; accepted 26 June 2025

Pneumonia is a major cause of morbidity and mortality in Ghana, especially among children <5 y of age and the elderly. However, comprehensive data on its prevalence and distribution remain limited. This systematic review addresses this gap by analysing the prevalence, regional variations, risk factors, antimicrobial resistance and mortality rates of pneumonia in Ghana. We searched PubMed, ScienceDirect, Web of Science and African Journals Online databases, including 21 studies with a total of 124 582 participants. A random-effects meta-analysis estimated pooled prevalence and subgroup differences based on age, region and participant type. Heterogeneity was assessed using the I^2 test and meta-regression, with sensitivity analysis also conducted. Study quality was evaluated using standardized Joana Briggs Institute checklists for prevalence studies. The pooled prevalence of pneumonia in Ghana was 22.01%, with significant regional variations. The highest prevalence was observed in a study conducted in the Greater Accra and Northern regions (32.31%), while the lowest was in the Upper West (4.83%). The prevalence in children <5 y of age was 17.79%. Hospitalized patients had a higher prevalence (22.14%) than community children (21.49%). *Streptococcus pneumoniae* was the most common pathogen, with high resistance (>70%) to co-trimoxazole, gentamicin and tetracycline. Key risk factors included indoor air pollution and seasonal changes. The mortality rate for pneumonia was found to be 3.07%. This systematic review highlighted significant regional disparities, pathogen resistance patterns and environmental risk factors that shape the burden of pneumonia in Ghana, providing critical evidence for targeted public health strategies. The findings highlight avenues for future research, including environmental drivers of transmission, focusing on underreported regions and surveillance of antibiotic resistance of pathogens isolated from pneumonia patients.

Keywords: antimicrobial resistance, *C. pneumoniae*, Ghana, pneumonia, pneumonia epidemiology, prevalence, respiratory infections, *S. pneumoniae*, systematic review.

Introduction

Pneumonia is a lung infection characterized by inflammation of the alveolar space, whereas the presence of microorganisms without an inflammatory response represents colonization rather than pneumonia.[1] Unlike other infectious diseases, pneumonia is not a single disease but a group of specific infections with distinct epidemiology, pathogenesis and presentation.[2] It is caused by a variety of pathogens, including bacterial, viral, fungal and parasitic agents.[3] The most common pathogens associated with pneumonia include *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Mycoplasma pneumoniae*, *Chlamydia pneumoniae* and respiratory viruses such as influenza A and respiratory syncytial virus (RSV).[4,5] These pathogens may act independently or in combination, complicating diagnosis and treatment.[6] Pneumonia remains a leading cause of hospitalization and mortality globally, responsible for 2.2 million deaths annually, including 502 000 children.[7,8] It is reported that pneumonia causes approximately 1.58 million deaths in children <5 y of age each year, exceeding the combined fatalities from human immunodeficiency virus/acquired immunodeficiency syndrome, malaria and measles.[9] By 2021, the burden of respiratory infections grew even more severe, with >6 million deaths linked to pneumonia and coronavirus disease 2019 (COVID-19).[10]

A recent study reported that >800 000 children <5 y of age died from pneumonia globally within a 3-y period, with more than half of these deaths occurring in just five countries.[11] Notably, 26% were concentrated in three sub-Saharan African nations: Nigeria, the Democratic Republic of Congo and Ethiopia.[11] In West and Central Africa, pneumonia alone accounts for 17% of under-5 mortality rates, highlighting its significant burden on child health in the region.[12] Although child mortality has

© The Author(s) 2025. Published by Oxford University Press on behalf of Royal Society of Tropical Medicine and Hygiene. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (https://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact reprints@oup.com for reprints and translation rights for reprints. All other permissions can be obtained through our RightsLink service via the Permissions link on the article page on our site-for further information please contact journals.permissions@oup.com

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

significantly decreased over the past 2 decades, pneumonia continues to rank among the top five causes of death in children <5 y of age in the sub-Saharan region.[13]

In Ghana, pneumonia remains a leading cause of morbidity and mortality, particularly among vulnerable populations such as children <5 y of age and the elderly, contributing to 18% of deaths and 72 000 cases annually.[9,14] A critical driver in pneumonia transmission is the high prevalence of pneumococcal carriage—asymptomatic colonization of the nasopharynx by *S. pneumoniae*, the leading cause of bacterial pneumonia worldwide.[15] In Ghana, Arhin et al.[16] reported prevalence rates of pneumococcal carriage ranging from 11% to 51%. Compounding this threat, multidrug-resistant strains are pervasive, with resistance rates ranging from 7% to 100% depending on geographic and socio-economic factors.[16] Despite this significant burden, the prevalence of pneumonia across Ghana's diverse demographics and regions has not been comprehensively assessed, as is often the case in many low-resource settings.[17]

Effective pneumonia management relies on accurate knowledge of microbial aetiologies and the ability to differentiate between them.[18] However, Ghana's healthcare infrastructure, like that of most low- and middle-income countries (LMICs), faces critical challenges, including scarcity of diagnostic tools, under-resourced laboratories and clinical differentiation of pneumonia cases.[19] Exacerbating these issues is a significant knowledge deficiency regarding pneumonia among Ghanaians, as one study found that two-thirds of participants had never heard of the disease,[20] suggesting low recognition of symptoms and delays in care-seeking.

To address these gaps, this systematic review aimed to examine geographic disparities in pneumonia research, identify literature gaps and provide a clear understanding of the disease's epidemiology by analysing its prevalence, mortality rates, risk factors and antimicrobial resistance rates. The findings will inform targeted interventions, guide evidence-based policies for more effective resource allocation, and contribute to addressing concerns related to antimicrobial resistance, laying the foundation for future research in Ghana.

Methods

The systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and the study protocol was registered in PROSPERO (CRD42024627892). The PRISMA checklist is included in the supplementary materials.[21]

Search strategy

The literature search was conducted from 1 December to 12 December 2024. The search included studies published in English and conducted in Ghana. The search strategy was designed to include studies published from the inception of each database to 11 December 2024. Original research articles including observational, cohort and case–control studies describing the proportion of pneumonia cases and its driving factors were identified from PubMed and three other databases (Web of Science, ScienceDirect and African Journals Online [AJOL]). The search was conducted using specific keywords; terms within the same concept were connected with the Boolean 'OR' and combined with other components of the search terms using 'AND'. The final search terms for the databases were:

- PubMed: ('Pneumonia' OR 'Pneumonitis' OR 'Bronchopneumonia' OR 'Community-Acquired Pneumonia (CAP)' OR 'Hospital-Acquired Pneumonia (HAP)' OR 'Aspiration Pneumonia' OR 'Fungal Pneumonia' OR 'Viral Pneumonia' OR 'Mycoplasma Pneumonia') AND ('Ghana' OR 'Ghanaian')
- Web of Science: ('Pneumonia' OR 'Pneumonitis' OR 'Bronchopneumonia' OR 'Community-Acquired Pneumonia (CAP)' OR 'Hospital-Acquired Pneumonia (HAP)' OR 'Aspiration Pneumonia' OR 'Fungal Pneumonia' OR 'Viral Pneumonia' OR 'Mycoplasma Pneumonia') AND ('Ghana' OR 'Ghanaian')
- ScienceDirect: ('Pneumonia' OR 'Pneumonitis' OR 'Aspiration Pneumonia' OR 'Fungal Pneumonia' OR 'Viral Pneumonia') AND ('Ghana')
- AJOL: ('Pneumonia' OR 'Pneumonitis' OR 'Bronchopneumonia' OR 'Community-Acquired Pneumonia (CAP)' OR 'Hospital-Acquired Pneumonia (HAP)' OR 'Aspiration Pneumonia' OR 'Fungal Pneumonia' OR 'Viral Pneumonia' OR 'Mycoplasma Pneumonia') AND ('Ghana' OR 'Ghanaian')

The reference lists of included studies and relevant reviews were also manually searched to identify additional publications not indexed in the databases. All publications from the databases were downloaded and imported into the Zotero reference manager (version 6.0.36), where they were merged into a single collection. The merged file yielded 844 articles that were later imported into the Rayyan online platform (www.rayyan.ai) and deduplicated before the study selection process.

Study selection process

Before screening, two reviewers (F.K and AA-D) designed a protocol that clearly defined characteristics qualifying a study for inclusion or exclusion. The reviewers independently screened all deduplicated records in three stages—title, abstract and full text—using the Rayyan online platform to assess eligibility based on predefined criteria. References were coded as 'included', 'maybe' or 'excluded'. Records whose titles and abstracts did not align with the study's objectives were excluded during the first two stages. Full texts of studies labelled as 'included' or 'maybe' progressed to the next screening stage. A calibration exercise was performed among reviewers to ensure consistency in applying inclusion/exclusion criteria. Full texts of potentially relevant studies were exported to the Zotero reference manager (version 6.0.36) and assessed independently against eligibility criteria by two reviewers. Reasons for final exclusion at this stage were recorded. Any discrepancies in study selection were discussed with a third reviewer (ESD) until a consensus was reached. All included studies proceeded to the data extraction stage.

Eligibility criteria

Inclusion criteria were cross-sectional, cohort or case–control studies reporting original data; studies conducted among the general population or specific subgroups (e.g. children, communities, etc.) in Ghana; studies reporting the prevalence

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

and specific aetiology of pneumonia; studies that diagnosed pneumonia using microbiological, radiological or molecular techniques (e.g. cultures, polymerase chain reaction, chest X-ray, computed tomography scans) and identified the microbial aetiology through appropriate methods, confirmed by clinical symptoms and radiological findings; and studies published from the inception of each database to 12 December 2024.

Studies were excluded if they were reviews, case reports, editorials or abstracts without full text. Additionally, studies conducted outside Ghana, not involving human participants, and those that included Ghana but did not provide Ghana-exclusive studies. Studies reporting outcomes unrelated to pneumonia prevalence or antimicrobial susceptibility were also excluded, including those focused on COVID-19-induced pneumonia, as this is considered a distinct condition of the pandemic, and may skew findings. Furthermore, studies that reported only pneumonia symptoms without conducting diagnostic tests (e.g. microbiological, radiological or molecular methods) to confirm the infection, or those that did not distinguish pneumonia from other respiratory illnesses, were not considered.

Data extraction

Two reviewers (FK and ESD) developed a standard data extraction form in Excel 2019 (Microsoft, Redmond, WA, USA) and piloted on three randomly selected studies before full abstracting. From each eligible study, the following key information was extracted: bibliographic details (author[s], publication year), study characteristics (location/setting [region], study design; population characteristics (sample size, age groups); and outcomes of interest, including pneumonia prevalence, aetiology, type of pneumonia, mortality rate and risk factors for its transmission.

The data were extracted independently by two reviewers (FK and AA-D) and were checked by a third reviewer (ESD). All discrepancies were discussed among the three reviewers until a consensus was reached. The extracted information was synthesized qualitatively due to heterogeneity in reported outcomes. This comprehensive data extraction process ensured all relevant information across studies were captured uniformly for subsequent analysis.

Statistical analysis

Meta-analysis was performed using RStudio version 4.3.3 (Posit, Boston, MA, USA). The software was used to estimate the proportion of pneumonia reported. The funnel plot and Egger's regression test assessed publication bias visually and statistically (Supplementary Figure 1). The Freeman–Tukey double arcsine transformation was used to stabilize variances among studies and the pooled prevalences were computed using the DerSimonian–Laird method. Heterogeneity between studies was evaluated using I^2 statistics with values of 0%, 25%, 50% and $\geq$75%, representing no, low, moderate and high heterogeneity, respectively. The proportion of pneumonia was measured by random-effects meta-analysis with a confidence interval (CI) of 95%. A leave-one-out sensitivity analysis and meta-regression were performed to assess the robustness and sources of heterogeneity in our study, respectively. An α-value <0.05 was considered statistically significant.

Quality assessment

Using the standardized Joana Briggs Institute checklist for prevalence studies, two reviewers methodologically assessed the quality of the included studies. The checklist comprised tools that included the appropriateness of the sample frame, appropriate recruitment of study participants, adequacy of the sample size, detailed description of study subjects and setting, comprehensiveness of data analysis to cover the entire sample, validity of diagnostic methods, reliability of standards to measure condition, the availability of appropriate statistical analysis and the adequacy of response rate. Each checklist item was scored 'yes', 'no', 'unclear' or 'not applicable'. A 'yes' response to each question was scored 1, while 'unclear', 'no' and 'not applicable' were scored 0. All included studies were subjected to each of these tools and the quality of the study (risk of bias) was determined as 'good' (low risk; score 7–9), 'fair' (moderate risk; score 4–6) or 'poor' (high risk; score 0–3). Disagreements were discussed until a consensus was reached, ensuring that the final quality analysis reflected a comprehensive understanding of the included studies' methodologies, findings and potential biases. The included studies were generally of high quality, with the majority (16 studies) scoring 'good' (achieving 7–9 points, indicating low risk) and the rest (7 studies) rated 'fair' (achieving 4–6 points, indicating moderate risk) (Supplementary Table 1).

Results

Search results

The search of the databases yielded a total of 944 articles, with 167 of them being duplicates. After resolving the duplicates, 848 non-duplicate articles were subjected to further evaluation. Of the 848 articles, 778 were excluded based on title and abstract screening. The remaining 70 articles were then subjected to a detailed full-text review. After full-text evaluation, 49 articles were excluded for various reasons (no data on pneumonia epidemiology [n=13], pneumonia not tested or clinically diagnosed [n=9], pneumonia data not segregated from other respiratory tract infections [n=6], population used by included study [n=2], population/sample size not stated [n=2], mortality study [n=2] no data on pneumonia [n=7], worked on animals [n=2] and COVID-19-induced pneumonia [n=6]), leaving 21 eligible articles (Figure 1).

Characteristics of included studies

The included studies had sample sizes ranging from 85 to 70 323. The geographic distribution of the studies restricted the studies to just 6 (Greater Accra, Ashanti, Volta, Upper West, Bono East and Northern) of the 16 regions (38%) in Ghana. The Greater Accra (seven studies) and Ashanti (six studies) regions were the most studied, representing 33% and 29% of the included studies, respectively, while the Volta and Upper West regions were the least studied, with two studies (10%) each. One study, representing 5% of the studies, was conducted in both the Greater Accra and Northern regions. The studies included two types of participants, with hospitalized patients being the most represented, in 71% (15 studies), and the other being community children, in 19% (4 studies). Two studies (10%) included both participant types.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

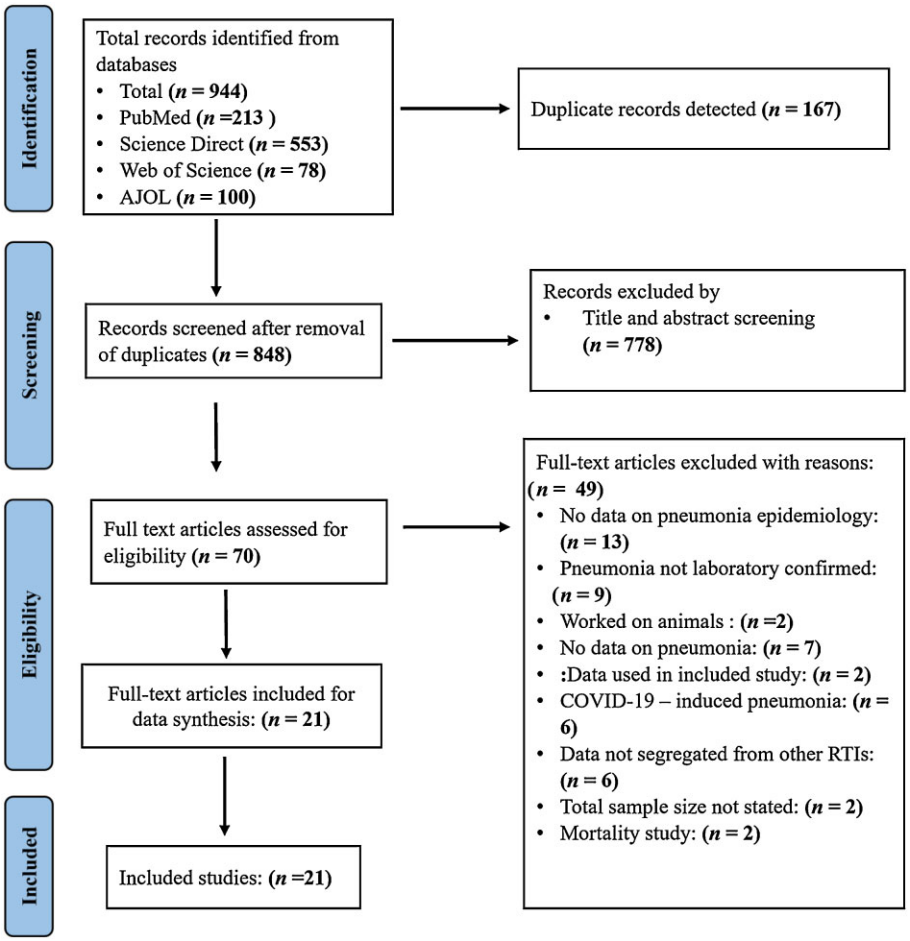

Figure 1. PRISMA flow diagram of included studies.

The participants belonged to different age groups, including children (0–10 y), adolescents (10–17 y), adults (18–60 y) and the elderly (>60 y). Children between the ages of 0–6 y were the most studied, representing 61% (14 studies), followed by studies involving children and adolescents and those involving people of all ages, with 13% (3 studies) each. Adults only and adults in combination with adolescents and the elderly were reported in three separate studies (4% each). A total of 124 582 participants were tested for pneumonia across the studies, of which 9222 were confirmed positive (Table 1). Of the 21 included studies, 11 (52%) reported the aetiology of pneumonia. Among these, nine studies identified *S. pneumoniae* as the causative pathogen, one study reported *C. pneumoniae* and one study identified a combination of both pathogens. Eight studies reported the types of pneumonia: three focused on community-acquired pneumonia, two on hospital-acquired pneumonia, two on severe pneumonia and one study reported cases of bronchopneumonia and lobar pneumonia. Mortality was recorded in four of the included studies, with calculated rates ranging from 1.6% to 36% (Table 2). Antimicrobial resistance was recorded in only two of the studies. However, these reported high resistance of *S. pneumoniae* isolates to co-trimoxazole (100%), gentamicin (77.8%) and tetracycline (75%). Ciprofloxacin and oxacillin had moderate resistance rates at 47.4% and 46.7%, respectively, while penicillin had the lowest resistance rate at 0.73%. Three studies reported risk factors associated with pneumonia prevalence.[22–24] Two studies highlighted weather, particularly the wet season, from June to December, as a key factor. One study identified household air pollution as a contributing factor to disease prevalence.

Pooled prevalence of pneumonia and subgroup analysis based on age groups

The pooled prevalence of pneumonia based on the included studies was 22.01% (95% CI 16.52 to 28.03, p=1.64). A random-effects model was used for the meta-analysis, due to the significant heterogeneity observed across the included studies (I^2=99.8%). The subgroup analysis based on the age group reported children and adolescents as the group with the highest prevalence of pneumonia (37.21% [95% CI 23.60 to 51.94]), followed by adolescents and adults (32.94% [95% CI 23.30 to 43.34]). The results show similar prevalence rates across studies with a combination of adults and elderly (26.07% [95% CI 21.44 to 30.99]) and those that included all age groups (22.24% [95% CI 5.64 to 45.61]). In comparison, the prevalence of pneumonia was higher in adults only (25.78 [95% CI 22.19 to 29.53]) as

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

Table 1. Characteristics of the included studies.

Study	Study design	Setting	Age group (years)	Participant type	Sample size, n	Positive cases, n	Pathogen	AMR rates	Pneumonia type	Risk factors
Adadey et al., 2019[23]	RS	Volta	0–5	Hospitalized patients	36 892	1392	N/A	N/A	N/A	Mid-wet season (June–December)
Addo-Yobo et al., 2011[25]	LS	Ashanti	0–5	Hospitalized patients	529	212	N/A	N/A	Severe	N/A
Adiku et al., 2015[24]	CS	Greater Accra	0–5	Hospitalized patients	108	71	*S. pneumoniae*	N/A	Bronch-opneumonia and lobar	Peaked in July
Akpalu et al., 2018[26]	CS	Greater Accra	28–92	Hospitalized patients	326	85	N/A	N/A	N/A	N/A
Ametefe et al., 2016[27]	RS	Greater Accra	4–86	Hospitalized patients	185	39	N/A	N/A	HAP	N/A
Arjarquah et al., 2022[28]	CS	Greater Accra	17–77	Hospitalized patients	85	28	*S. pneumoniae*	N/A	HAP	N/A
Boakye-Yiadom et al., 2023[29]	CS	Volta	0–105	Hospitalized patients	4278	1715	N/A	N/A	N/A	N/A
Bühl et al., 2018[30]	CS	Ashanti	0–5	Hospitalized patients & community children	1132	7	*C. pneumoniae*	N/A	CAP	N/A
Carrión et al., 2019[22]	CS	Bono East	0–5	Community children	669	130	*S. pneumoniae*	N/A	CAP	Household air pollution
Dadzie et al., 2020[31]	CS	Greater Accra	0–5	Hospitalized patients	70 323	3 337	N/A	N/A	N/A	N/A
Dayie et al., 2013[32]	CS	Greater Accra, Northern	0–6	Community children	848	274	*S. pneumoniae*	Oxacillin (46.7%), penicillin (0.73%)	N/A	N/A
Domo et al., 2017[33]	CS	Upper West	0–87	Hospitalized patients	233	21	*S. pneumoniae*	N/A	N/A	N/A
Hogan et al., 2018[34]	PS	Ashanti	1–4	Hospitalized patients	1238	120	*S. pneumoniae* and *C. pneumoniae*	N/A	N/A	N/A
Jack et al., 2021[35]	CS	Bono East	0–5	Community children	1306	408	N/A	N/A	CAP	N/A
Kaali et al., 2023[36]	CS	Bono East	0–5	Community children	1414	414	N/A	N/A	Severe	N/A
Krumkamp et al., 2023[37]	CS	Ashanti	0–15	Hospitalized patients & community children	889	340	*S. pneumoniae*	N/A	N/A	N/A
Kukoyi et al., 2016[38]	LS	Greater Accra	0–13	Hospitalized patients	140	42	N/A	N/A	N/A	N/A
Owusu et al., 2024[18]	CS	Ashanti	0–1	Hospitalized patients	404	231	*S. pneumoniae*	N/A	N/A	N/A
Saavedra et al., 2017[39]	RS	Greater Accra	18–60	Hospitalized patients	547	141	N/A	N/A	N/A	N/A
Schwarz et al., 2010[40]	CS	Ashanti	0–5	Hospitalized patients	1032	173	*S. pneumoniae*	Ciprofloxacin (47.4%), gentamicin (77.8%), tetracycline (75%), amoxiclav (11.1%), chloramphenicol (11.1%), co-trimoxazole (100%)	N/A	N/A
Tette et al., 2020[41]	CS	Upper West	0–14 d	Hospitalized patients	2004	42	*S. pneumoniae*	N/A	N/A	N/A

CS: cross-sectional study; RS: retrospective study; LS: longitudinal study; PS: prospective study; AMR: antimicrobial resistance; N/A: not applicable.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

Table 2. Mortality rates reported in some included studies.

Study	Positive cases, n	Deaths, n	Rate, %
Adadey et al., 2019[23]	1392	40	2.87
Dadzie et al., 2020[31]	3337	54	1.62
Saavedra et al., 2017[39]	141	51	36.17
Tette et al., 2020[41]	42	6	14.28
Total	4912	151	3.07

compared with children only (17.79% [95% CI 13.13 to 23.00]) (Figure 2).

Subgroup analysis based on participant population

The subgroup analysis based on the type of participants shows a slightly higher prevalence among hospitalized patients (22.14% [95% CI 16.29 to 28.60]) as compared with community children (21.49% [95% CI 11.28 to 33.90] (Figure 3).

Subgroup analysis based on region

Figure 4 presents the subgroup analysis based on the region in which the studies were conducted. The highest prevalence of pneumonia was recorded at 32.31% (95% CI 29.20 to 35.50) in a multiregional study that involved the Greater Accra and Northern regions. This was followed by the Greater Accra and Bono East regions with prevalence rates of 27.75% (95% CI 12.42 to 46.34) and 26.59% (95% CI 20.49 to 33.17), respectively. Similar prevalence rates were recorded in the Ashanti (21.19% [95% CI 8.29 to 38.02]) and Volta (18.18% [95% CI 0.00 to 63.38]) regions. The lowest prevalence was recorded in the Upper West region, with a rate of 4.83% (95% CI 0.32 to 13.85).

Meta-regression

Our meta-regression indicated that hospitalized patients exhibited a positive effect on pneumonia prevalence, with a notable trend, although not statistically significant ($p>0.05$). The Upper West region showed a significant negative association with pneumonia rates, suggesting potential regional disparities ($p<0.05$). Age groups and other regions had no significant effect on pneumonia prevalence ($p>0.05$). These findings underscore the complexity of pneumonia prevalence, with hospitalized populations and regional differences contributing to its heterogeneity in Ghana (Table 3).

Sensitivity analysis

A leave-one-out sensitivity analysis was performed to evaluate the influence of each included study on the pooled pneumonia prevalence in the meta-analysis. The point estimates

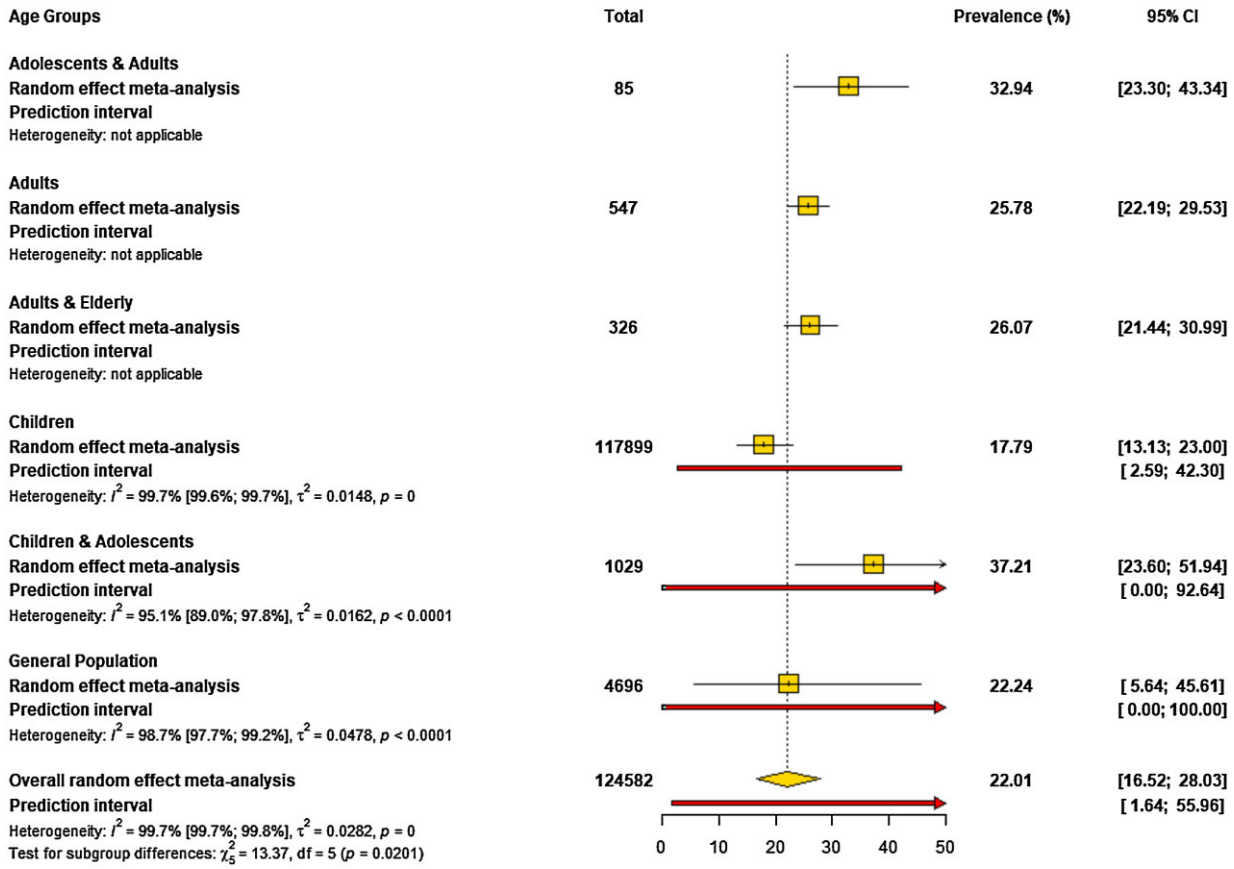

Figure 2. Pooled prevalence of pneumonia and subgroup analysis based on age groups.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

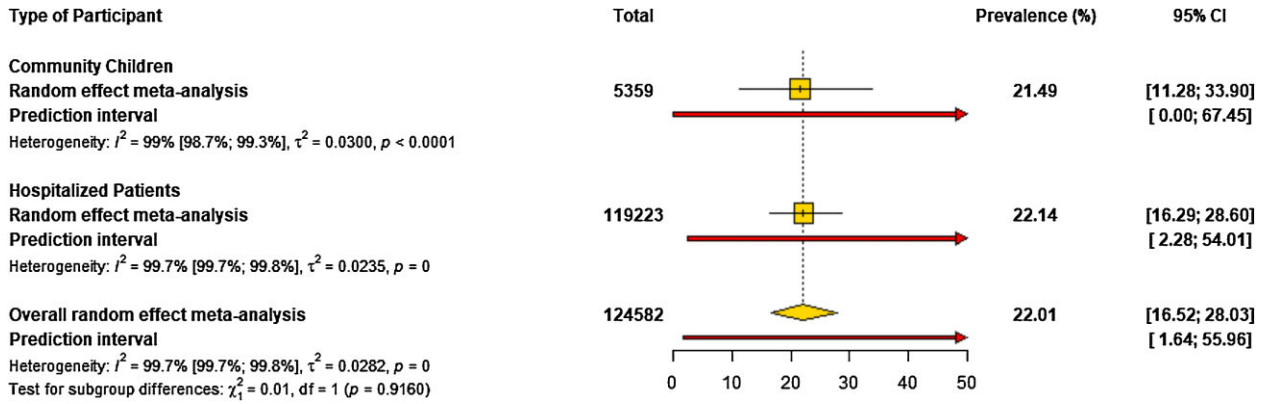

Figure 3. Subgroup analysis based on participant population.

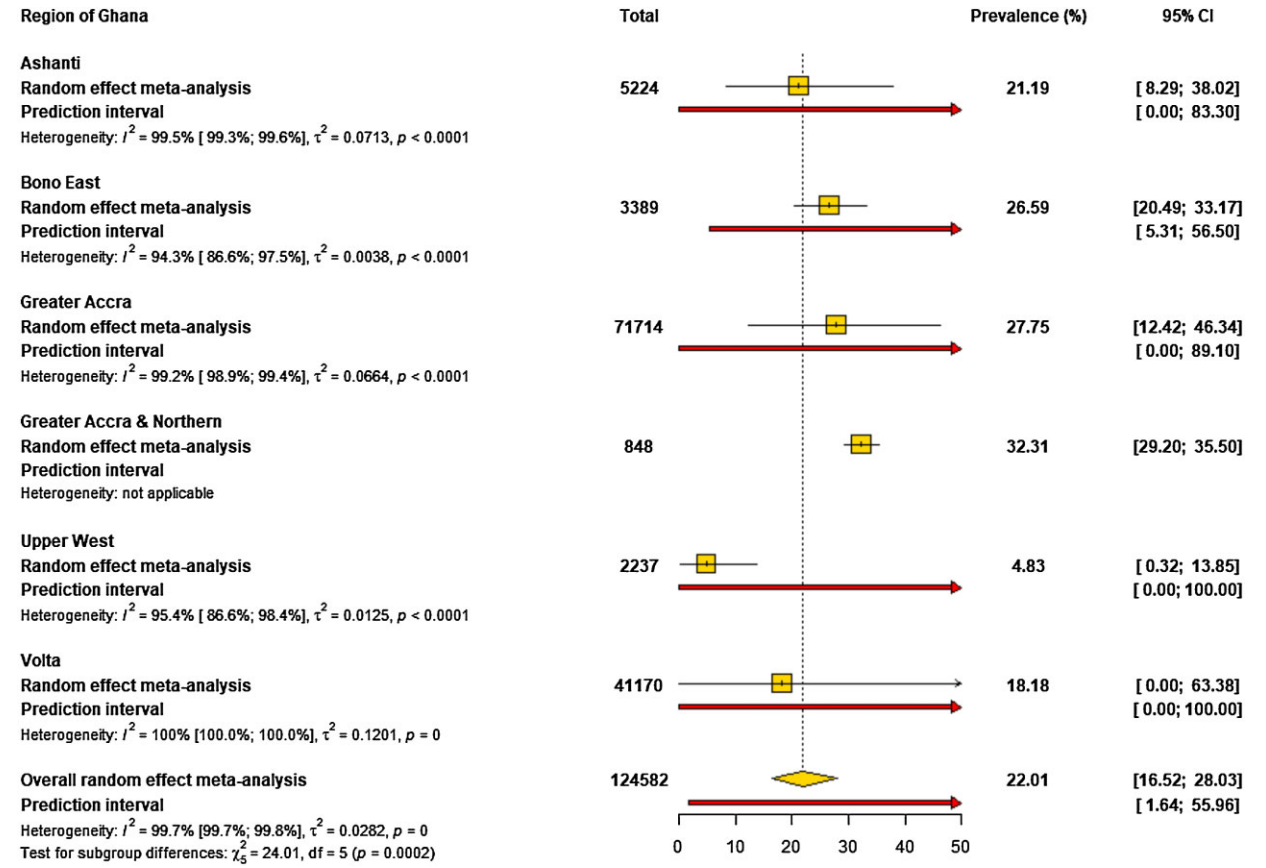

Figure 4. Subgroup analysis based on the regions in Ghana.

ranged from 20.41% to 23.59%, with consistently overlapping CIs. This overlap suggests that the variations in point estimates were not statistically significant. Although some differences were observed, the study selection can be considered reliable, as the individual prevalence estimates remained closely aligned with the pooled prevalence of 22.01% (Supplementary Figure 2).

Discussion

Pneumonia remains a significant public health challenge in Ghana, contributing to morbidity and mortality across various age groups. This systematic review examined the prevalence, distribution and characteristics of pneumonia cases reported in Ghana. The review included 21 studies on pneumonia, with a

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

Table 3. Meta-regression of the included studies.

Covariates	Estimate	Standard error	z-Value	p-Value	95% CI
Age group					
Adolescents and adults (intercept)	0.3692	0.2691	1.3723	0.1700	−0.1581 to 0.8966
Adults	−0.0804	0.2820	−0.2850	0.7756	−0.6331 to 0.4723
Adults and elderly	−0.0767	0.2825	−0.2713	0.7861	−0.6305 to 0.4771
Children	−0.1821	0.2318	−0.7856	0.4321	−0.6365 to 0.2723
Children and adolescents	0.1901	0.2491	0.4381	0.6613	−0.3791 to 0.5974
General population	0.0071	0.2524	0.0283	0.9774	−0.4876 to 0.5019
Participant type					
Hospitalized patients	0.2921	0.1668	1.7516	0.0798	−0.0224 to 0.5275
Region					
Bono East	0.3538	0.1918	1.8444	0.0651	−0.0222 to 0.7297
Greater Accra	−0.0479	0.1339	−0.3582	0.7202	−0.3103 to 0.2144
Greater Accra and Northern	0.4177	0.2498	1.6724	0.0944	−0.0718 to 0.9073
Upper West	−0.3467	0.1770	−1.9582	0.0502	−0.6936 to 0.0003
Volta	−0.1334	0.1766	−0.7552	0.4501	−0.4795 to 0.2127

total sample size of 124 582 participants. The studies reveal geographic disparities in research coverage, with studies concentrated in only 6 of the country's 16 regions. The Greater Accra and Ashanti regions accounted for most studies, representing 39% and 26%, respectively, likely due to the urbanization of these regions and the increased probability of access to healthcare facilities. These urban centres are characterized by higher population densities, better healthcare infrastructure and more research institutions, which facilitate the identification and reporting of pneumonia cases. In contrast, regions like Volta and Upper West were underrepresented, highlighting potential inequities in healthcare access and research focus. The studies predominantly involved hospitalized patients (15 studies), with children aged 0–6 y being the most studied demographic group (14 studies). *S. pneumoniae* emerged as the primary causative pathogen, consistent with findings from a study by Musher et al.,[42] which attributed 90% of all pneumonia cases to this pathogen. In contrast, the lowest occurrence of *C. pneumoniae* may be partly attributed to challenges in its detection and diagnosis, as studies have found that pneumonia associated with this pathogen is clinically indistinguishable from other types of pneumonia.[43,44] Additionally, 48% of the studies reported the aetiology of pneumonia, while eight studies provided details on pneumonia types, including community-acquired, hospital-acquired, severe pneumonia, bronchopneumonia and lobar pneumonia. The wet season and polluted household air were risk factors for the epidemiology of pneumonia. Studies highlight that meteorological conditions such as variations in daily temperature, humidity and particulate matter (PM) levels increase pneumonia risk by impairing respiratory defences and prolonging pathogen survival.[45,46] For instance, Huh et al.[47] demonstrated that these climatic factors directly correlate with pneumonia incidence, underscoring the need to integrate environmental considerations into public health strategies. Household air pollution (HAP) further exacerbates the burden: in Ghana, Kinney et al.[48] found that prenatal exposure to HAP increased the risk of pneumonia and severe pneumonia in infants. Similarly, exposure to PM that is $\leq 2.5\ \mu$m ($PM_{2.5}$)—a key pollutant from biomass burning—was linked to a 10% increase in pneumococcal carriage per unit increase in $PM_{2.5}$ levels,[49] directly increasing pneumonia susceptibility. These findings emphasize the dual role of seasonal environmental shifts and indoor air pollution in driving pneumonia transmission.

The pooled prevalence of pneumonia from the included studies is 22.01%, which is alarming, as it indicates that 22 of 100 Ghanaians are affected by pneumonia. However, these results may be skewed, as most of the studies included were conducted among children (people <18 y of age). Geographically, our reported prevalence is lower than that reported by a study conducted in Uganda, which reported a rate of 25.6%,[50] and other LMICs such as India and Taiwan, with rates of 64% and 31.6%, respectively.[51,52] However, a study in Ethiopia reported a lower rate (16.1%) than our reported pooled prevalence.[53] Ghana's intermediate prevalence may reflect its unique demographic and healthcare context. First, most included studies focused on children <18 y of age, a high-risk group for pneumonia in low-resource settings, due to malnutrition, incomplete immunization and exposure to indoor air pollution.[54] Additionally, Ghana's relatively robust healthcare infrastructure, including high pneumococcal vaccine coverage (approximately 96% in 2023),[55] may help moderate the prevalence compared with countries with weaker systems.

Our subgroup analysis based on age groups found variations in prevalence rates across different age groups. In comparison, our study reports a 17.79% prevalence of pneumonia among children, which is half the rates reported by similar studies conducted among children <5 y of age in East Africa (34%)[56] and Ethiopia (30%).[57] Children and adolescents exhibited the highest prevalence, followed by adolescents combined with adults, indicating a substantial burden of pneumonia in younger age groups. Interestingly, studies involving adults and the elderly or the general population showed comparable prevalence rates,

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

suggesting consistent disease distribution when broader populations are considered. Notably, adults alone had a higher prevalence (25.78%) than children alone (17.79%). However, it is important to note that the data for adults only might be skewed, as it is based on a single study with a small sample size. This limitation highlights the need for additional research focusing on adults, to provide a more accurate representation of pneumonia prevalence in this demographic.

The subgroup analysis revealed a slightly higher prevalence of pneumonia among hospitalized patients compared with community children (Figure 3). This difference is typical, as symptomatic children, who are a more vulnerable population to disease mortality, often require medical intervention.[58] Notably, the prevalence of pneumonia among community children, many of whom were asymptomatic controls, is particularly significant. This finding underscores the role of asymptomatic carriers in the community, who may serve as reservoirs for the transmission of respiratory pathogens.[59] Identifying and monitoring asymptomatic cases is critical for understanding the hidden burden of pneumonia and its potential spread within communities. The broader CI for community children also indicates variability in study findings, likely due to differences in study designs, diagnostic methods or population characteristics.

The regional subgroup analysis reveals significant variations in pneumonia prevalence across Ghana. The highest prevalence was found in a multiregional study involving the Greater Accra and Northern regions (32.31%), followed by the Greater Accra and Bono East regions. Similar prevalence rates were observed in the Volta and Ashanti regions, with the Upper West region showing the lowest prevalence (Figure 4). These results highlight regional disparities and suggest the need for targeted public health strategies to address the varying healthcare access and disease burden across regions.

This study reports a lower pneumonia mortality rate of 3.07% compared with higher rates observed in Mali (4.2%)[60] and Malawi (6.6%).[61] The difference in mortality rates may be attributed to variations in healthcare access and disease management, as well as the prevalence of risk factors such as hypoxaemia, severe acute malnutrition and decreased conscious state, which are strongly associated with increased mortality in children with pneumonia.[62] Despite the lower mortality rate in this study, there is still a need for targeted interventions and improvements in healthcare infrastructure to reduce pneumonia-related deaths. Despite most of the studies not assessing antimicrobial resistance in pneumonia cases, two studies that did, found high resistance in *S. pneumoniae* isolates, with co-trimoxazole (100%), gentamicin (77.8%) and tetracycline (75%) showing the highest resistance. Similar to our findings, a study in Kenya by Irungu[63] reported complete resistance of *S. pneumoniae* isolates to co-trimoxazole. However, it reported no resistance to gentamicin, which contrasts with our findings. Moderate resistance was observed for ciprofloxacin (47.4%) and oxacillin (46.7%), while penicillin had the lowest resistance rate at 0.73%, aligning with findings by Karcic et al.[64] These findings highlight the need for routine antimicrobial resistance surveillance to guide treatment decisions and ensure effective pneumonia management.

Ghana introduced the pneumococcal conjugate vaccine (PCV) in 2012 to protect children from pneumococcal diseases like pneumonia and diarrhea.[65,66] The program initially included the 10-valent and 13-valent vaccines,[67] achieving an impressive 96% national coverage rate by 2023.[55] While the vaccine has successfully reduced pneumococcal disease rates, particularly pneumonia and meningitis, achieving measurable public health and economic impacts, its impact has not been universal. Projections suggest that the program will reduce overall pneumococcal disease burden by 48% by 2031 compared with no vaccination.[68] However, carriage studies reveal important gaps in protection,[16] with recent data showing 54% of children still carrying pneumococcal bacteria,[69] while showing concerning serotype distributions with only about 33% of circulating serotypes being vaccine covered versus 66% non-vaccine type.[69] This explains why several reports[16,67,69] found no significant reduction in pneumococcal carriage rates following PCV introduction, with some even reporting a higher prevalence post-vaccination.[65] This suggests that while PCV has been valuable for preventing severe disease burden, its limited coverage of circulating strains allows persistent carriage and potential serotype replacement.

Strengths and limitations

The strength of our meta-analysis lies in its thorough examination of pneumonia prevalence, considering regional and demographic factors. The consistency of point estimates in the sensitivity analysis further reinforces the robustness of our findings. Our results highlight significant regional disparities, particularly in the Upper West region, and emphasize the impact of hospitalized populations on the overall prevalence. These findings provide valuable insights into the factors contributing to pneumonia variability in Ghana. However, the study highlights several limitations, including significant geographic disparities in research coverage, with studies concentrated in only 6 of Ghana's 16 regions. Most studies focused on children, particularly those <18 y of age, a high-risk group, which may overestimate prevalence among younger populations and underrepresent adults and the elderly. While this reflects clinical priorities, it neglects adults, particularly the elderly, who also have a high risk of pneumonia mortality. Additionally, variability in study design, diagnostic methods and population characteristics could affect the reliability of reported prevalence rates and complicate comparisons. The limited assessment of pneumonia aetiologies and their antimicrobial resistance patterns restricts our understanding of appropriate treatment strategies and likely underestimates the true burden of antibiotic resistance among pneumonia-causing pathogens. The small sample sizes in certain subgroups, especially adults, raise concerns about the statistical power and generalizability of the findings. The review is limited by potential publication bias, as only studies from selected databases were included, possibly excluding relevant grey literature.

Conclusions

Pneumonia remains a significant public health challenge in Ghana, with a pooled prevalence of 22.01%, indicating that nearly one in five individuals is affected by this disease. The findings highlight substantial regional disparities and variations

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

in pneumonia prevalence across different age groups, with children and hospitalized patients showing notable rates. The higher mortality rate associated with pneumonia underscores the urgent need for targeted interventions to improve healthcare access and disease management. Future studies should cover a wider geographic range in Ghana, include more balanced age demographics, and standardize diagnostic methods for better comparability. Antimicrobial resistance surveillance should be integrated to guide treatment strategies, and longitudinal studies are needed to track trends in pneumonia incidence, risk factors and outcomes for improved public health planning.

Supplementary data

Supplementary data are available at *International Health* online.

Authors' contributions: ESD and FK were responsible for the conceptualization, validation,. FK and AA-D were responsible for the methodology, formal analysis and review and editing. FK was responsible for the software, investigation, data curation, writing the original draft. ESD was responsible for resources, visualization, supervision and project administration.

Acknowledgments: None.

Funding: This review was supported by the Fogarty International Center of the National Institutes of Health through the Research and Capacity Building in Antimicrobial Resistance in West Africa Training Programme hosted at the Department of Medical Microbiology, University of Ghana Medical School (award no. D43TW012487). The content is solely the responsibility of the authors and does not represent the official views of the National Institutes of Health.

Competing interests: None declared.

Ethical approval: Not required.

Data availability: The data are available in the article and its supplemental material.

References

1 Lim WS. Pneumonia—overview. In: Janes SM, editor. Encyclopedia of respiratory medicine, 2nd edition, vol. 4. Amsterdam: Elsevier; 2022:185–97. doi: 10.1016/B978-0-12-801238-3.11636-8

2 Levison ME. Pneumonia, including necrotizing pulmonary infections (lung abscess). In: Braunwald E, Fauci A, Kasper DL, et al., editors. Harrison's principles of internal medicine, vol. 2. New York: McGraw-Hill; 2001:1475–84.

3 Steel HC, Cockeran R, Anderson R, et al. Overview of community-acquired pneumonia and the role of inflammatory mechanisms in the immunopathogenesis of severe pneumococcal disease. Mediat Inflamm. 2013;2013:490346.

4 Chen J, Li X, Wang W, et al. The prevalence of respiratory pathogens in adults with community-acquired pneumonia in an outpatient cohort. Infect Drug Resist. 2019;12:2335–41.

5 Mani CS. Acute pneumonia and its complications. In: Long SS, Prober CG Fischer M, editors. Principles and practice of pediatric infectious diseases, Fifth edition. Philadelphia: Elsevier; 2018:238–249.e4.

6 McCullers JA. Insights into the interaction between influenza virus and pneumococcus. Clin Microbiol Rev. 2006;19(3): 571–82.

7 Choi MJ, Song JY, Noh JY, et al. Disease burden of hospitalized community-acquired pneumonia in South Korea: analysis based on age and underlying medical conditions. Medicine (Baltimore). 2017;96(44):e8429.

8 Naghavi M, Ong KL, Aali A, et al. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2100–32.

9 Iddrisu A, Alhassan A, Amidu N. Survival analysis of birth defect infants and children with pneumonia mortality in Ghana. Adv Public Health. 2019;2019:856510.

10 The Issues. Pneumonia is the world's largest infectious killer. Available from: https://stoppneumonia.org/issues/

11 Okafor C, Olaniran A, Darj E. Challenges and recommendations for addressing under-five pneumonia morbidity and mortality in Nigeria. Afr Health Sci. 2023;23(2):193–201.

12 Sanyang Y. Prevalence of under-five years of age mortality by infectious diseases in West African region. Int J Afr Nurs Sci. 2019;11:100175.

13 World Health Organization. Pocket book of hospital care for children: guidelines for the management of common childhood illnesses, 2nd ed. Geneva: World Health Organization; 2013.

14 Abbey M, Afagbedzi SK, Afriyie-Mensah J, et al. Pneumonia in Ghana—a need to raise the profile. Int Health. 2018;10(1):4–7.

15 O'Brien KL, Wolfson LJ, Watt JP, et al. Burden of disease caused by *Streptococcus pneumoniae* in children younger than 5 years: global estimates. Lancet. 2009;374(9693):893–902.

16 Arhin RE, Donkor ES, Slotved H-C, et al. Etiologic profile of the pneumococcus in Ghana: a systematic review. Biomed Res Int. 2024;2024:8368996.

17 Rambaud-Althaus C, Althaus F, Genton B, et al. Clinical features for diagnosis of pneumonia in children younger than 5 years: a systematic review and meta-analysis. Lancet Infect Dis. 2015;15(4):439–50.

18 Owusu M, Adu E, Kalu L, et al. Aetiological agents of pneumonia among HIV and non-HIV infected children in Ghana: a case–control study. PLoS One. 2024;19(3):e0299222.

19 Chidzwondo F, Mutapi F. Challenge of diagnosing acute infections in poor resource settings in Africa. AAS Open Res 2024;4:28.

20 Abbey M, Chinbuah M, Gyapong M, et al. Community perceptions and practices of treatment seeking for childhood pneumonia: a mixed methods study in a rural district, Ghana. BMC Public Health. 2016;16:848.

21 PRISMA 2020 checklist. Available from: https://www.prisma-statement.org/prisma-2020-checklist

22 Carrión D, Kaali S, Kinney PL, et al. Examining the relationship between household air pollution and infant microbial nasal carriage in a Ghanaian cohort. Environ Int. 2019;133(Pt A):105150.

23 Adadey SM, Ayee R, Languon S, et al. Patterns of frequently diagnosed pediatric morbidities in hospitalized children in the Volta Region of Ghana. Glob Pediatr Health. 2019;6: 2333794X19889230.

24 Adiku TK, Asmah RH, Rodrigues O, et al. Aetiology of acute lower respiratory infections among children under five years in Accra, Ghana. Pathogens. 2015;4(1):22–33.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

25 Addo-Yobo E, Anh DD, El-Sayed HF, et al. Outpatient treatment of children with severe pneumonia with oral amoxicillin in four countries: the MASS study. Trop Med Int Health. 2011;16(8):995–1006.

26 Akpalu J, Yawson AE, Osei-Poku F, et al. Stroke outcome and determinants among patients with and without diabetes in a tertiary hospital in Ghana. Stroke Res Treat. 2018;2018:7521351.

27 Ametefe M, Bankah P, Yankey K, et al. Spinal cord and spine trauma in a large teaching hospital in Ghana. Spinal Cord. 2016;54(12):1164–8.

28 Arjarquah AK, Obodai E, Anie HA, et al. Occurrence of influenza and bacterial infections in cancer patients receiving radiotherapy in Ghana. PLoS One. 2022;17(7):e0271877.

29 Boakye-Yiadom E, Najjemba R, Thekkur P, et al. Use and quality of blood cultures for the diagnosis of bloodstream infections: a cross-sectional study in the Ho Teaching Hospital, Ghana, 2019–2021. Int J Environ Res Public Health. 2023;20(3):2238.

30 Bühl H, Eibach D, Nagel M, et al. Chlamydiae in febrile children with respiratory tract symptoms and age-matched controls, Ghana. New Microbes New Infect. 2018;22:44–8.

31 Dadzie D, Addo-Lartey AA, Peprah NY, et al. Evaluation of surveillance system for pneumonia in children below five years, Tema Metropolis, Ghana, 2012–2016. Ghana Med J. 2020;54(2 Suppl):11–7.

32 Dayie N, Arhin R, Newman M, et al. Penicillin resistance and serotype distribution of *Streptococcus pneumoniae* in Ghanaian children less than six years of age. BMC Infect Dis. 2013;13:490.

33 Domo NR, Nuolabong C, Nyarko KM, et al. Uncommon mixed outbreak of pneumococcal and meningococcal meningitis in Jirapa District, Upper West Region, Ghana, 2016. Ghana Med J. 2017;51(4):149–55.

34 Hogan B, Eibach D, Krumkamp R, et al. Malaria coinfections in febrile pediatric inpatients: a hospital-based study from Ghana. Clin Infect Dis. 2018;66(12):1838–45.

35 Jack DW, Ae-Ngibise KA, Gould CF, et al. A cluster randomised trial of cookstove interventions to improve infant health in Ghana. BMJ Glob Health. 2021;6(8):e005599.

36 Kaali S, Jack D, Mujtaba M, et al. Identifying sensitive windows of prenatal household air pollution on birth weight and infant pneumonia risk to inform future interventions. Environ Int. 2023;178:108062.

37 Krumkamp R, Kohsar M, Nolte K, et al. Pathogens associated with hospitalization due to acute lower respiratory tract infections in children in rural Ghana: a case–control study. Sci Rep. 2023;13:2443.

38 Kukoyi O, Renner L, Powell J, et al. Viral load monitoring and antiretroviral treatment outcomes in a pediatric HIV cohort in Ghana. BMC Infect Dis. 2016;16:58.

39 Saavedra A, Campinha-Bacote N, Hajjar M, et al. Causes of death and factors associated with early mortality of HIV-infected adults admitted to Korle-Bu Teaching Hospital. Pan Afr Med J. 2017;27:48.

40 Schwarz NG, Sarpong N, Hünger F, et al. Systemic bacteraemia in children presenting with clinical pneumonia and the impact of non-typhoid salmonella (NTS). BMC Infect Dis. 2010;10:319.

41 Tette EMA, Nartey ET, Nuertey BD, et al. The pattern of neonatal admissions and mortality at a regional and district hospital in the Upper West Region of Ghana; a cross sectional study. PLoS One. 2020;15:e0232406.

42 Musher DM, Abers MS, Bartlett JG. Evolving understanding of the causes of pneumonia in adults, with special attention to the role of pneumococcus. Clin Infect Dis. 2017;65(10): 1736–44.

43 Emre U, Roblin PM, Gelling M, et al. The association of *Chlamydia pneumoniae* infection and reactive airway disease in children. Arch Pediatr Adolesc Med. 1994;148(7):727–32.

44 Goldstein EJC, Kumar S, Hammerschlag MR. Acute respiratory infection due to *Chlamydia pneumoniae*: current status of diagnostic methods. Clin Infect Dis. 2007;44(4):568–76.

45 Liu Y, Liu J, Chen F, et al. Impact of meteorological factors on lower respiratory tract infections in children. J Int Med Res. 2016;44(1):30–41.

46 Tasci SS, Kavalci C, Kayipmaz AE. Relationship of meteorological and air pollution parameters with pneumonia in elderly patients. Emerg Med Int. 2018;2018:4183203.

47 Huh K, Hong J, Jung J. Association of meteorological factors and atmospheric particulate matter with the incidence of pneumonia: an ecological study. Clin Microbiol Infect. 2020;26(12):1676–83.

48 Kinney PL, Asante K-P, Lee AG, et al. Prenatal and postnatal household air pollution exposures and pneumonia risk: evidence from the Ghana randomized air pollution and health study. Chest. 2021;160(5):1634–44.

49 Dherani MK, Pope D, Tafatatha T, et al. Association between household air pollution and nasopharyngeal pneumococcal carriage in Malawian infants (MSCAPE): a nested, prospective, observational study. Lancet Glob Health. 2022;10(2):e246–56.

50 Kiconco G, Turyasiima M, Ndamira A, et al. Prevalence and associated factors of pneumonia among under-fives with acute respiratory symptoms: a cross sectional study at a Teaching Hospital in Bushenyi District, Western Uganda. Afr Health Sci. 2021;21(4):1701–10.

51 Chi H, Huang Y-C, Liu C-C, et al. Characteristics and etiology of hospitalized pediatric community-acquired pneumonia in Taiwan. J Formos Med Assoc. 2020;119(10):1490–9.

52 Kasundriya SK, Dhaneria M, Mathur A, et al. Incidence and risk factors for severe pneumonia in children hospitalized with pneumonia in Ujjain, India. Int J Environ Res Public Health. 2020;17(13):4637.

53 Fekadu GA, Terefe MW, Alemie GA. Prevalence of pneumonia among under-five children in Este Town and the surrounding rural Kebeles, Northwest Ethiopia: a community based cross sectional study. Sci J Public Health. 2014;2(3):150–5.

54 World Health Organization. Pneumonia in children. Available from: https://www.who.int/news-room/fact-sheets/detail/pneumonia

55 ViewHub. Ghana. Available from: https://view-hub.org/map/country/gha

56 Beletew B, Bimerew M, Mengesha A, et al. Prevalence of pneumonia and its associated factors among under-five children in East Africa: a systematic review and meta-analysis. BMC Pediatr. 2020;20:254.

57 Solomon Y, Kofole Z, Fantaye T, et al. Prevalence of pneumonia and its determinant factors among under-five children in Gamo Zone, southern Ethiopia, 2021. Front Pediatr. 2022;10:1017386.

58 Aston SJ. Pneumonia in the developing world: characteristic features and approach to management. Respirology. 2017;22(7):1276–87.

59 Shaikh N, Swali P, Houben RMGJ. Asymptomatic but infectious – the silent driver of pathogen transmission. A pragmatic review. Epidemics. 2023;44:100704.

60 Bénet T, Sylla M, Messaoudi M, et al. Etiology and factors associated with pneumonia in children under 5 years of age in Mali: a prospective case-control study. PLoS One. 2015;10(12):e0145447.

61 Lazzerini M, Seward N, Lufesi N, et al. Mortality and its risk factors in Malawian children admitted to hospital with clinical pneumonia, 2001–12: a retrospective observational study. Lancet Glob Health. 2016;4(1):e57–68.

62 Wilkes C, Bava M, Graham HR, et al. What are the risk factors for death among children with pneumonia in low- and middle-income countries? A systematic review. J Glob Health. 2023;13:05003.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

63 Irungu A. Prevalence of streptococcal pneumoniae carriage in the upper airway of children in Kenyatta National Hospital. Master's thesis, University of Nairobi, 2010.

64 Karcic E, Aljicevic M, Bektas S, et al. Antimicrobial susceptibility/resistance of *Streptococcus pneumoniae*. Mater Sociomed. 2015;27(3):180–4.

65 Walana W, Al-Azab M, Yabasin IB, et al. Childhood immunization in Ghana: tracing the history and projecting the future. Public Health Challenges. 2024;3(2):e176.

66 Sally ET, Kenu E. Evaluation of access and utilization of EPI services amongst children 12–23 months in Kwahu Afram Plains, Eastern region, Ghana. Pan Afr Med J. 2017;28:238.

67 Dayie NTKD, Arhin RE, Newman MJ, et al. Penicillin resistance and serotype distribution of *Streptococcus pneumoniae* in Ghanaian children less than six years of age. BMC Infect Dis. 2013;13:490.

68 Ibrahim A-M, Owusu R, Nonvignon J. Sustainability of pneumococcal conjugate vaccination in Ghana: a cost-effectiveness analysis in the context of donor transition. Front Public Health. 2024;12:1383668.

69 Dayie NTKD, Tettey EY, Newman MJ, et al. Pneumococcal carriage among children under five in Accra, Ghana, five years after the introduction of pneumococcal conjugate vaccine. BMC Pediatr. 2019;19:316.

Downloaded from https://academic.oup.com/inthealth/article/18/3/369/8321495 by University of Ghana. Balme Library user on 17 June 2026

© The Author(s) 2025. Published by Oxford University Press on behalf of Royal Society of Tropical Medicine and Hygiene. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (https://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact reprints@oup.com for reprints and translation rights for reprints. All other permissions can be obtained through our RightsLink service via the Permissions link on the article page on our site-for further information please contact journals.permissions@oup.com